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# Heat transfer—a review of 1985 literature

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## INTRODUCTION

THIS REVIEW surveys papers that have been published in the open literature covering various fields of heat transfer during 1985. The literature search was made as inclusive as possible, however, the great number of publications made selections in some of the review sections necessary.

Several conferences were devoted to heat transfer or included heat transfer topics in their sessions during 1985. A symposium on *Off Shore Mechanics and Arctic Engineering* was held 17–21 February at Dallas, TX. It included a session on arctic thermal design analysis and icing problems were discussed in other papers. The proceedings are available as a bound volume. Information on those may be obtained at the Energy-sources Technology Conference and Exhibition, P.O. Box 59489, Dallas, TX, or through the ASME Order Department. The *30th International Gas Turbine Conference and Exhibit* 17–21 at Houston, TX, was sponsored by the Gas Turbine Division of the American Society of Mechanical Engineers. Four of the sessions were devoted to external and internal heat transfer as well as to film cooling. The 1985 Gas Turbine Award was presented to Chunill Han for the paper "A Navier–Stokes analysis of three-dimensional turbulent flow inside turbine blade rows at design and of design conditions" and the 1985 Tom Sawyer Award was presented to Anselm Franz in recognition of his pioneering contributions to the Gas Turbine Industry. Papers may be obtained at the ASME Order Department. A *Symposium on Transport Phenomena in Rotating Machinery*, held in Honolulu, Hawaii, 28 April–3 May and sponsored by American and Japanese Engineering Societies as well as the Universities of Michigan and Hawaii, included in its program papers on turbine blade cooling, channel flow heat transfer, rotational effects, liquid and evaporation cooling, heat transfer in seals, and superconducting generators. The *29th Heat Transfer and Fluid Mechanics Institute*, held 20–21 June at Sacramento, CA, included in its proceedings papers on melting, vortex flow, combustion of solid propellants, vapor and droplet transport, transient and oscillatory heat transfer, and two-phase flow. Proceedings are published by the California State University, Sacramento, CA. The 1985 *International Solar Energy Congress and Exhibition* sponsored by the American Section of the International Solar Energy Society was held 28 July–1 August at Los Angeles, CA. Sessions dealing with solar radiation and solar furnaces, solar collectors and energy storage, solar heating and cooling of buildings, drying and distillation, focusing collectors, and solar thermal power were included in the program. The *Twenty-third National Heat Transfer Conference*, sponsored by the American Institute of Chemical Engineers and the American Society of Mechanical Engineers held 4–7 August at Denver, CO, was organized in 61 sessions, many of them dealing with heat transfer in specific technology processes like combustion, hazardous waste incinerators, drying and dehumidification, glass, alternative energy technologies, steam generators, nuclear reactors, aerodynamic systems, fibers, buildings and structures. Courses on numerical solutions and augmentation of heat transfer, thermal analysis, control of aerodynamic equipment, and compact heat exchangers as parts of the professional development program rounded off the proceedings. The Max Jakob Memorial Award was presented to L. London and the Donald Q. Kern Award to D. Gidaspow. The papers at this conference sponsored by the ASME are available in paper or volume form through the ASME Order Department. AIChE papers are contained in the volume "Heat Transfer/Denver 1985" of the AIChE Symposium Series. The *20th Intersociety Energy Conversion Engineering Conference*, held 18–23 August at Miami Beach, FL, did not include in its program specific sessions on heat transfer but this topic is touched upon in various of their lectures. Conference Proceedings are available from SAE, 400 Commonwealth Drive, Warrendale, PA. The *17th International Symposium of the International Centre for Heat and Mass Transfer* held 26–30 August at Dubrovnik, Yugoslavia, was devoted to the topic of high temperature heat exchangers. An introduction lecture by Y. Mori, Japan, discussed future development in high temperature heat exchangers, eight invited lectures were given by experts from the Federal Republic of Germany, Great Britain, Japan, U.S.A., U.S.S.R., and Yugoslavia and 41 lectures discussed various topics of heat exchangers and their applications for gas turbines, Stirling cycle engines, metallurgical processes and future power plants. The Proceedings of the conference are collected in a volume, published by Hemisphere Publishing Corporation. The *1985 Beijing International Gas Turbine Symposium and Exposition*, 1–7 September at Beijing, People's Republic of China, sponsored by the Gas Turbine Division of ASME and by several Chinese professional societies, brought together researchers and engineers from the Pacific Basin. Two sessions on heat transfer dealt with recouperators, turbine blade cooling, liquid and vapor cooling, transpiration and film cooling. Inquiries about papers should be directed to the ASME Order Department. An *International Symposium on Refined Flow Modelling and Turbulence Measurements*, held 16–18 September at Iowa City, IA, was sponsored by the Iowa Institute of Hydraulic Research in cooperation with a number of engineering societies. Two sessions were devoted to modeling and turbulence effects on heat transfer. The proceedings will be published in book form by Hemisphere Publishing Corporation. The *ASME Winter Annual Meeting*, held 17–22 November at Miami Beach, FL, included in its program 17 sessions with discussions on a variety of heat transfer processes. Six symposia dealt with stability in convective flows, mixed convection, fouling and corrosion, augmentation of heat transfer, in energy systems, nuclear steam generators, and heat exchangers. A panel discussion, moderated by R. K. Shah, inquired into opportunities and challenges in heat transfer. In the Robert Henry Thurston lecture, Y. C. Fang discussed the interplay of mechanical engineering and health science and at the heat transfer luncheon, Raymond Colladay talked about thermal management in space stations. At the same luncheon, the heat transfer memorial awards were presented to Ralph Grief and Virgil E. Schrock. Preprints of the papers are available at the ASME Publications Department and many of the papers will also be published in the *Journal of Heat Transfer*.

A number of books have become available during the past year. They are listed under references.

## HIGHLIGHTS

The following highlights describe areas of research which have found special attention during last year.

In heat conduction, the emphasis was on nonlinear behavior, presence of internal heat sources, and geometrical irregularities.

Many of the channel flow papers dealt with increasingly complex flow fields created by modern heat transfer augmentation devices, i.e. roughening ribs and fins. Also noted were flows with non-Newtonian fluid behavior, as with polymers and micropolar fluids.

Heat transfer in supersonic and hypersonic flows has emerged as a significant portion of the boundary-layer section. Some papers on this topic include the effects of non-equilibrium chemical reactions. Numerous papers on heat transfer variations due to unsteady flow were published. An example would be the effect of passing wakes on gas turbine airfoil heat transfer. Boundary-layer transition research continues to increase in popularity; common applications which were noted are gas turbine airfoils and heat transfer in high velocity flight.

Heat transfer studies in porous media are beginning to consider seriously departures from Darcy flow. Many papers dealt with fluidization, including several involving three-phase fluidized beds. Simultaneous heat and moisture transfer through porous material was the subject of a number of articles as was the modeling of reactor core debris bed heat transfer.

The development of experimental techniques included the application of thin films for heat flux and temperature measurements, impressive advances in the use of laser-based and other optical diagnostics for making temperature measurements in high-temperature gases, continued work in the area of liquid crystals, and numerous refinements in the use and interpretation of hot-wire anemometry for heat transfer research.

Many studies on natural convection in internal flow include nonlinear phenomena in horizontal fluid layers at relatively low Rayleigh number as well as numerical studies for differentially heated layers. There was an increase in studies on Marangoni or surface tension driven flows and the effect of large property variations on natural convection. The need for turbulent transport parameters in buoyancy driven flows was emphasized.

The vertical flat plate geometry dominates the natural convection boundary-layer literature. Variations include coupled conductive or radiative heat transfer, double-diffusive convection, aiding or opposing mixed convection and the effects of plate motion.

Rotational effects were studied especially in connection with gas turbines. Highlights for combined heat and mass transfer include a very large number of studies related to film cooling particularly for gas turbine systems; the influence of large density difference, pressure gradient, and curvature were studied using an array of mass transfer analogies.

Papers on boiling reviewed this year continued to display our interest in the fundamentals of nucleate boiling. Experiments with boiling of mixtures and with boiling at enhanced surfaces reflected continuing interest in new applications of boiling heat transfer. Still well represented in the literature are studies relating boiling heat transfer to nuclear reactor safety and the service life of steam generators.

Noteworthy developments in condensation heat transfer included a systematic series of experiments on film condensation on horizontal cylinders and tube banks, and several analytical studies of free condensation heat transfer to nucleated droplets.

New analytical methods continue to evolve describing the solidification process. A significant amount of work had been done on freezing within molds, however discussion of continuous casting processes is not emphasized as much as in previous years. Some interesting work on the movement of a heat source as it melts its way through a solid has also been presented.

Radiative transfer combined with other modes of heat transfer and/or phase change received increased attention. There was also a renewed interest in participating one-dimensional media, while the research in multi-dimensional media continued. Surface radiation was still considered in a number of studies, but the papers on participating media greatly outnumber those considering surface exchange.

Developments in numerical methods continue to be directed towards the treatment of arbitrary shapes, removal of false diffusion, and improvement of computational speed.

Significant interest was demonstrated in the thermal conductivity of composite and nonisotropic materials: idealized systems used as analytical models and those used in industrial/commercial application. A number of nonsteady-state techniques are proposed for obtaining thermal conductivities and overall coefficients of heat transfer of sufficient accuracy for everyday commercial practice.

Papers dealt with economical ways of enhancing heat transfer by extended surfaces, flow modification, and heat pipes (thermosyphon). Heat transfer solutions formerly restricted to scientific and advanced technology areas are increasingly found at various levels of application. General applications of heat transfer are scattered in a large number of journals. A cross-section of those can be recognized in Section S.

Plasma heat transfer research was primarily associated with plasma processing of materials.

To facilitate the use of this review, a listing of the subject headings is made below in the order in which they appear in the text. The letter which appears adjacent to each subject heading is also attached to the references that are cited in the category:

Conduction, A
Channel flow, B
Boundary-layer and external flows, C
Flow with separated regions, D
Heat transfer porous media, DP
Experimental techniques and instrumentation, E
Natural convection—internal flows, F
Natural convection—external flows, FF
Convection from rotating surfaces, G
Combined heat and mass transfer, H
Change of phase—boiling, J
Change of phase—condensation, JJ
Change of phase—freezing and melting, JM
Radiation in participating media and surface radiation, K
Numerical methods, N
Transport properties, P
Heat transfer application—heat pipes and heat exchangers, Q
Heat transfer applications—general, S
Solar energy, T
Plasma heat transfer and MHD, U

## CONDUCTION

Most of the literature on heat conduction deals with theoretical studies, although some experimental investigations have been reported. Solutions have been presented for steady and unsteady problems in multi-dimensional geometries with nonlinearity, anisotropy, and complex boundary conditions.

A variational method has been proposed for solving two-dimensional heat conduction with finite internal heat source [12A]. For axisymmetric bodies, a boundary element method is used to solve steady heat conduction [47A]. A method is described for the shape optimization of a fin to arrive at minimum volume for a given heat loss [43A]. References [14A] describes a flux formulation for hyperbolic heat conduction. A method has been developed for the analysis of heat conduction by a dual difference equation [19A]. For heat conduction with chemical reaction, a method has been described for treating discontinuous boundary conditions [28A]. A moving-mesh finite-element analysis has been applied to calculate the temperature field with a moving heat source [22A].

A number of complex multi-dimensional geometries have been treated. A new class of functions are used to solve for the temperature distribution in a rectangular parallelpiped with longitudinal cylindrical cavities [31A]. The same type of method is used for a rectangular plate with inner circular boundaries [32A]. Heat conduction is analyzed for a plate with a square cut [21A]. An investigation is made of the effect of circumferential variation of heat transfer coefficient and gas radiation on the temperature distribution in a multilayered cylinder [9A]. A numerical method is described for the solution of the heat conduction equation with internal heat generation and thermal anisotropy [18A]. A variational principle is used to obtain a new solution to the heat equation in composite media [8A].

Numerical solutions have been used to determine the critical radius of insulation when circumferential variations of the heat transfer coefficient are present [40A]. Heat conduction analysis is applied to the rolling mill process where a three-layer composite strip is compressed by two rotating cylinders [48A]. The finite-element method is used to determine the temperature distribution in a helix as influenced by the curvature and torsion [38A]. Nonlinear conduction analysis is used to study the self-similar expansion of dense matter [34A].

Nonlinear boundary conditions for heat conduction problems have been considered in refs. [36A] and [41A]. Some papers focus on the solution of the inverse heat conduction problems. A direct analytical approach for these problems is given in ref. [2A], while the solution of three-dimensional inverse problems is discussed in ref. [3A]. Reference [1A] deals with optimal control in the solution of certain inverse heat conduction problems. A numerical method is used to determine the optimum locations of temperature sensors for the solution of inverse conduction problems [7A].

Research continues on the problem of thermal contact resistance. An analytical model is developed and experimentally verified for the resistance of the line contact between a circular cylinder and a smooth flat surface [6A]. Theory and experiment are presented for the contact resistance between spherical and plane surfaces with micro-irregularities [42A]. Reference [4A] shows that the contact resistance can be reduced by the use of metallic coatings. Use of fine powders for producing high thermal resistance is evaluated in ref. [46A].

A number of papers have dealt with unsteady heat conduction. References [20A, 33A] present an analysis of unsteady nonlinear problems. Unified solutions for heat conduction with a surface film of finite heat capacity are given in ref. [27A]. A study is made of the evolution of temperature in the core of a high voltage electric cable [37]. Transient conduction in a multi-layer medium is considered in ref. [10A]. Reference [30A] deals with periodic heat transfer in triangular fins. The unsteady conduction in a hollow cylinder is analytically calculated in ref. [45A]. A numerical technique is presented for the unsteady conduction in nuclear fuel rods [16A]. Transient conduction with convective and radiative boundary conditions is solved by a semi-analytical method [11A]. Some two-dimensional unsteady conduction processes are optimized in ref. [35A]. A coupled conduction and convection problem in the unsteady mode is considered in ref. [15A]. The thermal effects caused by placing a fiber in an ideal gas through which an acoustic wave propagates are described in ref. [24A]. Solutions are obtained for the enhanced heat conduction in fluids within tubes subjected to sinusoidal oscillations [25A]. Reference [17A] deals with unsteady heat conduction with mixed boundary conditions. A variational formulation is used to solve for the unsteady temperature field in heat generating bars of doubly connected cross section [13A].

Experimental work related to heat conduction is mainly directed towards the measurement of thermal conductivity and diffusivity. Reference [39A] proposes a method for the simultaneous measurement of these properties. Measurement of diffusivity is described in ref. [29A]. For multi-layer insulations, the equivalent conductivity is measured [23A]. References [5A, 6A] deal with the measurement of diffusivity of liquids. Heat conduction through a layered pressure vessel wall is investigated in ref. [44A].

## CHANNEL FLOW

Heat transfer rates in a laminar duct flow of a non-Newtonian fluid were numerically evaluated [23B]. Viscous dissipation was considered. Experimental results were presented showing the turbulence structure in the vicinity of the wall [54B]. The fluids were water and weak polymer solutions. The addition of polymers leads to an increase of the characteristic time scale determined from the frequency of temperature excursions. Measured Nusselt numbers for laminar flow of a viscoelastic fluid in a rectangular channel were found to be much larger than if the fluid were purely viscous or Newtonian [31B]. The effect was traced to secondary flows which are induced by normal force differences at the boundaries which are unique to elastic fluids. The influence of a thermal field imposed on a laminar pipe flow of pseudoplastic fluid was numerically evaluated [62B]. Correlations were presented. Numerical solutions were found for the Graetz problem for a Bingham plastic in laminar tube flow [6B]. This work was motivated by the use of aqueous foams for drilling wells in high-temperature formations. Numerical results were presented for turbulent flow of an incompressible, initially low-viscosity liquid which undergoes a thermal or induced polymerization in a long tubular reactor [29B]. Various flow regions along the tube, due to the continuing reaction, were discussed. A new approximate substitution principle was presented for flows in which both heat transfer and momentum interchange by viscous stresses are significant [27B]. Calculated results were compared with experiments. Heat transfer was analyzed for compressible flow of a fluid of varying thermophysical properties in a plane-parallel channel [64B]. An analytic solution was proposed for the effect of a resonant acoustic field on heat transfer to laminar channel flow [59B]. An analysis was presented for heat transfer in a porous wall channel with a micropolar fluid [5B]. Temperature distributions were found for several values of suction rate, convection rate and micropolar parameter. An analysis was made of thermally induced flow in a shallow two-dimensional slot [11B]. The extent of surface stagnation due to nondiffusing surfactant was discussed. When the absorbed species are insufficient to fully cover the surface, the interface is either clean and subject to constant stress or contaminated and no-slip is observed. The region between these two types was discussed. Heat transfer in a rarefied polyatomic gas was analyzed [53B]. The problem was transformed to a system of integral equations which were solved numerically. Dependence of heat transfer on Knudsen number, internal energy, Eucken factor and collision relaxation number was discussed. The F//N method for computation of heat transfer in a rarefied gas was applied to flow between parallel plates to demonstrate its efficiency [74B]. Total heat flux, temperature and density profiles, and molecular distribution functions were computed. The mechanisms of heat and mass transfer in a two-component medium were presented using a system of alternating adjacent plates [9B]. The stability of pressure-driven flow in a vertical U-shaped loop with one heated leg was evaluated experimentally and numerically [79B]. When heating is sufficient, buoyancy opposes the driving pressure, oscillation begins and, eventually, the flow reverses. The stability limits are identified. Tests were run with a single-phase fluid and with a packed bed. A numerical model was presented for axisymmetric film flow from a slot taking into account the evaporation and deposition of the substance [36B]. Thermal equilibrium of air/water flow through an annulus was investigated [67B]. Equilibrium depends upon axial length, gas and liquid mass fluxes and void distribution. Heat transfer to an air–solid suspension flow was discussed [42B]. Heat transfer rates from horizontal pipe walls to forced convection of water and suspended glass beads (or ion exchange resin beads) were measured [30B]. When the beads were larger than 0.35 mm, heat transfer was enhanced; when less than 0.15 mm, heat transfer was reduced. Convective heat transfer for steady laminar flow of a radioactive slurry between two concentric pipes with walls heated independently and subject to parabolic heat generation was analyzed [3B]. The parabolic heat generation was shown to have both positive and negative effects on Nusselt numbers. A numerical solution was presented for the heat transfer in turbulent pipe flow of supercritical carbon dioxide under cooling conditions [55B]. The effect of buoyancy on turbulent flow of mercury was numerically evaluated [17B]. One heating effect, also measured, was the reversal of the turbulent axial flux. Measurements of heat transfer to laminar tube flow of mercury showed close agreement with theory; and, in the turbulent regime, measurements agreed well with nonwetted tube literature [28B]. The separation theory of horizontal thermal diffusion columns with external refluxes was derived using an orthogonal expansion technique [73B]. The method could be applied to continuous-contact countercurrent separation processes. A numerical study was made of heat transfer to turbulent flow of supercritical helium [16B]. The mixing length turbulence model was shown to give more accurate results than the $k$ or $k$–$\varepsilon$ models. The Yaskin correlation was superior to the Nusselt correlation for near-pseudocritical temperatures. Measurements of heat transfer, critical heat flux and pressure drop in forced flow of cryogens were made [70B]. Effects of operating conditions on heat transfer in superconducting devices were discussed and correlations were presented. The correction factor for property variations for laminar convective transport in tubes was discussed [25B]. The exponent on the bulk-to-wall Prandtl number ratio is shown to be a function of 11 dimensionless parameters. An asymptotic theory was presented which accounts for property variations [32B]. Numerical results showed the influence of variable properties on laminar fully-developed pipe flow [33B]. Dependence on the properties was expressed as a Taylor series. Analytical results were given for laminar convection in open and closed channels with large wall-to-wall temperature differences [13B]. The solutions are valid where the hot and cold wall boundary layers have merged. It was shown that variations in static pressure are more sensitive to property variations than are variations in heat flux. Results of experiments were presented which show that channels of reduced density created in the atmosphere can diffuse by turbulence [26B]. Uniform (axisymmetrically or axially) channels diffuse by conduction, whereas nonuniform channels diffuse by turbulent mixing. An analysis was made showing the convective heat transfer in a side-heated planar, two-layer system [65B].

Numerical results were presented for heat transfer in curved channels of various aspect ratio [43B]. At moderate values of Dean number, a double-vortex secondary flow pattern was established. The change of the vortex pattern with increasing Dean number was documented. The influence of buoyancy on fully-developed laminar flow in curved tubes was studied numerically [50B]. Buoyancy acts to increase the average Nusselt number and rotate the orientation of the secondary flow. Density effects following a change in inlet temperature to a U-shaped pipe were computed [76B]. Results computed using the $k$–$\varepsilon$ model of turbulence were shown to be accurate. The three-dimensional flow and heat transfer situation in a rectangular, 90° miter-bend was studied to investigate the flow curvature effect in a corrugated-wall heat exchanger channel. A detailed examination of the heat transfer mechanism was presented [46B]. Reynolds number and aspect ratio effects were also investigated [47B]. Local heat transfer coefficients were measured for air flow around a 180°, square-section bend [37B]. Consistencies between velocity and temperature fields were noted. Measurements and calculations were made for heat exchange in short cylindrical chambers with swirl [61B]. Velocity and pressure distributions were measured. Turbulence data for swirling flows along an annulus were presented [15B]. Measured eddy diffusivity values for various axial and radial positions were given. The hot-wire anemometer techniques were discussed. An analysis of a screw-type swirl promoter was presented leading to an equation for optimum geometry [41B]. Unsteady, swirling, boundary-layer heat transfer in a compressible fluid flowing through a nozzle or diffuser was numerically evaluated [44B]. The heat transfer rate was found to be sensitive to free-stream velocity, variation in density-viscosity product across the boundary layer, mass transfer (suction) and swirl.

Temperature fluctuations and heat flux values were measured in grid-generated isotropic turbulence in which streamwise and transverse mean temperature gradients were imposed [8B]. The skewness of the temperature fluctuation derivatives was found to be nonzero even though the mean shear was zero. Experimental measurements were made on the enhancement of heat transfer due to laminar flow oscillation within a capillary bundle [45B]. Axial conduction heat flow was shown to be at least four orders of magnitude larger than that without oscillations. Analysis and generalizations of experimental data were presented for unsteady heat transfer and flow in tubes under conditions of heating/cooling and variations in flow rate, heat release in the walls and entrance flow temperature [38B]. Calculation methods for real, unsteady thermal processes were suggested. An analysis was presented for density-wave instabilities in heated, ventilated channels [72B]. Applications include boiling flow instabilities in boiling water reactor cores. Nonisothermal, quasistationary gas flow in an inclined rectangular tube was theoretically investigated [7B]. Dependencies were found for pressure, temperature and the discharge fluctuations. The effect of natural convection on heat transfer in a Graetz-type entry flow was computed [34B]. An oscillatory flow pattern of one-pair and two-pairs of counter-rotating vortices appeared for $Ra \geqq 5 \times 10^5$. Eventually, with increasing $Ra$, a pair of counter-rotating vortices prevails. Measurements were made of heat transfer in a tube with large-amplitude velocity pulsations and shock waves radiating from the open end [21B].

Results of an analysis of the dynamic aspects of spontaneous ignition were presented [24B]. Effects of three factors—ambient temperature, reactant temperature, and the order of the reaction were discussed. A gaseous mass transfer model was proposed for evaluation of chemical chainback reaction with volatile species in a boiling channel [35B]. The results show that gas release and absorption rates were not consistent with Henry's law. Numerical solutions were presented for isothermal laminar convective transport of reaction products in a rectangular duct with irreversible heterogeneous and homogeneous reactions [12B].

Approximate solutions of the Graetz problem with axial conduction were presented [48B]. The results of the approximate method were more easily computable than those of the exact solution. For Péclet numbers between 1 and 10, the approximate method gives satisfactory results. Results of an analysis for laminar, developing-flow heat transfer between parallel plates were presented [52B]. A fourth-order polynomial was used for the profiles' shapes to improve on the accuracy of a previous study. The effect of substantial amounts of heat addition on the convergence characteristics of implicit algorithms was investigated for convergent–divergent nozzle flow [51B]. The Beam and Warming algorithm was shown to converge more readily than MacCormack's algorithm. Real gas effects were shown to be minor. An experimental study of boundary layer turbulence assisted by flow visualization in a plane diffuser showed that two peaks in turbulence energy generation could be found; one near the wall and the other in the shear layer [40B]. Convective heat transfer rates were measured under forced convection, developing laminar flow conditions in short elliptical channels [14B]. The effects of geometry, properties and free convection were discussed. An analysis was made of steady turbulent flow in an annular channel with an internal wall moving independent of the fluid [20B]. Results were compared with experiments. A numerical analysis including radiative heat transfer was made of turbulent flow in a planar duct [63B]. The selectivity of the gas was taken into account by using a set of four gray gases.

Measurements of heat transfer were made on one wall of a rectangular channel whose other wall was covered by an array of block-like elements [68B]. Nusselt numbers compared well with correlations when the hydraulic diameter was based on the rectangular section between the tops of the elements and the opposite wall. A conversion technique for extending heat transfer data in air-heated annuli with rough inner tubes to fully-rough channels was presented [66B]. The converted data was in agreement with data on rough channels and bundles of rough tubes. An experimental investigation was made of heat transfer to gas flow in annuli with an inner rough tube [75B]. In contrast to smooth tubes, the effect of variable physical properties depends on the roughness size and the Reynolds number, diminishing with increases in these parameters.

Analytical results were presented for two-dimensional heat conduction in a rectangular solid with a cylindrical hole filled with a gas which is transparent to thermal radiation [58B]. Results of a parametric study were presented.

Laminar, fully developed flow in an internally radial-finned, vertical annulus was numerically evaluated [57B]. Accounting for buoyancy effects improves the finned passage as an effective heat exchanger device. Laminar, forced convection heat transfer coefficients for the entrance region of an internally-finned duct were numerically evaluated [56B]. Results for several fin geometries were presented. The convective cooling problem of laminar pipe flow with radiation at the wall and conduction within the wall was analyzed [19B]. Streamwise wall conduction was shown to have an effect on the results. A general procedure which combines the superposition principle with a finite-element method was applied to the conjugate heat transfer problem of laminar pipe flow with external heating [4B]. The importance of axial conduction was discussed. An energy balance was presented for single-phase flowing fluids [60B]. Heat transfer characteristics were numerically analyzed for a constant property fluid flowing laminarly through a parallel plate channel with staggered, transverse ribs [77B]. Significant augmentation by the ribs was found for high Prandtl number fluids. Also, conduction in the wall plays a large beneficial role in enhancing heat transfer. Heat transfer coefficients were measured for laminar and turbulent flow in rectangular passages open along the lateral edges but closed at the downstream end [69B]. Streamwise uniformity of heat transfer coefficient was promoted by shrouding and by increasing the interwall spacing and Reynolds number. Numerical results were presented for turbulent flow in channels of complex geometry as found in heat exchangers [10B]. Wall-bounded flows were predicted well, but jets and external flows required a modification to the modeling of the turbulent length scale. Local heat transfer rates in periodically corrugated wall channels were computed for both laminar and turbulent flow [2B]. The effects of separation; deflection, recirculation and reattachment were discussed. Patterns were shown to drastically change between laminar and turbulent flow. A numerical method for three-dimensional transport processes was presented for laminar flow to power-law fluids flowing in ducts of arbitrary, but uniform, cross section [49B]. Demonstrations were given for square, pentagonal and trapezoidal ducts.

Forced convection heat transfer measurements were made in a narrow vertical channel with upflow and downflow—both laminar and turbulent [71B]. Existing correlations were tested. The channel simulates a subchannel of a nuclear reactor. A simulation of mass transfer between cells in reactor rod bundles for longitudinal flow was presented [78B]. It was shown how results from experiments of this type would be used for calculation of enthalpies of the coolant.

A methodology was presented for the inverse design of interior coolant flow passages with application to turbine cascade blade design [39B]. The user may specify surface temperature and the wall thickness variation is found by the technique.

The transient momentum and energy equations were solved to find the transient temperatures in a thrust bearing [18B]. Analytical results were presented for the problem of two-dimensional transient heating of a circular source in a semi-infinite surface [22B]. The heating transient and a convective cool-down transient were studied. These transients simulate the thermal behavior of a single asparity in an apparent area of contact in a bearing. A numerical study was presented of the steady-state bubble-thermohydrodynamic behavior of rigid circular pad thrust bearings [1B]. The influence of air/gas bubbles included in the lubricant on important design criteria was discussed.

## BOUNDARY-LAYER AND EXTERNAL FLOWS

A survey on aeroassisted orbit transfer was presented [88C]. Analytical, computational and experimental methods used in aerothermodynamic design were discussed [56C]. Comparison between flight tests and prediction show that these methods are satisfactory for design. Aerothermodynamic problems associated with hypervelocity flight were described, including their severity [40C]. Problems that require experimental and theoretical research were highlighted. Chemically reacting viscous flow in complex geometries were analyzed using a two temperature model [81C]. Results were almost identical to one-temperature results—an almost negligible difference in electron concentration across the shock layer was observed. Laminar heating was measured at hypersonic conditions on straight and bent-nose (simulating the proposed interplanetary aeroassisted vehicle) biconics [58C]. Equilibrium density ratios were as large as 19. Measurements were made of the effect of Reynolds number, angle of attack and nose shape on the aerothermal heating of a cone at Mach 6.7 [62C]. Surface pressure data were independent of Reynolds number and laminar heating on the windward surface scaled on stagnation point heat transfer. Enhancement by free-stream turbulence of convective heat transfer to the stagnation region of a hemisphere was studied [37C]. Predictions agreed well with experimental results. The effect of free-stream turbulence on the stagnation point velocity gradient was evaluated. An inviscid flow field method was extended to include heat transfer and deal with angle-of-attack conditions [96C]. It can be applied to flow over bodies of revolution of several geometries and was shown to agree well at even high incidence angles for flow over sphere-cones. The results of a study of the shock wave on the front surface of a sphere in supersonic flow were given [32C]. Increases in Reynolds number and cooling of the surface lead to the formation of a vortex ahead of the body. Real-gas, inviscid supersonic flow fields over three-dimensional configurations were computed for three Mach numbers and two altitudes [11C]. The results compared well with previous results. Hypersonic heat transfer and aerodynamic loads to a Mars aerocapture vehicle in a $CO_2$ atmosphere were evaluated [26C]. Contemporary low-density ablative thermal protection materials were selected. Heat transfer to simulated shuttle tiles was measured at Mach 7 and 3300°R total temperature [9C, 10C]. Sensitivity to flow angle and gap width on local and average heat flux was documented. Computational results were presented for three-dimensional nonequilibrium flow over the windward surface of the shuttle [48C]. The model accounted for the finite rate chemical reactions of multicomponent ionizing air. Three-dimensional effects were shown. Phase-change paint was used to measure heat transfer on space shuttle orbiter models with differentially deflected elevons [92C]. These deflections affected the wing heat transfer about 40% (or less) but the windward elevon heat transfer coefficient could be many times that without deflections. Flight-derived aerodynamic heat transfer data for the shuttle orbiter wing lower surface was compared with ground-based experimental data and computational results [84C]. An interference heat transfer region correlated with the region of minimum static enthalpy predicted by computation. A review of nonequilibrium flow field computations and methods was presented where the results were compared to temperature and heat flux measurements on the space shuttle [76C]. Three thermal protection systems are evaluated for protection of surfaces of future space transportation systems [77C]. They were shown to be viable up to 2300°F. An analysis of radiative heating during aeroassisted orbital transfer was made to determine the impact of the computational chemistry [23C]. The analysis showed that predictions of radiative intensity, exitation rates, reaction rate constants, particle ionization and spectral line widths could be made. The effect of chemical nonequilibrium on the flow field around an aeroassisted orbital transfer vehicle was numerically evaluated [78C]. A vehicle experiences a lower ratio of nonequilibrium/equilibrium heating than computed for the shuttle. This is due to higher velocities of the AOTV. The three-dimensional flow of a hypersonic stream around bodies was analyzed, with the inclusion of radiation, using the method of an optically transparent shock layer [33C]. As an example, radiation heat transfer was determined for a symmetric conical body. The effect of an exothermic reaction within the boundary layer on convective heat transfer was measured and computed [30C]. The effect is negligible until the wall temperature becomes sufficiently high that the exothermic reaction takes place in the boundary layer. Particle to gas heat transfer rates were calculated for an endothermic cyclohexane dehydrogenation reaction [65C]. Heat transfer rates were lower than without reaction, as one might expect for an endothermic reaction. A study was made of the flow of a multicomponent gas in a three-dimensional boundary layer near a surface where there is a heterogeneous chemical reaction [31C]. A formula for heat flow to the surface was proposed. Joint probability density functions of temperature and its dissipation are measured in the reacting zone of a plane jet [5C]. Correlation between the two is weak and their independence increases with distance from the jet centerline. LDA measurements in the flow over a wall heated by combustion were made to investigate the contributions due to a burst in low-momentum fluid from the wall [22C]. Changes in Reynolds stress due to combustion were seen in the sublayer of the combustion products and were not found where the combustion takes place. The nonequilibrium thermodynamics model given by the governing principle of dissipative processes was applied to solve for the characteristics of two-dimensional laminar, constant-property flow with nonuniform wall temperature and main-stream velocity [79C]. The theory of viscous dissipation of high Prandtl number fluid in laminar flow was reviewed [50C].

Measurements were made to show the effect of large-scale obstructions on the heat transfer and flow field of a turbulent boundary layer [18C]. An example is at the leading-edge of a gas turbine airfoil. Measurements and visualization studies were made to investigate mechanisms which cause free-stream turbulence and surface roughness to increase heat transfer in the stagnation region of turbine blades [86C]. A correlation was found between vortices caused by mean velocity gradients and spanwise variations in heat transfer. Heat transfer measurements were made on cooled, flat plates with various degrees of free-stream turbulence intensity, pressure gradient and cooling intensity [74C]. Special emphasis was placed on boundary-layer transition. It is shown that free-stream turbulence and pressure gradients are of primary importance. Measurements were made of channel heat transfer with repeating ribs as used in gas turbine cooling [36C]. Ribs oriented at oblique angles to the flow gave higher heat transfer rates and reduced pumping power. Measurements were made using the laser two-point technique of the effect of impingement of stator wakes on rotor blade heat transfer [17C]. The effect of the wake of a nozzle guide vane on rotor heat transfer under transonic conditions was measured [7C]. The interaction of the rotor and the wakes results in variations in the incidence angle. The shock waves from the moving wake have a major effect on instantaneous heat transfer rates on the rotor surface. Measurements of local heat transfer coefficients were obtained on a modern gas turbine blade with and without film cooling injection using a shock tube [25C]. The presence of an upstream rotor was shown to have a large effect on downstream heat transfer but little effect in the leading edge and midchord locations. Experimental results for transition on gas turbine blades were reviewed [68C]. The effect of free-stream disturbance level was discussed. Data sets, which include transition, were reviewed to extract information about the transition process [29C]. This information may be useful in turbine applications. It shows that free-stream turbulence and pressure gradient have strong and opposite effects on both the location of the start of transition and on the transition length. Measurements were made of heat transfer in boundary layers undergoing transition [91C]. A late-laminar state was documented. Turbulent Prandtl number in late-transitional flow was shown to be higher than that measured in fully turbulent flows. The flow on the leading edge of a turbine blade was experimentally investigated and the effects of Reynolds number, compressibility, incidence and free-stream turbulence were discussed [38C]. The flow is extremely complex even at design conditions, showing separation and reattachment and transition and relaminarization. The effect of heating the surface on transition and the growth of instabilities was studied—the rise in critical Reynolds number with heating was given [47C]. The effect of sinusoidal flow pulsations on heat transfer from a cylinder in cross-flow was measured for pulsation amplitudes as large as 25% and frequencies above and below the shedding frequency [3C]. Calculations of gas turbine blade heat transfer coefficients were made using a low Reynolds number $k$–$\varepsilon$ turbulence model [71C]. Good agreement was found, even in the complex flow on the pressure surface which is transitional over most of the length. An exact solution was presented for heat transfer from an impulsively started plate cooled by transpiration cooling [70C]. Injection was shown to amplify the temperature and momentum boundary-layer growth. Computational predictions were made of the external convective heat transfer on gas turbine blades using a boundary layer program and the $k$–$\varepsilon$ turbulence model [90C]. Free-stream turbulence and transition were included in the model. They agreed with measurements on the pressure side but discrepancies were noted between computation and experiments on the prediction of transition.

A method of multiple scales was proposed to determine the partial differential equations which describe the modulation in amplitude of three-dimensional waves propagating into two-dimensional heated liquid layers [8C]. A new criterion for the most likely frequency was presented. Measurements were made of velocity and temperature fluctuations in the wall region of fully-developed, unstably-stratified flow between horizontal parallel plates [28C]. The stratification effect on turbulent intensity, skewness and flatness factors and bursting speed were presented. Experimental results were presented for the effect of destabilizing heating on Goertler vortex instability in a laminar boundary layer on a concave surface [44C]. When nonlinear effects become important, the vortices become distorted and meander in the lateral direction. The convective character of inviscid instabilities in parallel shear flows was determined by examining branch-point singularities of the dispersion relation for complex frequencies and wave numbers [41C]. A flow is convectively unstable when the branch-point singularities are in the lower half complex-frequency plane. Spacially growing waves can only be observed if the mixing layer is convectively unstable, otherwise, the instability develops temporally. Businger's universal functions were used to compute the friction velocity and the Monin–Obukhov length in unstable boundary layers [75C]. It was shown that the functions behave well outside the normal range. Flow visualization was used to study the flow resulting when a potential vortex rotates normal to a stationary horizontal disc [66C]. Vorticity removes the singularity on the vortex axis leading to the development of a three-dimensional boundary layer. The boundary layer transcends to turbulence then relaminarizes with increasing Reynolds number. Heat transfer from an isothermal cylinder to time-independent cross-flow with fluctuations larger than the mean flow was analyzed and an example with sinusoidal flow was presented [13C]. Results were presented of an experimental, theoretical investigation of the upstream-side heat transfer from a sphere or transversely oriented cylinder in a flow which experiences a step change in temperature [80C]. Mass transfer in converging or diverging channels of equal or different wall concentrations was analyzed [12C]. The analysis involved an infinite series of eigenfunctions. A two-region model was used to analyze the heat transfer problem of laminar flow of a low Prandtl number fluid passing a wedge [21C]. An asymptotic low $Pr$ expression for local Nusselt number was given. An approximate analytical solution was presented for the transient problem of a constant temperature plate moving at constant velocity initially at rest and in thermal equilibrium with the surrounding flow [14C]. The convergence of the method was discussed. Results of an experimental investigation of very low Reynolds number forced convective heat transfer to a sphere were presented [93C]. The new experimental technique used for these measurements was discussed. The effect of interface waviness, due to instability, on mass transfer rates was investigated for the subcritical and critical flow regimes [51C]. A convection analysis of a negative pressure gradient laminar boundary layer with suction or blowing was made [49C]. An analysis of laminar flows over surfaces of roughness length less than the boundary-layer thickness was presented [19C].

Heat transfer of a micropolar fluid past a moving semi-infinite porous plate was computed [83C]. The effects of suction and microrotation were discussed. The convective stability of a horizontal layer of micropolar fluid heated from below and rotating about a vertical axis were analyzed [16C]. Rotation has a destabilizing effect, contrary to earlier assertions, and, in the absence of rotation, microinertia has a destabilizing effect. A set of equations are found and solved for the two-dimensional flow of an incompressible micropolar fluid near a stagnation point [15C]. Viscous dissipation effects were included. Heat transfer from a linearly stretching, continuous surface with a power law temperature distribution was solved to give closed-form solutions for several specified conditions [34C]. A boundary-layer approach was applied to evaluate the heat transfer coefficient when a viscoelastic fluid flows past a cylinder [73C]. It is shown that the heat transfer coefficient becomes independent of Reynolds number for large values of Reynolds number. Analytical solutions were provided for Stokes flow fields induced by instantaneous thermal sources in a liquid field and at the center of a solid spherical surface [2C]. The evolution of the flow field was presented. Experimental and theoretical results were given for slow translation of a hot sphere through a fluid at rest [4C]. Separation of the thermal layer ceases when the drag is controlled by the most viscous fluid. The problem of dissipative heating of a fluid under a solid, isothermal plate was considered [54C]. A new analytic technique applicable to the outer region was presented for calculating the momentum and heat transfer in flat plate and circular cylinder turbulent boundary layers [59C]. A new version of the $k$–$W$ model was proposed for computation of a wide range of fluid dynamic and heat transfer problems [42C]. The main advantage over previous models is the removal of modifications to near-wall constants. Measurements were made of fluctuating velocity and temperature in a turbulent plane jet mixing layer [20C]. Where Reynolds stresses and turbulent heat flux were high, turbulent Prandtl number was 0.4, indicating strong coherence in the flow. The effect of isolated surface projections on heat transfer from a plate to a turbulent flow was measured [95C]. Zones of steep decrease in heat transfer and increase in skin friction were identified. The surface rejuvenation model was applied to the field of mass transfer [53C]. Theoretical expressions for Sherwood and Stanton numbers compared well with experiments. Heat transfer enhancement in turbulent flow on a plate due to edge effect secondary flow was measured [61C]. The effect was always present and depended mostly on the plate thickness. Computations were made to study the effect of outer flow turbulence on turbulent transport using the two-parameter turbulence model [94C]. The results were compared with experimental data. A similarity solution was given for the local Nusselt number on a flate plate with uniform heat flux and a small Prandtl number fluid [27C]. A heton, two discrete baroclinic geostrophic vortices in a two-layer system, was defined [39C]. Hetons transport heat, repel similar hetons (i.e. hot repels hot) and attract dissimilar hetons. A two-heton engine exhibits vortex splitting, loss of potential energy and meridional heat transport. Measurements were taken of the heat transfer from a circular cylinder which is normal to the flow and parallel and near a planar surface [1C]. The effect of separation distance was discussed. Average heat transfer rates were measured for forced convection air flow over inclined and yawed rectangular plates [60C]. It was found that the average heat transfer coefficient is insensitive to aspect ratio but does vary with the angle of attack and Reynolds number. Correlations were given. Experiments showing heat transfer on a disk which is perpendicular to the flow showed a minimum coefficient at the stagnation point increasing to twice the stagnation value at the edge [82C]. Data collapsed when scaled on the root of the Reynolds number. Optimum nozzle-to-plate spacing for heat transfer to a plate with a normal impinging jet was experimentally evaluated [45C]. Maximum stagnation point heat transfer was found when the plate was at the end of the potential core of the jet. A generalized model for predicting optimal spacing was presented. A computational model was presented for predicting the flow and heat transfer of a single semi-confined turbulent jet on an impermeable isothermal surface [67C]. Effects of jet Reynolds number, nozzle-to-surface spacing, and jet turbulence level were discussed. Comparisons with data were favorable; but, further refinement of the turbulence closure model is needed. The problem of a lighter fluid impinging upon a heavier, otherwise quiescent, fluid was analyzed [89C]. The convective heat transfer coefficient was found. The effect of viscous dissipation on mixed convection flow about a rotating sphere was analyzed [69C]. A method was presented for calculating the hydrodynamics and scalar transport at the end-wall of a vortex chamber [87C]. The parameters varied were boundary-layer thickness, local friction, heat transfer rate and gas flow rate.

Laminar flow heat transfer in tube assemblies was computed where the assemblies were inclined slightly to the flow [6C]. The effect of the transverse component is strong and nearly-axial flow shows much higher heat transfer than purely-axial flow. Measurements were made to document the effect of surface roughness on local and average heat transfer coefficients for tube banks in cross flow [97C]. General relations for prediction of local heat transfer, local skin friction and efficiency were presented. Direct measurements of turbulent Reynolds analogy factors were made for 15 nonplanar surface microgeometries including riblets, wavy walls, etc. [52C]. Increases in this term are of the value in optimizing heat exchanger design. Measurements were made of flat plate heat transfer to turbulent flow when there is a cylinder parallel to the plate and perpendicular to the flow but imbedded in the boundary layer [55C]. An optimum separation distance was found. Heat transfer augmentation was due to the turbulence in the lower shear layer of the cylinder wake. Heat transfer from a flat plate, influenced by an array of cylinders normal to the flow and parallel to the plate, was measured [46C]. Optimum values of position and spacings were made. Comparisons were made with the case of a single cylinder inserted in the boundary layer. Convection and radiation heat transfer rates from fixed, rotary metallic and brick type regenerators were computed [43C]. The nature of the variation of heat transfer coefficient was important in evaluating average parameters.

Results were given of research on the behavior of liquid films on heat transfer surfaces as in condensers and film evaporators [63C]. Incentive is provided by a need to strip the water film from the wall of a steam main prior to sampling for steam quality. Experiments were made to measure the thermal effect of burst-type fission gas release [35C]. The surface upon which the gas impinges showed extreme temperature rises. With gas injection, the liquid sodium heat transfer coefficient reduced to as low as 5% of that with single-phase flow. Experimental results and supporting analyses were used to study the rewetting of a hot surface with impinging water jet [24C]. The history of the process was documented with photographs and measurements of the wall temperature history. It was shown that a thin, electrically insulating coating could be used in ionic liquids [57C]. Key to its use was the measurement of the heat transfer resistance. An analytical study of the behavior of a gas in a pressurized container during the early stages of expansion was made [64C]. The outflow was choked. A key quantity, heat transfer from the cylinder wall, was included in the analysis. Combined radiative–convective heat transfer in a laminar boundary layer on a permeable plate was analyzed [72C]. The effect of scattering was presented. The convection Stefan problem with Newton's radiation condition was solved with a new technique which formulates the moving boundary problem as one with a fixed boundary [85C]. The convergence was shown to be improved over the classical series solution.

## FLOW WITH SEPARATED REGIONS

Experiments of the effects of sinusoidal flow pulsations on the heat transfer from a cylinder in cross flow at $Re = 50{,}000$ showed no significant increase in the heat transfer due to the pulsations in either the wake or attached boundary-layer region [2D]. In order to examine the effect of the roughness characteristics on icing, a boundary-layer model of heat transfer from the front half of a rough circular cylinder is proposed [11D]. An experimental study has been conducted on the effect of the clearance between a circular cylinder and a plane surface on the heat transfer from the cylinder to a cross flow [1D]. The mass transfer characteristics of a subliming flat naphthalene surface on which a protruding cylinder is mounted were studied for two cylinder height to diameter ratios, 1 and 12. The cylinder height influences the local mass transfer distribution downstream of the cylinder, but has little effect on the upstream region [6D]. Local and mean heat transfer characteristics were measured on an elliptic cylinder of an axis ratio 1:3, on which particles of silica scale are uniformly distributed in order to clarify fouling effects of geothermal water scale on heat transfer [14D]. Experimental investigations on the local and average heat transfer from a square prism to an air stream were carried out in the range of subcritical Reynolds numbers and the average heat transfer coefficients at zero and 45° angles of attack were found to be as high as 40% of the well-known values of Hilpert [9D].

Correlations for heat transfer and pressure drop for in-line and staggered banks of tubes are suggested for $Re$ from 1 to $2 \times 10^6$, $Pr$ from 0.7 to $10^4$ and a wide range of relative transverse and longitudinal pitches [21D]. The Nusselt number and pressure loss coefficient were found to be highly sensitive to the transverse pitch in a two-row array of finned tubes [19D].

Measurements of the local heat transfer coefficient for a separating water flow past a step in a rectangular channel are presented [13D]. A viscous–inviscid interaction procedure is described for predicting the heat transfer in separating flow in a rearward-facing step/asymmetric channel expansion [8D]. Results of numerical calculations for heat transfer in turbulent recirculating flow over two-dimensional, rearward-facing steps and sudden pipe expansions are presented [7D]. Theoretical results concerning the flow and heat transfer in laminar flow past a backstep show that the size of the initial boundary layer can have opposing effects on the reattachment distance, depending on whether the Reynolds number is held constant [4D]. Combined heat transfer and fluid dynamic measurements in a separated and reattaching boundary layer demonstrate that fluctuating skin friction controls the heat transfer rate near reattachment, while the conventional Reynolds analogy applies in the redeveloping boundary layer [20D].

A theoretical investigation of unsteady marginal separations in a classical, unsteady boundary layer suggest that the nonlinear properties of such separations may be largely responsible for the central features often observed experimentally in the abrupt turbulent reattachment of eddies that follow laminar separation near the leading edges of aerofoils [17D]. Arguments are presented to prove identical results in determining the most thermohydraulically efficient surface in three comparison studies: the heat flux at equal pumping power and area; the pumping power at equal heat flux and surface area; and the surface area at equal heat flux and pumping power [10D].

The average and local heat transfer at the base surface of a cylindrical cavity whose opening is perpendicular to an oncoming free stream were found experimentally to decrease sharply with increasing cavity depth [18D]. In an attempt to investigate numerically buoyancy-induced enclosure flows in which the fluid is radiatively participating, energy conservation equations are derived over a finite, not infinitesimal, control volume [16D]. Heat transfer to and from slender cylinders (filaments, fibers and wires) travelling along the axis of a vertical duct with heated walls was investigated experimentally and it was found that there is a difference between the heat transfer coefficients of monolithic filaments and of multistrand fibers [5D].

Heat transfer studies were conducted experimentally on axisymmetric rocket nose cones with separationless and separated flows using sounding rockets and the results were compared to predictions [15D]. Distributions of the temperature–pressure gradient correlations obtained from measured budgets of the longitudinal and lateral heat fluxes in the self-preserving region of a slightly heated turbulent plane jet into still air are consistent with a model which includes only the turbulence interaction contribution to the pressure fluctuations [3D]. A numerical investigation of the unsteady heat transfer to a droplet suspended in an electric field predicts there is a maximum steady-state Nusselt number equal to about 30 [12D].

## HEAT TRANSFER IN POROUS MEDIA

The largest single category of papers in this section deals with saturated porous media. An extensive overview of steady solutions was published in three parts [60DP, 61DP, 62DP]. A very large number of works in this area deal with natural convection heat transfer, the widely used Boussinesq approximation for which was evaluated for its suitability [26DP]. A less restrictive variant of the Boussinesq approximation was compared with the more common assumption, and while the flow field calculations were sensitive to their differences, overall heat transfer quantities were insensitive. Similarity solutions were obtained for free convection boundary-layer flow adjacent to long vertical plate fins in porous media under conditions of power law variations of the fin conductivity–thickness product [63DP]. A numerical and experimental investigation of natural convection in saturated porous media in the annulus between vertical concentric cylinders with small aspect ratio, $L/D$, was reported [69DP]. As radius ratio (outside/inside) was increased, smaller aspect ratios were required to introduce multicellular flow structures. Solutions were developed for free convection flow and heat transfer from a nearly horizontal, semi-infinite, isothermal, heated surface in a saturated porous medium [73DP]. An asymptotic solution was found for positively inclined surfaces, and solutions were found near the leading edge for both positively and negatively inclined surfaces. Natural convection about a line source at the vertical interface of two saturated porous media of differing permeabilities and diffusivities was analyzed [80DP]. Natural convection from a two-dimensional horizontal line source embedded in saturated porous media has been analyzed using matched asymptotic expansions suitable for use at lower Rayleigh numbers than a previous boundary-layer solution [1DP]. Stably heated corners of saturated porous media were explored by numerical experiments and scale analysis [42DP]. Experiments performed in shallow gas–solid packed beds of a regular packing of spheres between horizontal isothermal surfaces confirmed a value of $4\pi^2$ as the critical Rayleigh number [17DP]. Linear stability analysis was used to determine the critical onset time at which convection starts in a porous layer saturated with water initially at a uniform temperature near, but above, the temperature of maximum density, 3.98°C, when the upper surface is impulsively lowered to a temperature below 3.98°C [66DP]. A numerical model was described for natural convection in saturated porous medium with simultaneous motion of the pore fluid and the matrix, which was treated as a viscous medium [19DP].

Linear stability analysis procedures employed in double diffusion were applied to explore the effect of a third diffusing component in a saturated porous medium providing general expressions for various stability boundaries [67DP]. The effects of simultaneous mass transfer upon buoyancy-driven heat and fluid flow from a concentrated source in a saturated porous medium were analyzed for low Rayleigh numbers for both transient and steady solutions [65DP]. For a porous horizontal cylinder immersed in a gas-filled porous medium, a boundary-layer analysis was carried out for the coupled free convective heat and mass transfer [29DP]. For a vertical surface, natural convection heat and mass transfer was studied through scaling arguments and similarity solutions of the boundary layer approximation to the governing equations [3DP]. Both numerical and scale analyses were presented [89DP] for combined heat and mass transfer by natural convection in finite layers of porous media.

Mixed convection was investigated for special cases of plane surfaces in media with variable permeability [8DP,9DP] yielding similarity solutions for horizontal and inclined surfaces. A nonlocal similarity method was employed to determine effects of buoyancy and wall temperature variations about nonisothermal spheres and cylinders in mixed convection circumstances in porous media [51DP]. Analysis was also performed [72DP] upon a saturated porous media flow with natural convection at a permeable, absorbing boundary and simultaneously a forced oscillatory flow parallel to but distant from that boundary.

An analysis was presented [40DP] of the temperature fields of a single-phase coolant and a porous channel through which it flows. A method was proposed for computer-aided mathematical modeling of a steam-thawing process for treating permafrost in advance of building construction [50DP]. Transient conduction and radiation in nonconvective planar porous materials was analyzed for the case of sudden increases in heat generation at one boundary [86DP], applicable to transient methods of measuring properties of porous insulation, and an analytic method was proposed for calculating unsteady heat exchange in soil applicable to energy analysis of pipeline transportation systems [56DP].

Developing flows through porous media in channels bounded by isothermal parallel plates were analyzed using a modified Darcy model [38DP]. Boundary, convective, and inertia effects were shown to become more important in natural convection in saturated media adjacent to a vertical plate as porosity increases [33DP]. These effects all reduce the heat transfer relative to the conventional solutions based on Darcy flow. Using matched asymptotic solutions for a three-layer model for natural convection at a semi-infinite vertical plate in saturated porous media the Brinkman model was incorporated [34DP]. The boundary effect became more important at larger Rayleigh numbers and higher Darcy numbers. Inertial (non-Darcy) effects at high Rayleigh number in a vertical porous layer subjected to uniform heat fluxes at the sides were numerically evaluated using the Forchheimer model [64DP]. Numerical experiments in a porous layer heated from the side were used to confirm the non-Darcy flow prediction of an analytical solution [68DP] and to illustrate the regime between Darcy flow and flow affected by inertia. Effects of inertia were demonstrated to be significant in natural convection at realistically large values of the Rayleigh number in thin layers of saturated porous media with small Prandtl number [55DP]. A Brinkman-extended Darcy model, incorporating the no-slip condition at an impermeable surface, was shown to give superior predictions of natural convection heat transfer in vertical porous enclosures for large modified Reynolds number and large aspect ratios [87DP]. Steady non-Darcy free convection was analyzed for wedges of saturated porous media bounded by a flat heated surface at an arbitrary angle from the vertical and by another surface which is either at ambient temperature or insulated [74DP].

Boundary and variable porosity effects were demonstrated to be significant in forced convection through packed beds in an experimental and numerical study [91DP]. Simple thermal resistance models were developed for use in predicting steady-state, packed-bed heat transfer characteristics [21DP]. The Blake–Kozeny model for pressure drop in a granular bed was used to develop a model for heat and mass transfer from a fluid to a particle in a granular bed [39DP]. Analytic expressions were presented for asymptotic radial heat transfer coefficients for packed bed reactors [23DP]. Comparisons were made of numerical solutions for the transient gas–solid heat transfer in packed beds using a two-phase model and a single-phase model [32DP], displaying the advantages and limiting parameters of the latter. A new model was developed [45DP] and experimentally supported [46DP] for transient thermal response of a packed bed, employing the method of spatial averaging. An analytical method was proposed for predicting transient temperature distributions in a porous bed subject to a step change in fluid inlet temperature [88DP]. It is suggested that the method could be extended to other high-order partial differential equations resulting from coupled phenomena. Measured transient temperature distributions in a high temperature pebble bed regenerative heat exchanger were shown to be well predicted by a numerical model [94DP]. Heat and mass transfer processes between gas and particles in a fixed bed dryer were numerically investigated, showing that moisture diffusion taking place inside the particles can control the drying process even at moderate Biot numbers [58DP]. Heat and mass transfer from an object immersed in a packed bed was studied, incorporating the effect of the high porosity zone near the surface of the body [6DP]. Experiments were performed and correlations presented for heat transfer and pressure drop of particulate laden gas flow through a tube packed with spheres [27DP].

Orthogonal collocation was demonstrated [59DP] to be a simple and useful method for predicting the combined heat and mass transfer process of drying of porous media. Evaporation in porous media was analyzed with a kinetic model, replacing the collision integral with an external force, the collective interaction of gas molecules with the stationary media [48DP]. A theoretical model was proposed [44DP] for drying and sorption processes in unsaturated porous media. Theoretical and experimentally determined rates of property changes were presented for the heating of a cylindrical sample of water-saturated limestone in hot air [93DP]. A two-dimensional, finite-element formulation was presented for coupled heat and mass transfer in partly saturated soils [85DP]. Modeling and experiments identified void fraction and its distribution, fiber radius, directionality, and tortuosity as properties controlling liquid diffusion in fibrous insulation material [53DP]. Another combined theoretical and experimental investigation of heat and moisture transfer in a fibrous insulant displayed consistent distributions of moisture but overestimations of heat transfer [18DP]. Experiments demonstrated that heavy porous material (brick walls) undergo strong variations of apparent thermal transmission related to slowly stabilizing moisture profiles [5DP]. Analytical evaluation of unsteady filtration in hydrofractured low-permeability rock produced a parameter which may be used as a feasibility test for extracting geothermal energy from specific geological conditions [49DP]. A mathematical model was proposed for describing heat and mass transport within a porous granule of a catalyst which, itself, assists in forming a two-phase mixture within its pores [22DP]. A descriptive review of the processes and consequences of the drying of wood, a distinctly nonisotropic porous medium, was published [82DP].

A dryout model for a particle debris bed was developed with focus on the inter-facial resistance between countercurrently flowing vapor and liquid [10DP] and shown to fit available data well. Safety analysis of liquid metal fast breeder reactors motivated the development of equations governing the transient vapor formation of a hypothetical debris bed [11DP] and those governing particle melting and penetration of the guard vessel lining of an overheated, dried out debris bed [12DP]. A study of countercurrent flooding limitations in porous media led to the conclusion that differences in dryout heat flux data from shallow and deep volume heated beds of large particle diameter and differences in bottom and volume heated beds can be attributed to the role played by coupling between the particulate bed and the overlying liquid layer [47DP]. Physical experiments simulating core debris beds with internal heat generation [41DP] likewise indicated that significant coupling exists between convective flow within the bed and an overlying liquid layer. Boiling of water in an unconstricted bed of granular material was studied visually and with temperature profile measurements [24DP]. Analysis of heat transfer and two-phase flow in porous media with porosity varying with height showed strong influence of the porosity profile upon the height of the two-phase zone and the temperature difference [15DP]. Analysis and experiments were addressed to the length of and the dryout heat flux of the two-phase zone in porous media [90DP].

The suitability of gas fluidized beds for use in heat recovery systems was explored and experiments were performed with inclined distributor plates intended to help the particles to flow through the system [31DP]. Mass transfer coefficients were measured from both freely moving and fixed spheres to a dense phase fluidized bed with results showing no dependence upon the superficial velocity, dependence instead upon the minimum fluidizing velocity, and a 20–50% increase in mass transfer rates for fixed spheres relative to freely moving spheres [70DP]. A correlation was developed for longitudinal dispersion coefficients determined by the tracer impulse response method in fluidized beds which were similar in properties to biofilm reactors [57DP]. The effects of inert particle size and density upon circulation rate and heat transfer were explored for drying equipment of various scales incorporating fluidized beds [81DP]. A mathematical model for drying of particles in an inclined, vibrated, fluidized bed was shown to predict quite well the temperature and moisture variations observed in an extensive experiment with a three-stage unit [30DP]. Vibration considerably enhanced the drying ability of the device. Design considerations for fluidized bed drying equipment were reviewed [25DP]. A computer model was developed to simulate the drying process in a rotary dryer [36DP].

A composite dense phase and lean phase model for heat transfer to tubes immersed in gas fluidized beds has been demonstrated to fit extensive experimental data [7DP]. A relationship was demonstrated between contact resistance models and a property boundary-layer model of transient dense-phase heat transfer to surfaces in fluidized beds [43DP]. A boundary-layer model of heat transfer between fluidized beds and immersed surfaces was presented [13DP], and estimates of maximum Nusselt numbers thereby developed agreed reasonably with data from the literature. Mass transfer from an immersed surface to a fluidized bed, previously considered to bear little similarity to heat transfer, was shown to have strong similarity to heat transfer when particles have large specific mass capacity [16DP]. A modified packet model was shown to agree with data from beds of large and small specific mass capacity. A mechanistic model was proposed for heat transfer between a slugging fluidized bed and a vertical immersed surface, more suitable for long vertical surfaces than previous models [2DP]. It gave good agreement with time-averaged data. Experiments on heat transfer from V-thread finned tubes to gas fluidized beds and analysis of heat conduction in the fins led to correlations applicable to single finned tubes and finned tube bundles [28DP]. An experimental technique involving batch-wise drying of wet porous particles in fluidized beds of identical dry particles provided measures of gas–particle and particle–particle heat transfer rates in large particle systems [20DP]. The gas–particle heat transfer rates measured were rather insensitive to fluidizing velocity. Heat transfer coefficients and local voidage on immersed cylindrical surfaces in a tube bundle were measured in a large particle pressurized fluidized bed [4DP], displaying a large effect of the pressure upon the heat transfer coefficients. An extensive comparison of data with models and correlations for heat transfer coefficients on immersed surfaces in pressurized fluidized beds produced recommendations of preferred predictions for three distinct regimes of fluidization segregated by bounding Reynolds and Archimedes numbers [78DP]. Heat transfer coefficients on a vertical tube in fluidized beds of small particles at elevated temperatures were found to increase with increased bed temperature but were quite insensitive to a change in bed diameter from 25 to 15 cm [79DP]. Experiments of heat transfer from horizontal cylinders at various heights in liquid fluidized beds of glass beads revealed the concentration profiles of segregated regions of different sized particles [35DP].

Using a continuum model to simulate fluidized bed hydrodynamics, predicted heat transfer coefficients compared favorably with a previously performed experiment thereby lending credence to the hydrodynamic simulation [84DP]. Experiments with a fluidized bed furnace revealed considerable axial and radial temperature gradients at low fluidizing velocities [92DP]. Heat transfer coefficients from a fluidized bed to a porous distributor plate were experimentally measured, correlated, and found to vary in a similar way as bed-wall coefficients of heat transfer [95DP].

A comprehensive review article was published covering the status of understanding of fundamentals of gas–liquid–solid fluidization with recommendations of areas for further research [54DP]. Experiments upon wall-to-bed heat transfer in three-phase fluidized beds led to a generalized correlation equation for heat transfer coefficients in liquid–solid and in three-phase fluidized beds, based upon the equality of the product of the heat transfer coefficient and liquid holdup in three-phase beds with the corresponding product for liquid–solid beds [14DP]. A semi-theoretical correlation was proposed for heat transfer coefficients in three-phase fluidized beds based on a correlation for bubble column wall heat transfer and constants were evaluated to fit data from existing literature [83DP]. Heat transfer coefficients were measured at the wall of a three-phase fluidized bed with upward co-current flow of liquid and gas with the liquid at low velocities [77DP]. Previous correlations inadequately predicted these coefficients and a new correlation was proposed.

Other fluid–particle systems involving the transfer of heat are here loosely combined. A variational method was used to predict the time development of coating thickness in fluidized bed coating of a thin metallic substrate [71DP]. A theoretical model was developed and a simple design chart presented for analysis of heat transfer and pressure drop in vibro-fluidized beds [75DP]. Small glass and aluminum particles suspended in gas streams were reported to reduce heat transfer coefficients inside vertical and horizontal tubes except at small loading ratios and moderately low (11,000 to 13,000) Reynolds numbers [37DP]. Experiments and analysis were reported regarding a raining packed bed heat exchanger [76DP]. A numerical solution confirmed that laser-induced thermophoresis improves the efficiency of deposition of aerosol particles on a surface [52DP].

## EXPERIMENTAL TECHNIQUES AND INSTRUMENTATION

A review of several new experimental methods and diagnostic techniques for heat transfer research was presented by the faculty of the A. V. Luikov Heat and Mass Transfer Institute of the Byelorussian Academy of Sciences [5E]. Pitfalls in the correlation of engineering data by the use of dimensionless groups were discussed [54E].

One avenue of improvement in heat transfer instrumentation lies in the application of thin-film coatings. In experiments where a uniform wall heat flux is desired, but where the heat transfer coefficient is low, the use of an electrically heated, thin, gold-coated plastic sheet appears to provide a method for providing the flux without having wall conduction overwhelm the results [3E]. Another advantage of thin films is in their improved dynamic response; a gold thin-film resistance thermometer plated onto a non-conducting substrate was developed for heat flux measurements at a moving surface subjected to rapidly varying heat flux; measurements were reported with a resolution of about 0.002 K at sampling rates up to 5 kHz [50E]. A heat flux sensor/thermocouple was constructed by sputtering an electrically insulating, thin-film coating over most of the instrument surface, leaving bare metal exposed only at locations where temperature measurement was desired; minimal disturbance of boundary-layer temperature and wall heat flux was claimed for measurements over a flat plate tested to temperatures up to 911 K [31E]. Thin films of fired metal paints were used as resistance thermometers for measuring surface temperatures to a reported accuracy of $\pm$ 0.023 K [44E]. A coaxial thin-film thermocouple was modeled for measuring the time-varying temperature on the surface of the combustion chamber wall of an internal combustion engine [11E]. Results were presented of heating rates in hypersonic wind tunnels in which it was claimed that the principal uncertainty associated with the use of thin-film gages on MACOR substrates had been resolved (namely, the thermal properties of MACOR) [36E].

Important advances are occurring in the application of optical techniques for temperature measurement, especially for high-temperature environments. A planar laser-induced fluorescence method was developed for obtaining measurements of the two-dimensional temperature field in a combustion flow [46E]. A technique utilizing two optical multichannel analyzers detecting light scattered by two separate mechanisms (e.g. Rayleigh and Raman) makes possible the simultaneous two-dimensional mapping of both temperature and species concentrations in turbulent flames [33E]. An optoacoustic laser beam-deflection technique for measuring flame temperatures at a sampling rate $>1$ kHz was reported [16E]. A two-color optical pyrometer was developed for measuring the temperature of individual particles (typically 50 $\mu$m in diameter) over the temperature range 1200–2500°C, with an accuracy of $\pm 50$ K [23E]. The simultaneous measurement of three quantities—the temperature, size and velocity of individual carbon particles of a burning pulverized fuel—was achieved by an optical method [39E]. The calibration of an optical pyrometer against a tungsten strip lamp at a maximum temperature of 2300°C was extended to 3100°C using a linear extrapolation accurate to 0.65% [21E]. The theory and application of the laser shadow technique was discussed for the case of axisymmetric turbulent flow [14E]; it was shown that three-dimensional spatial resolution could be obtained by use of the Abel transform method.

The application of liquid crystals for temperature measurements was reviewed [15E]. A measurement system consisting of a composite sheet containing a heater element and liquid crystals was reported to provide high-resolution measurements of local heat transfer on a large-scale model turbine blade airfoil [20E]. An intriguing method was reported whereby the velocity and temperature of a thermochromatic fluid are measured simultaneously; the velocity is measured by laser Doppler anemometry while the temperature is measured using the otherwise-discarded intensity of the scattered light [45E]. The temperature can be observed directly by the fluid color change or can be quantitatively measured by a suitable optical detection method. An improved flow visualization technique utilizing photochromic dye and an inexpensive pulse laser was described [22E].

Several improvements in schlieren techniques were reported; a review of color-coding schlieren visualization was presented [47E]. A study of schlieren photography in a water tunnel showed this method to be a viable means of visualization in water flows [12E]. A method was developed to obtain from schlieren fringe patterns information about the propagation of a gravity wave in a density-stratified liquid [41E].

Development of hot-wire anemometry as a tool for heat transfer research continues to receive considerable attention. The static and dynamic response of a hot-wire were examined analytically [10E], and the transient response of the Nusselt number to variations in the Reynolds number over a range from 1 to 40 was investigated in a numerical simulation of a hot-wire [8E]. Hot-wire dynamic behavior was studied in experiments, in which it was found that an alteration in dynamic response can occur at frequencies around 1 Hz [27E]. The influence on hot-wire measurements of the wire diameter and overheat ratio of a wire placed near a conducting wall in a turbulent boundary layer was studied [26E]. Expressions for the response of an inclined hot-wire to an imposed flow were extended to three-dimensional flows of moderate turbulence intensity [42E]. Calibration procedures for inclined hot-wire probes were investigated [7E]; the results show significantly different yaw correction factors depending on the procedure chosen. Yaw, pitch and velocity parameters were derived as functions of the effective cooling velocity of triple hot wires in unsteady flows with large direction changes [35E]. Directional sensitivities of quartz-coated and alumina cylindrical hot-film anemometers were investigated in air and liquid Refrigerant-113 flows [43E]. A simplified hot-wire calibration procedure was described based on the assumption of linear dependence of the fluid temperature on the square of the anemometer voltage [6E]. An experimental investigation of oscillatory phenomena produced by a hot wire located near and below a free surface was reported [53E]. Finally, an alternative whirling hot-wire system was described, including optical data transmission by an LED [52E].

Pyroelectric anemometers received some attention, including one study of geometric considerations in their operation [13E] and another which presented a heat transfer model of their response [19E].

Several new methods for determining thermal properties were reported, including a photoacoustic-phase method for simultaneously determining thermal conductivity and specific heat of a solid [28E]; a digitally controlled heater power supply for measurement of specific heat at cryogenic temperatures [29E]; a calorimeter with mixing-flow cells of aneroid type for determining heat capacity at high pressures and temperatures [48E]; and utilization of the thermal strain of solids to measure the thermal conductivity and thermal diffusivity of solid-phase polymers [2E]. An overview was presented of a workshop at the 9th European Thermophysical Properties Conference, which considered the "effect of radiation on thermal transport measurements" [37E].

Correlations were presented for the response time of chromel–alumel thermocouples with different bead sizes in flowing hot air; the response time was found to be unaffected by the air temperature [40E]. A theoretical study of the dynamic response of thin-wire resistance thermometers found significant nonlinear effects in the measurement of temperature fluctuations under certain velocity conditions [30E]. Reported developments of new heat flux sensors for specific applications include calorimetric loops for determination of thermal loads of steam-generating waterwall tubes [24E] and a temperature-controlled, multiple-chamber indirect calorimeter for measuring heat transfer between animals and the environment [38E]. A monotone-wall calorimeter was developed in which the heat generated by a body is determined by measuring the temperature difference between that body and a reference body which is in the same temperature environment; the detector is shielded from surrounding temperature effects [34E]. A precision *ac* resistance bridge suitable for thermometry was described [9E]. Systems were described for measuring temperatures in optical-fiber preform fabrication [4E] and in liquid metal flows, the latter using a permanent magnet probe [51E]. A rod-like temperature probe for studying heat transfer in flowing polymer melts was examined theoretically [49E]. The error in measuring the heat flux from a furnace wall due to perturbation of the flux by a heat flux transducer was calculated [1E]. The temperature-control system designed for the calorimetric experiment planned for the Spacelab D1 mission was described; the purpose of this experiment is to measure the singularity in specific heat near the gas–liquid critical point under zero-gravity conditions [17E].

Finally, new instrumentation for cryogenic heat transfer studies was reported, including a semiconductor resistance thermometer [32E], rotating cryostats [18E], and a device for investigating heat transfer of a cryogenic liquid under centrifugal forces [25E].

## NATURAL CONVECTION—INTERNAL FLOWS

Buoyancy-driven flows in enclosures continue to gain the attention of a number of researchers spanning the disciplines from pure and applied mathematics, to physics, to engineering science, including those interested in nonlinear phenomena and turbulence. Applications include manufacturing, cooling of electronic components, and geophysical and astrophysical flows. As has been true for some time, there is considerable activity in nonlinear phenomena for convection within horizontal layers heated from below (Rayleigh–Bénard or Bénard convection), differential heating of vertical and inclined layers, the influence of internal energy sources on flow, convection in annuli, the influence of surface tension on flows, convection in porous media and mixed convection. A number of studies considered the instability and low Rayleigh number laminar flow in a horizontal layer heated from below. The onset of instability is advanced with temperature fluctuations on the boundary [106F]. Another study [54F] considers time-varying as well as random fluctuations in the bottom surface temperature and their influence on the onset of flow. A study predicts the influence of spatially varying temperature on the lower wall of a horizontal layer of fluid containing two components [11F]. Conditions under which the principle of exchange of stability holds for a viscoelastic fluid layer heated from below were described [96F]. Linear stability theory has been used to predict the instability in a horizontal layer with suction through the boundaries of the container [92F]. Hexagonal cells are found to be preferred for the onset of flow in a horizontal layer of fluid with temperature-dependent properties [57F]. With stress-free boundaries, the maximum Rayleigh number for steady rolls is found to be relatively low [16F]. Three-dimensional numerical solutions for a horizontal layer with stress-free boundaries and a square planform show the heat transport is strongly dependent on Prandtl number [7F]. Square cells are the preferred form of convection in a horizontal layer, with finite conducting boundaries for a very limited range of conditions [80F]. With large variations in viscosity across the layer the transition from square cells to rolls has been predicted [22F]. Another analytical study [39F] of convection in a layer of fluid whose viscosity is strongly dependent on temperature has been reported. The onset of oscillations in a low Prandtl number fluid have been examined analytically to predict instability in superfluid mixtures of helium [35F].

A prediction of the transition to chaos in a fluid layer heated from below has been described [38F]. Another study [64F] on the transition to chaos uses Bénard convection as the example in the analysis.

Large-eddy-scale simulation has been used to study turbulent Rayleigh–Bénard convection up to modest Rayleigh number [36F]. Long-term changes in the temperature of the boundaries with Bénard convection have been analyzed using a nonlinear diffusion equation [40F]. Penetrative convection in water near 4°C is studied assuming the presence of long convection rolls with a constant heat flux boundary condition [81F]. A fluid in which thermal waves travel with finite speed (second sound) has been analyzed to predict Bénard instability [62F].

Experiments on Rayleigh–Bénard flow include the use of a specially designed heat flux meter [32F]. Oscillations in low temperature helium have been studied using a very sensitive thermometer [60F]. Apparatus for precision measurement of Rayleigh–Bénard convection in a cylindrical container include the use of a computer-enhanced shadowgraph imaging system [97F]. Turbulence has been observed at low Rayleigh number in a narrow vertical cylinder heated from below [1F].

Oscillatory instability is predicted when heating a horizontal layer of fluid on which is superimposed another layer of immiscible fluid [77F]. In a related study, a perturbation analysis is used to examine the oscillatory onset of flow [78F]. Experiments performed by heating a layer of liquid water overlaid with ice show different patterns of interactions at the solid–liquid interface [34F].

Several papers consider fluids with internal energy sources in horizontal, vertical or inclined layers. Modeling [5F] of turbulent natural convection in such a horizontal layer indicates different regimes (layers) in terms of temperature profiles. The critical Rayleigh number has been found for a horizontal layer with a linear variation in internal energy source [79F]. In a vertical layer with internal energy sources, instability appears in the form of traveling waves [98F]. An analysis for nonuniform internal energy source predicts the stability that might occur with radiation absorption in a liquid in a vertical slot [88F]. Another paper considering radiation absorption in a vertical slot presents stability and flow calculations [43F]. For an inclined square box containing internal energy sources and also differentially heated, the temperature and velocity fields have been calculated [3F]. A later paper considers the case of internal energy sources and flow if the enclosure is cooled from below [2F].

The breakdown of the conduction region to convection in a differentially heated, vertical slot appears to be quite different at different Prandtl numbers [31F]. A related analysis indicates elongated horizontal rolls in a nonuniformly heated, vertical layer [30F]. The analysis of the flow in a differentially heated, vertical layer for non-Newtonian fluids has been presented [76F]. The laminar convection between vertical plates with fixed outer temperature indicates that the inner surface temperature and the flow are dependent on the relative conductivity of the plates to that of the fluid [21F]. A numerical study for large Rayleigh numbers with a low Prandtl number fluid in a differentially heated, vertical layer has been described [89F]. In experiments on differential heating of a variable-viscosity fluid in a vertical slot, a shadowgraph is used to detect the onset of instability [27F]. The flow of supercritical helium in a heated vertical slot has been analyzed [33F]. The transient temperature distribution in a vertical layer with suddenly heated sidewalls has been described [47F].

Experiments using differential heating across a vertical annulus have been performed over a large range of Rayleigh and Prandtl numbers; turbulence is initiated at a fixed value of the local Grashof number on the inner wall [73F]. Experiments show progressive waves of instability for convection in a differentially heated, vertical annulus [104F].

A number of studies considered square or rectangular enclosures. Numerical finite-difference solution indicates the effect of variable properties on the temperature, velocity distributions and heat transfer in a differentially heated, square cavity [111F]. A numerical and experimental study shows the effect of finite conductivity in walls of a differentially heated, square enclosure [53F]. Convection in a square enclosure when one wall is suddenly cooled, has been studied experimentally and numerically [67F].

Transient heating causes oscillatory flow in a low Prandtl number fluid contained in a cylindrical enclosure [46F]. Stratification develops quite differently with a turbulent boundary layer as compared to a laminar boundary layer in an enclosed heated fluid layer [105F].

Convection in a corner containing a hot vertical wall and a cold horizontal wall yields a single cell over a range of Rayleigh number [55F]. The analysis of flow in a rectangular enclosure when one of the vertical walls is held at one temperature in its upper half and a different temperature in the lower half has been described [71F]. Finite-difference methods for enclosures have been extended to high Rayleigh number; a more refined turbulence model is required at high Rayleigh number [70F]. The velocity distribution in a differentially heated rectangular enclosure has been determined with a laser-Doppler velocimeter [19F].

Several studies consider flow across a differentially heated, inclined layer. One numerical and experimental paper presents results for low Rayleigh number flows when air is the working fluid [85F]. The flow in an inclined layer from a cell immersed in a cooling liquid has been presented [61F]. Experimental and theoretical results are presented for flow when one end-wall of an inclined layer is heated [56F]. Convection in an inclined layer is much weaker with the presence of a partition [4F]. Analysis of the flow in a differentially heated, inclined layer of porous material shows three potential flow structures: two-dimensional unicellular, polyhedral convection cells, and longitudinal coils [23F].

Applications of natural convection occur in the flow near a crystal–melt interface [37F]. Reduced flow occurs in a vertical circular duct when internal fins are inserted, but there is a net increase in heat transfer [72F]. Experiments on convection in a vertical rod bundle indicate decreased Nusselt number for a higher Prandlt number fluid at a fixed Rayleigh number [52F]. The influence of various geometric parameters on convective heat transfer in enclosures with localized heat sources have been experimentally studied to simulate cooling of electronic circuit boards [42F]. Numerical modeling of three-dimensional laminar flow in tanks indicates a circular flow pattern when there is a localized heat source [94F]. A lumped-parameter model analysis is used to predict thermal response of a liquified petroleum gas container exposed to a fire [95F]. Spacing and offset within an array of columns of horizontal cylinders have a significant influence on the overall heat transfer [82F].

The convection in the annulus between two horizontal cylinders has been the subject of a number of investigations. One analysis [6F] includes the effect of internal energy sources and their influence on Nusselt number. Another [44F] includes the influence of variable properties on the differentially heated annulus with large radius ratio; for a radius ratio greater than 10, the Nusselt number appears to be independent of the outer cylinder. A transformation maps the annulus for both concentric and eccentric cylinders into a rectangular region; numerical determination of the flow in this region provides local heat transfer and temperature fields over a range of Prandtl numbers [75F]. An experimental study [87F] indicates that even with a radius ratio of 11.4, the heat transfer from the inner cylinder is not the same as when it is immersed in an infinite medium. Analysis for laminar convection in the region between confocal elliptical cylinders has been performed with different orientations of the line between the two foci [86F]. Three-dimensional flow in a horizontal annulus has been studied for the case of finite cylinders differentially heated on the plane (end) walls [90F].

In a differentially heated spherical annulus, the streamlines are in the form of pairs of double helixes for low Rayleigh number conditions [69F]. Another study on flow in a spherical shell has been performed with stress-free boundaries and a radial gravitational vector [109F]. Experiments for convection between different bodies and external cubical enclosure find a general Nusselt–Rayleigh number correlation [102F]. A design equation has been provided to predict the heat transfer across enclosures of various geometries [10F]. Experiments on natural convection in a horizontal cylindrical cavity included effects of a transient in the wall temperature [28F].

Partially opened enclosures—really open cavities—are important in a number of areas. Laminar convection in open horizontal cavities has been analyzed for small aspect ratios and aspect ratios of unity [25F]. A related study considers different thermal boundary conditions [26F]. Correlation of experimental results in open-ended inclined channels has been provided [9F] for differential heating across the walls. Electrochemical systems have been used to study an open cylindrical cavity at high Rayleigh number [91F].

Flow in porous media is often driven by buoyancy forces. Sidewall heat loss has a strong stabilizing effect on the initiation of convection in a vertical porous slab [51F]. In a saturated porous layer heated from below, three-dimensional flow appears in the form of a square cell [17F]. Experiments on a vertical annulus of saturated porous media indicate the need for a simple model to estimate the effective thermal conductivity of the fluid filled media in a correlation of the results [74F].

Double-diffusive convection occurs when there are two diffusive flows, often one of heat driven by a temperature difference, the other of matter driven by a concentration difference, one example being thermohaline convection. The effect of variable stratification on double-diffusive flow in a horizontal layer has been examined with reference to stability of solar ponds for collecting solar energy [108F]. Thermohaline convection has been studied [8F] to determine the flow in large bodies of water, such as lakes or lagoons. The instability of three-dimensional salt fingers is found to be similar to that encountered with two-dimensional salt fingers [45F]. A differentially heated vertical plane layer has been studied with a stable temperature and unstable salinity gradient to determine the breakdown of steady flow [107F]. Models developed to predict the transient response of salt-stratified, double-diffusive systems demonstrate good agreement with existing data in terms of the mixed layer thickness and temperature distribution [13F]. The propagation of undamped transverse thermal waves in binary mixture have been examined [14F]. Experiments were performed [50F] in a low aspect ratio layer having double-diffusive convection produced by differential heating and an electrochemical reaction.

Surface tension or thermocapillary or Marangoni flow occurs when there is a variation of surface tension or surface free-energy at the interface between two fluids. Marangoni flow near the interface of two liquids has been studied [20F]. The effect of local heating from above has been studied to examine thermocapillary flow in a heavy liquid [100F]. The influence of a deformable upper surface on Marangoni flow has been analyzed [24F]. A steady thermocapillary flow in a square cavity with a free upper surface has been examined in the absence of gravitational forces [110F]. The importance of the convective contribution to heat transport in a liquid column in the absence of gravitational forces has been predicted [12F]. A low gravitation experiment in a rocket shows the importance of thermocapillary convection [59F]. In another study [62F] in a low-gravity environment unsteady Marangoni flow was measured. Analysis of surface tension driven flow has been used to predict performance with electron beam welding [103F]. Rotation can be used to inhibit the instability in a thermocapillary driven flow [84F]. Critical Marangoni numbers have been calculated when surface tension gradients on the top surface of a liquid layer drive the flow [41F].

Mixed convection occurs when buoyancy-driven flows and forced flows are superimposed upon one another. In many geometries this leads to complex three-dimensional patterns even when the flow is laminar. Studies for such flows in the entrance region between horizontal parallel plates include a numerical analysis [65F]. In the transitional and turbulent flow regime, quite different effects are found on the top and bottom plates [68F]. Numerical simulation for the entrance region of a horizontal rectangular duct indicates that the heat transfer can be enhanced by up to 400% when the bottom wall is heated [48F]. The possibility of bifurcation into two different solutions with different vortex flow patterns has been indicated for mixed convection in a horizontal rectangular duct [66F]. A three-dimensional numerical model confirms experimental results for laminar mixed convection in a horizontal heated tube [29F]. In horizontal annuli, constant temperature and constant heat flux boundary conditions have been used in a finite-difference solution [58F]; there is good agreement with experimental results. The stability of mixed convection in a vertical slot with porous walls and cross flow has been analyzed [93F]. Experimental data provide information on up flow and down flow of supercritical helium in vertical tubes where mixed convection is of importance [15F]. Buoyancy can have a significant effect on fully developed laminar flow and heat transfer for flow through shrouded arrays of blocks that simulate electronic devices on a circuit board [18F]. The principle of exchange of stabilities is found valid for some boundary conditions even with a nonlinear temperature profile in the presence of a shear flow [49F]. The onset of instability for a nonuniformly heated horizontal layer is more sudden when there is a weak shear flow imposed on it [101F]. Thermocapillary effects in a thin moving liquid layer with local heating from above can be quite large [83F].

## NATURAL CONVECTION—EXTERNAL FLOWS

The vertical flat plate geometry continues to receive considerable attention. A similarity boundary-layer solution for plates of prescribed variable surface temperature or heat flux was presented [32FF]. Approximate solutions to the Navier–Stokes and energy equations were obtained for small Grashof number but large Prandtl number [29FF,52FF]. Experiments in water near 4°C and the use of asymptotic expansion theory were used to show the care which must be used when employing the Boussinesq approximation [16FF]. Experiments simulating the melting of ice were conducted using a salt-stratified fluid [6FF]. Similarity problems were reviewed for a plate of constant wall temperature or uniform heat flux immersed into a stratified fluid [50FF]. Experimental interferograms and finite-difference numerical solutions of natural convection from a heated plate partially in air, partially in water were presented [42FF,43FF]. Reference [17FF] gives numerical results which show the effect of variable fluid properties on the heat transfer. Solutions to the boundary-layer equations were obtained using variable fluid properties near the critical point of $CO_2$ [58FF]. A review of existing data and heat transfer correlations was made for isothermal flat plates near the critical point of $CO_2$ or $H_2O$ [12FF]. Two extensive studies on turbulent flow were published. In ref. [51FF], variable property effects were studied in turbulent flow using air up to a Grashof number of $2 \times 10^{12}$. Reference [27FF] presented results for turbulent flow in water adjacent to a uniform flux plate. Hydrogen bubbles were used for flow visualization and liquid crystals indicated the local plate temperature up to a modified Rayleigh number of $6 \times 10^{16}$. A combination of matched asymptotic expansion and finite-difference technique was used to solve the boundary-layer equations for a step change in plate temperature at low Prandtl number [41FF]. Similarity solutions for a similar problem were obtained as were asymptotic solutions valid at long times after the initial transient [22FF].

Inclined plates and vertical plates with localized heating or insulated boundaries were also investigated. Neutral stability curves were given for a heated, inclined plate facing up [64FF]. Perturbation solutions were given for inclined plates with [18FF] and without [24FF] an unheated surface upstream. The effects of an adiabatic wall parallel to [54FF] and adjacent to the sides of [55FF] a vertical flat plate were studied. An extension of previous work on the effects of localized heaters placed on a vertical adiabatic wall was presented [23FF].

Heat transfer from horizontal surfaces has been studied for heated strips or circular plates facing down [49FF] and for a cooled strip facing upwards in a porous medium [26FF]. Heat loss above a heated plate covered with liquid potassium was studied experimentally [60FF] as a function of potassium layer thickness and evaporative cooling from the upper free surface. A matched asymptotic expansion technique was used to study heat transfer above a heated horizontal plate [1FF]. A similar study was presented for a heated circular disk [33FF] where the curvature effects were found to be restricted near the center of the disk.

Numerical solutions to heat transfer from an insulated horizontal cylinder were obtained to determine the critical radius of insulation under more realistic conditions [56FF]. An approximate integral method was developed for predicting laminar and turbulent natural convection from curved surfaces with a horizontal cylinder used as an example [35FF]. Experimental studies of natural convection from horizontal cylinder arrays include an interferometric study of two vertically aligned cylinders [46FF] and a flow visualization and mean heat transfer coefficient study of two vertical arrays of cylinders bounded by two vertical, adiabatic walls [47FF].

Several papers considered laminar natural convection from a variety of objects of small aspect ratio including a numerical study of short vertical and horizontal plates and prisms [34FF]. A spherical segment [59FF] and a cone frustum [30FF] were also considered. Mean heat transfer coefficients from cubes and spheres were measured in air with varying pressure to change the Grashof number [7FF]. A similar study in air and water was performed [57FF] with the results correlated using a length parameter defined as the surface area divided by the square root of the horizontal projection.

A numerical study was presented for the stability of a natural convection boundary layer adjacent to a vertical flat plate with uniform blowing [11FF]. Theoretical and experimental studies were made on a heated vertical flat plate with blowing or suction through a permeable section at the bottom of the plate [28FF]. Numerical solutions were obtained for blowing or suction through a vertical permeable cylinder surrounded by a standard porous medium [19FF].

A comprehensive study of combined heat and mass transfer from a vertical plate was given in ref. [38FF] where regions of aiding and opposing flows were delineated as a function of Lewis number and buoyancy ratio. A numerical study of particle deposition onto the surface of a vertical cooled plate was given for both laminar and turbulent flow regimes [10FF]. Transient combined heat and mass transfer in air was studied numerically in ref. [53FF]. A semi-analytical approach was used to evaluate the rate of water evaporation from a vertical plate of varying heat flux [36FF]. Three papers by the same authors describe analytical solutions to the combined heat and mass transfer problem for mixed convection from a vertical cone [13FF], and pure natural convection form a horizontal cylinder [14FF] and a sphere [15FF].

Coupled conduction or radiation and natural convection is receiving increased attention. Coupled conduction on a vertical flat plate was solved using transformed boundary-layer equations and the Blasius method [61FF]. Conjugate conduction–natural convection [21FF] and conduction-aiding mixed convection [20FF] were solved numerically for a heated downward facing circular pin fin. An experimental study of coupled conduction–natural convection was performed for a horizontal cylinder with one axial plate fin at various angles [63FF]. A local nonsimilarity technique was used to obtain a solution for natural convection in an optically thick, cold liquid adjacent to a nonemitting, nonreflecting, radiation-transmitting vertical flat plate [9FF].

Mixed convection studies include heat transfer from a suddenly accelerated vertical flat plate [62FF]. Reference [8FF] considers an oscillating vertical heated plate where the natural convective flow is superimposed on the primary Rosenblat flow. Measurements and analyses were made for steady aiding or opposing mixed convection [44FF] and transient aiding flow [48FF] from a vertical flat plate. Laminar aiding flow was studied theoretically for a slender vertical cylinder [5FF] and experimental measurements were made for cross flow [68FF]. The

Navier–Stokes and energy equations were solved for cross flow over a heated horizontal cylinder [3FF,31FF]. A similar approach was used for aiding or opposing flow from the cylinder [4FF]. Two papers presented numerical studies of aiding mixed convection from a point heat source [45FF,2FF]. An experimental study produced three-dimensional flow visualization and local surface heat transfer results for mixed convection in a horizontal channel bounded by two asymmetrically heated plates [40FF]. Linear perturbation theory was used to determine the nature of the flow above the downstream of a heated patch [66FF]. Transverse or longitudinal roll cells were formed depending on whether the flow Reynolds number was above or below a critical value. Secondary mixed convective flows were obtained numerically in fully developed flow in a horizontal annulus [37FF].

A numerical study of a plume with positive or negative buoyancy was given [67FF] which included several tables and figures of velocity and temperature profile information. The stability of a buoyant plume above a line heat source was described with analytical wave numbers compared with available experimental data [65FF]. The morphology and ascent rate of a buoyant plume in a homogeneous viscous fluid was measured to predict the hot-spot volcanism activity in the earth's mantle [39FF]. Simple jet trajectory models were used to determine the behavior of a buoyant jet injected into fully developed pipe flow [25FF].

## CONVECTION FROM ROTATING SURFACES

Heat transfer from rotating surfaces has been attracting considerable interest, especially in connection with rotary engines.

Studies of laminar heat transfer in a tube rotating about an axis perpendicular to the tube axis show that the secondary flow induced by the Coriolis terms always tends to increase the heat transfer coefficient [18G]. Studies of heat transfer enhancement from a rotating cylinder show that with increasing rotating Reynolds numbers, the heat flux increases also and becomes more uniform [17G]. Numerical solutions for the full Navier–Stokes equations in the nonlinear range for axisymmetric compressible flow in a rotating cylinder with axial convection are presented, and the validity of the present approach is confirmed [23G]. Finite-difference solutions for laminar flow of air in a rotating rectangular duct with aspect ratio 2/1, where the duct wall is subjected to a uniform heat flux, show the effect of rotation on the development of the flow patterns, velocity and temperature variations [13G]. Numerical studies of the effect of sidewall heating in the pressure-driven laminar flow of an incompressible viscous fluid through a rectangular channel that is subjected to a spanwise rotation, show that an increase in the rotation speed leads to an increase in the net heat transfer [22G]. Numerical predictions of the influence of cylinder rotation on turbulence and heat transfer in an annulus are in excellent agreement with available experimental data [1G].

Numerical predictions for the centrifugally driven free convection in a sealed rotating cavity and for the buoyancy-affected flow through a cavity with an inner cylindrical source and an outer cylindrical sink are in good agreement with experimental data [3G]. Finite-difference solutions for forced laminar convection in a rotating cylindrical cavity with radial outflow show that the local Nusselt number changes from that of a free disk near the center of the cavity to that for Ekman layer flow at the larger radii, provided that the fluid enters the cavity from a uniform radial source [4G]. Studies of the source-sink flow inside of a rotating cylindrical cavity using a 'free disk' model for the outflow and a free vortex for the inflow case, are in good agreement with available experimental data [14G].

Studies of turbulent heat transfer in co-rotating annular disks indicate that the disk rotation produces a surge in the local Nusselt number of the near-exit region and a substantial enhancement in the average heat transfer performance [19G]. The thermal effect on the transverse vibration of a high-speed rotating disk is considered under steady-state heat conduction. A new critical speed of disk rotation has been obtained and this critical speed is found to depend on central temperature, thermomechanical anisotropy, etc. [7G]. Studies of laminar cooling of two nonmixing liquids are reported contained between two coaxial disks rotating in opposite directions [15G].

The nature of small amplitude Rayleigh–Bénard convection for a horizontal plane layer of fluid rotating about a vertical axis and heated from below is considered. Steady-state and time-periodic solutions of this system are derived and their stability is discussed [21G]. The stability of a horizontal, viscoelastic fluid layer heated from below is studied for the case of a container rotating with uniform speed and new threshold values for overstability are established [9G]. Studies of the convective stability of a horizontal layer of incompressible micropolar fluid heated from below and rotating about a vertical axis show that the rotation has a destabilizing effect which contradicts an earlier assertion [2G]. The effects of compressible work and frictional heating in axisymmetric swirling flows have been clarified and formulae have been provided for use in engineering calculations [5G]. Experimental studies of the behavior of transient isolated convection in a rigidly rotating fluid revealed an increase of the maximum temperature in the thermal caps with increasing rotation and a more rapid cooling of the buoyancy source [12G]. A unique data base has been established for the assessment of the effects of spin and mass addition on high-angle-of-attack re-entry [11G].

Analytical studies of mixed convection flows generated by a heated rotating sphere reveal interesting flow patterns [6G]. Studies of viscous dissipation on mixed convection about a rotating sphere show that an increase of the viscous dissipation causes a decrease of the heat transfer rate [16G]. A rotating condenser with a scraper is considered as a new device for promoting condensing heat transfer [24G]. The effect of rotation on heat transfer in the channels of moving turbine blades has been determined experimentally with a loop system of cooling [8G].

Overall heat transfer coefficients to water and silicone fluids in cans rotating in a steam retort have been correlated with an analytical expression [20G]. A rotating, packed-drum reactor has been proposed as an immobilized whole cell reactor and its performance for ethanol production has been studied with yeast cells immobilized in a calcium alginate gel [10G].

## COMBINED HEAT AND MASS TRANSFER

There has been considerable interest recently in film cooling processes, primarily as they relate to high-temperature gas turbine systems. In addition, transpiration cooling and ablation cooling continue to be studied to some extent as do a variety of processes related to combined heat and mass transfer.

Many studies consider film cooling on a flat surface with or without a pressure gradient along the surface. The flow produced with injection into a mainstream through a vertical slot has been analyzed for its potential influence on film cooling [8H]. Mass transfer from a swollen polymer along with a holographic interferometer is used to measure film cooling on a surface with zero pressure gradient [15H]; a continuation of that work shows little influence of an adverse pressure gradient on film cooling, but a significant effect when a favorable pressure gradient occurs along the surface [16H]. The importance of free-stream turbulence on film cooling downstream of a porous section has been demonstrated experimentally [25H]. The results for film cooling performance with a large temperature difference between the injected coolant and the hot mainstream has been correlated; the measurements were taken in a transient high-pressure tunnel [23H]. Measurements of film cooling following injection through two rows of cooling holes [18H] shows good agreement with earlier studies. On a highly roughened (but flat) surface to simulate actual engine conditions, the film cooling effectiveness can be higher or lower than that on an equivalent flat plate, primarily depending on the magnitude of the blowing parameter [14H]. A two-phase film cooling heat transfer study has been performed [33H] over a range of parameters.

Measurements conducted near the leading edge of a turbine blade demonstrate the importance of different parameters on heat transfer following film cooling [4H]. In a related study [5H], a significant decrease in heat transfer is found with film cooling on the suction side of a simulated turbine blade. In a considerable region along the suction side of a blade near its end wall, the film coolant is swept off the blade by the passage vortex [13H]. Film cooling effectiveness decreases with frequency and amplitude of vibration of a turbine blade on its pressure side; on the suction side, there is an increase in effectiveness upstream of the separation point [21H]. An analysis of the flow distribution through inserts used in gas turbine blades provides information needed to predict film cooling performance [31H]. The film cooling on turbine blades using several sections of porous wall has been calculated to provide a universal correlation [28H]. An analysis [3H] includes the influence of internal convective cooling on the film cooling performance on a turbine blade.

With transpiration cooling, the surface or wall to be protected is permeable with the coolant fluid passing directly through this surface. A study of a low Mach number mainstream with high blowing rate transpiration cooling indicates a reduction in heat transfer with transpiration up to the blow-off condition [11H]. An interferometric study with a porous cylinder demonstrates the major influence of blowing on the heat and mass transfer particularly near the separation point [26H]. Analysis indicates that the instability of transpiration cooling from nonuniform flow can lead to over-heating of a surface [19H]. Analysis shows the importance of thermophoresis on the heat transfer to a transpiration cooled wall from a particle-laden gas flowing over it [12H].

Experiments on transpiration cooling of a surface with a supersonic turbulent boundary layer flowing over it show the interaction of the coolant with an incident shock and the influence of pressure gradient [7H]. Analysis of the heat transfer for a re-entry vehicle show that with large blowing rates in the stagnation region the heat flux can be made very small [29H].

An analytical technique has been developed to predict the influence of a time varying heat flux on an ablating surface [6H]. Perturbation that alters the shape of an ablating body has been studied to see the conditions under which the perturbation would be amplified; generally it is damped [24H].

A turbulence model has been developed to predict the heat transfer of an axisymmetric jet impinging on a flat plate [1H]. The influence of ambient temperature on the heat transfer from a plane surface to an impinging jet has been demonstrated [17H]. An impinging jet has been used to cool the bottom of a cylindrical enclosure [22H]. A flow distribution model for an array of impinging jets helps predict the heat transfer characteristics with nonuniform geometries [9H].

Other studies on combined heat and mass transfer include the development of a similarity solution for mass transfer to a thermally driven boundary layer [20H]. Dehumidification of a flow of moist air over a tube bank has been studied to determine the Nusselt and Sherwood numbers [10H]. Approximations are introduced to predict the influence of gas addition on the transient heat transfer in a stirred liquid [27H]. Studies are reported on the heat transfer to micropolar fluids in a channel with porous walls [2H] and passing over a continuously moving porous plate [30H].

## CHANGE OF PHASE—BOILING

*Nucleate boiling*

An exact analytical solution was presented [1J] for the potential flow due to growth of a spherical bubble at or near a solid wall, applicable to idealized nucleate bubble departure size. A mechanism was proposed [20J] for bubble growth in nucleate boiling within thin falling superheated water films, capable of explaining the much faster observed growth rate of these bubbles than their counterparts in pool boiling. Experimental evaluation of bubble dynamics in subcooled nucleate pool boiling [48J] confirmed bubble growth predictions but illustrated that the models for bubble waiting period diverge from observed behavior at greater subcooling. Transient and permanent nucleation sites were studied by means of high-speed infrared cinephotography [95J], displaying fluctuations in bubble nucleation periods. It was proposed [78J] that short-lived nucleation sites might be the consequence of circulating microbubbles, small enough to be dragged by superheated liquid approaching the surface, but large enough to be thermodynamically stable. Offered as a possible explanation of certain hysteresis effects, this proposal suggests that surface and pool geometry may play a larger role than previously expected in nucleate boiling. Nucleation sites were experimentally shown to interact with one another [16J]; the nature of the interaction appeared to be determined by the dimensionless ratio of the separation distance to the bubble departure diameter. The effect of surface orientation on nucleate boiling, evident only at lower nucleate boiling heat fluxes in some recent experiments, was discussed as exemplary of the Moissis–Berenson transition from an isolated bubble regime to one of slugs and columns: both are considered to be nucleate boiling, but hydrodynamically they are quite distinct [63J]. Two separate heat transfer correlations were presented [11J] respectively for the 'interference' and the 'macrolayer' regions of the nucleate boiling regime. A one-dimensional transient model employing the liquid macrolayer thickness was employed to investigate the effect of heater wall thickness upon nucleate pool boiling heat transfer [89J]. Boiling curves and ebullition cycle periods were measured for subatmospheric pressure pool boiling of potassium on a horizontal surface, varying the height of the liquid level above the heater surface [66J]. The period was found to increase as the level decreased, and liquid levels less than 5 mm seemed to suppress nucleate boiling. Boiling heat transfer experiments with water and organic liquids on microsurfaces, those with dimensions less than a few bubble break-off diameters, led to a correlation for correcting for differences from large surface boiling behavior [58J]. Acoustic phenomena in boiling; the acoustics of single bubbles, acoustic interactions among bubbles, and the sound associated with the approach to critical heat flux were discussed [34J]. A numerical investigation of the one-dimensional transient conduction during hardening of a plate of steel [57J] predicted reasonably well the duration of the nucleate boiling regime; for plate thicknesses greater than a limiting value these durations were invariant with thickness.

*Pool boiling*

Metal-fiber porous coatings and vibration and impact-machined surfaces were explored as enhancements to boiling of refrigerant 113 at pressures of 1 and 2 atm [28J]; the machined surfaces were found to be superior, while high porosity coated surfaces proved to be less effective than smooth surfaces for subcooled boiling. Pool boiling heat transfer rates of ammonia and refrigerant 22 were shown to be enhanced to considerably different extents by differing enhancement techniques: small patches of thin Teflon layers enhanced boiling of ammonia much more than refrigerant 22, while a porous metallic layer showed the reverse behavior [35J]. Quenching experiments with samples of differing materials, surface roughnesses and surface energies (as indicated by contact angle) illustrated that smaller contact angle had no effect on nucleate boiling but raised both the critical flux and minimum film boiling flux, improving heat transfer throughout the transition regime [26J]. Surface roughness enhanced nucleate boiling but had much smaller effect upon transition boiling. The influence of surface conditions on the pool boiling of liquid metals was analyzed, and the thermal conductivity of the heating surface was shown to have a strong effect on surface temperature distribution [38J]. Pool boiling at atmospheric pressure at porous surfaces of horizontal tubes in water, ethanol and refrigerant 113 exhibited small superheats at bubble initiation, substantial increases in the critical heat flux, and a transition, subject to hysteresis in thick porous layers, from bubble generation near the external surface to the penetration of a vapor film layer through the porous layer [4J]. Preliminary design curves were developed analytically for boiling of water, isopropyl alcohol, and refrigerant 113 on surfaces with longitudinal fins [12J]. Experiments with boiling of refrigerant 113 on finned surfaces produced boiling curves consistent, at near atmospheric pressures, with predictions based upon the use of pool boiling curves of smooth surfaces to prescribe the relationship between heat flux and temperature along the surface of a one-dimensional fin [2J]. Poorer agreement at lower pressures shed doubt on the general utility of this predictive method.

A combined experimental and analytical investigation of thermosyphon boiling of water in vertical parallel-walled channels with uniform heat flux demonstrated and explained smaller wall superheats with closer spacing of the channel walls [8J]. Experiments were described for natural convection on the heated internal surface of a horizontal annulus [113J]. Heat transfer coefficients and critical heat flux increased markedly with the annular gap size up to a size at which normal pool boiling correlations were applicable. In another experimental investigation of boiling in annuli, effects of fluid properties, pool subcooling, crevice length and gap size were examined for both concentric and eccentric annular crevices [47J].

The effects of subcooling and binary mixture composition were explored experimentally with focus upon the density of boiling sites [46J]. Experiments and analysis suggested that pool boiling heat transfer coefficients for binary mixtures and pure liquids in strong gravitational fields are reduced by reductions in active nucleation sites [83J]. A monotonic decrease in pool boiling heat transfer coefficients was reported [6J] with increase in centrifugal field strength for water/propanol mixtures at all propanol concentrations. Horizontal wire pool boiling experiments were performed on mixtures of lubricating oils to examine the effects of molecular weight distribution [94J]. Blended oils displayed higher maximum heat transfer coefficients than those of the base oils and typically exhibited two peaks in their boiling curves. Wire superheat at the onset of nucleate boiling increased linearly with increase in the molecular weight of the base oils. Boiling curves were experimentally determined for immiscible water/$n$-nonane mixtures on horizontal tube bundles in pool boiling [82J]. A matrix method was proposed [50J] for calculating interphase flow rates of heat and mass in a multicomponent vapor/liquid system.

Experiments of pool boiling of water and salt-water solutions on smooth and rough horizontal copper plates were performed at atmospheric and subatmospheric pressures [108J]. The smooth surface provided largest heat fluxes for a given superheat in most cases. Results were presented from an experimental study of the effect of a stationary electric field on the probability of boiling of superheated $n$-pentane [120J]. Heat transfer to the horizontal bottom of a volumetrically heated boiling pool was analyzed [24J]. The propagation rate and the width of the front of changes in modes of boiling were investigated and distinctions were made among the dynamic behaviors expected dependent upon the shape of the boiling curve [110J].

Experiments with short intense pulse heating of a fine wire in a pool of water appeared to produce spontaneous nucleation at temperatures consistently 20°C below predicted homogeneous nucleation temperatures [30J]. Heat fluxes up to 120 MW per square meter were induced. Transient experiments were also reported [85J] in closed narrow channels to validate a simulation of behavior of waterlogged reactor fuel elements.

*Flow boiling*

Subcooled flow boiling experiments using refrigerant 113 showed little influence of mass flux and subcooling upon the incipient boiling wall superheats and suggested a mechanism of departure from nucleate boiling triggered by coalescence of bubbles into larger voids, producing temporary liquid film dryout [44J, 45J]. The effect of turbulent forced flow upon bubble behavior characteristics was developed and compared with experimental findings [114J]. An experimental technique was developed for measuring volumetric vapor contents of forced two-phase refrigerant flows through vertical and horizontal tubes [64J]. Boiling of water in vertical and horizontal pipes at low pressures was studied experimentally [118J]. Improvements in heat transfer coefficients and in stability of the flow were found to result from lining the pipe walls with metallic cloth. A new correlation was proposed [9J] for predicting the onset of 'intensive evaporation' marked by substantial presence of vapor in subcooled flow boiling. Scaling laws for coupled transient heat transfer and two-phase flow were used to derive several scaling numbers applied to investigation of a water cooled nuclear reactor [10J]. Subcooled flow boiling at high heat flux was studied experimentally and modeled [29J]: among the conclusions were that very thin metallic heater surfaces gave lower rates of heat transfer and that microlayer evaporation contributed negligibly to the heat flux. Friction and heat transfer relationships in turbulent gas/liquid flow were developed and employed to permit prediction of conditions which would cause salt to be precipitated on the wall of a steam generating channel [62J]. An improvement was proposed to earlier predictions of pressure and temperature fluctuations in a particular sodium boiling test apparatus [41J], based upon a hypothesized bubble breaking mechanism inferred from experimental data. A simple prediction method was proposed for the critical mass flow rate of initially subcooled liquid in long channels, built upon many empirical relations but successfully demonstrated against experimental data [18J].

A two-layer liquid film model combined with an accounting of liquid droplet entrainment was proposed for predicting heat transfer in annular two-phase flow [33J]. A simplified model was developed and demonstrated for prediction of void fraction in this significant flow regime [106J]. The developing region of two-component annular two-phase flow was studied experimentally and theoretically with emphasis upon the interfacial wave behavior [42J].

A few reports dealt with flow boiling in other geometric configurations. Experiments with bubbly water/air mixtures in cross-flow over a horizontal cylinder were described [107J]. The effects of tube diameter and forced flow velocity were investigated for cross-flow boiling on the outside of horizontal tubes [13J]. While nucleate boiling during flow was only mildly decreased with increasing diameter, the peak heat flux decreased approximately as the 0.28 power of diameter. Falling film evaporation of water over horizontal tubes was shown to be enhanced by both axial grooves and circumferential grooves in both boiling and nonboiling modes [43J]. Effects of surface tension were examined in flow visualization of two-phase flow in a channel with offset strip fins and incorporated in determining the minimum value of the boiling heat transfer coefficient in such a geometry [17J].

A correlation was presented for heat transfer coefficients for flow boiling of gasoline/ethanol mixtures in a vertical tube [59J]. Analysis of the effect of oil in mixture with refrigerants upon their boiling heat transfer coefficients was described [7J]. A semi-empirical formula was developed anticipating a concentration gradient as an additional resistance to vapor generation. Coefficients of heat transfer for boiling mixtures of freon and nitrogen were determined to be lower than those of the pure components while the variations of the coefficients with heat flux were of the same form [98J]. Equations were presented to describe the dynamics of evaporation of a multicomponent mixture flowing through extremely narrow channels [65J].

*Film and transient boiling*

Natural convection film boiling on a 10.3-cm-tall vertical surface showed no dependence of heat transfer coefficient on distance from the leading edge, and a physical model was proposed consistent with the expectation of laminar flow and the observed vapor/liquid interface behavior [15J]. Asymptotic results for film pool boiling on a vertical surface in a saturated liquid were found using an integral boundary-layer method under conditions of negligible inertia and negligible convection within the vapor film [80J]. An integral method was applied to a two-phase boundary layer in laminar film boiling on a hot plate or cone in a saturated pool, displaying excellent agreement with exact solutions [81J]. Experiments with several cryogenic fluids undergoing free convection film boiling in transient and steady conditions showed substantially smaller heat transfer coefficients for spheres compared with vertical cylinders at large superheats [56J].

Natural convection transition boiling on a vertical surface during slow transient experiments produced two distinct transition boiling curves, one for heating and one for cooling [14J]. A micro thermocouple surface probe was used to measure frequency and duration of liquid–solid contact in film and transition boiling of atmospheric pressure water, with results indicating that these contacts may be the dominant mechanism of heat transfer in transition boiling [61J]. In another experiment [32J] the extent of liquid–solid contact during transition pool boiling was measured by measuring the impedance across a thin dielectric layer deposited on a test surface in water and methanol. A model was proposed [53J] to explain the early (high minimum temperature) transition from film to transition boiling on surfaces insulated by thin layers of low conductivity materials. Experiments with Teflon coatings upon copper supported model predictions to a greater extent than tests with more conductive coatings.

A semi-empirical model was developed for turbulent forced convection film boiling of a subcooled liquid on a flat plate, hypothesizing a vapor–liquid mixing layer between the vapor film and the bulk liquid [116J]. Vapor thickness was analyzed [39J] at the stagnation point during forced convection film boiling on a solid sphere, including the effect of the liquid viscosity which was shown to be important.

An alternately advancing and retreating quench front was assumed in a transition flow boiling model which predicts the proper magnitude of oscillations of wall temperatures [51J]. Using a slow reflood quenching process, nonequilibrium vapor temperature and wall temperature were measured downstream of the quench front in upflow of water in a vertical tube [37J]. Comparison with existing models demonstrated that the models predict wall temperatures reasonably well but fail at predicting the vapor temperatures. Experiments with a large rod bundle provided data on dispersed flow film boiling with which empirical correlations were compared [74J]. Spacer grids caused large rod surface temperature reductions.

*Critical heat flux*

Theory and experiments were presented [115J] to suggest that the boiling crisis occurs when a maximum superheat is attained in a system, that temperature for which one viable nucleus is generated per second in each cubic centimeter of the liquid. A correlation was developed for pool boiling peak heat flux based upon the principle of corresponding states and employing a function of geometry which is thus applicable to all except extremely low boiling temperature liquids, and which can be extended to flow boiling [97J]. Extensive tables of data supporting the hydrodynamic analogy between nucleate boiling and the bubbling of gas into a liquid at a porous boundary were published [60J], having been presented in implicit form over several years. Although various heater materials and thicknesses of given heater materials altered the critical heat flux of helium on a flat horizontal surface, the film boiling heat transfer coefficient was experimentally shown to be independent of these variations [88J]. Critical heat fluxes for helium in natural circulation in vertical channels of circular and rectangular cross-section were measured and contrasted with the magnitudes of forced convection critical heat fluxes [87J]. In another geometry, the pool boiling crisis of nitrogen in an annular channel was examined with various orientations and gap sizes [54J]. Small, externally induced flows were part of a steady state model presented for predicting tube wall temperatures and potential dryout on the heated inner tube of an eccentric annulus with line contact [112J]. This approximated the conditions of pressurized water reactor steam generator tubes at their support locations. Critical heat flux was also part of the concerns of previously mentioned reports on boiling in annular spaces [47J, 113J].

Critical heat flux and flow instabilities were explored in both upflow and downflow of water in a vertical tube at atmospheric pressures at low flow rates [69J]. Departure from nucleate boiling heat flux [105J] and critical heat flux [68J] were measured in upflow and downflow in vertical rectangular channels. The latter experiments, performed at atmospheric pressure, demonstrated that the critical heat flux at low flow rates can be much lower than that for pool boiling and that the direction of flow is significant. Thermally induced flow instabilities in boiling channels were considered with the inclusion of fluid inertia effects, leading to the conclusion that linear stability boundaries may be inadequate for design of related systems [3J]. Forced convection boiling heat transfer coefficients and critical heat fluxes were experimentally investigated for refrigerant 12 on a locally heated 16-mm-diameter surface mounted flush with a channel wall [119J]. Variations of critical heat fluxes in annular channels with changes in surface structure were reported [111J]. Greater heat fluxes were found possible with most turbulence-promoting roughness geometries, with greatest increases, relative to smooth walls, attained in emulsion and dispersed annular flows. A new correlation of existing data for critical heat flux in the impinging-jet-on-disk configuration was presented [96J]. It is expected to be valid when viscosity and gravity have little influence. Another such correlation was presented [71J] with emphasis on accuracy at moderately low pressures achieved by better accounting for the effect of the liquid/vapor density ratio. The critical heat flux for liquid films in rotating channels was measured experimentally [75J] and modeled as being limited by droplet departure. Increased pressure and rotational speed were both found to increase the critical flux.

Several investigations dealt with hydrodynamics and thermal aspects of reflood, most with application to nuclear reactor safety. A predictive method for determining countercurrent gas/liquid flow in parallel channels was developed and compared with experimental observations [77J]. Experimental wall temperatures and vapor film thicknesses were reported for the inverted annular (liquid core, vapor film) boiling for liquid upflow in a vertical tube [36J]. A true quench temperature was defined as the quench temperature at the onset of rewetting in a flow channel, wherever the rewetting begins, and in the absence of axial conduction [25J]. Experiments were performed so as to measure this temperature rather than apparent quench temperatures, which are always higher. In a one-dimensional analysis, the effects of temperature dependent properties of the solid upon the quench front velocity were shown to be small relative to the uncertainties of rewetting temperature and heat transfer coefficients [86J]. Experimental findings on critical heat flux in closed-bottomed vertical channels were reported for several channel geometries [99J]. Results were reported for experiments with bottom reflooding of a vertical channel including void fraction, quench time, and quench front quality [31J]. Quench promotion and quench delay were both observed, related to high and low reflood velocities, respectively, as a consequence of large scale blockage in reflood tests of the Slab Core Test Facility [100J]. Flow regimes, void fractions, and heat transfer characteristics were reported for upward reflooding with both steady and controlled oscillatory injection of coolant [52J]. Other experiments were performed [5J, 76J, 79J], to validate safety-evaluation codes relating to reflood conditions.

*Droplet evaporation*

Evaporation rate and heat flux were evaluated for a droplet in a rarefied vapor using kinetic theory analysis [102J, 103J]. Drag coefficients for evaporating and condensing droplets were evaluated numerically [27J], yielding results which compared favorably with experimental data of another investigation. The use of surfactant additives or the presence of traces of surfactant impurities appeared not to significantly alter the electroconvective enhancements predicted for heat and mass transfer from drops and bubbles in electric fields [22J]. Thermocapillary forces acting on a droplet due to its chemical reaction with its surroundings were analyzed [93J], suggesting that conditions could result in either drag or thrust acting on the droplet. Rates of droplet evaporation were modeled in the extremely high temperature medium of a thermal plasma [55J]. Comparison of experimental measurements of evaporating spray characteristics with several models emphasized the importance of finite rates of interphase transport and drop dispersion [104J]. Transient temperatures were measured and modeled for the response of hot metal cylinders to the impingement of a water droplet [73J]. Boiling curves were experimentally obtained for single drops of water 4 mm in diameter impinging on a solid surface at temperatures corresponding to the transient regime of pool boiling [49J]. The maximum heat flux of the boiling curves thus determined was found to lie on an extension of the nucleate boiling segment of the pool boiling curve. Equilibrium and phase-changing configurations of two-phase vapor/liquid bubbles in an immiscible liquid were described and categorized [72J]. Single drops of refrigerant 113 were allowed to fall upon a hotter, less dense, and less volatile liquid and the consequent motions and evaporation times were observed [84J]. Five vaporization modes were observed, including submerged film boiling. A model was developed for evaporation of droplets in direct contact heat exchangers incorporating the effects of sloshing, which was deemed significant for droplets larger than 2 mm diameter [92J].

*Flashing and other evaporative processes*

The production of bubble nuclei by electrolysis upstream of a nozzle was shown to strongly enhance the evaporation rate and approach to liquid/vapor equilibrium of spray flash evaporation [70J]. Flashing nozzle flows were experimentally found to produce substantially fewer bubbles which are larger and grow at faster rates than predictive models currently suggest [67J]. Heterogeneous nucleation was not observed in the bulk flow; bubble generation appeared exclusively at the wall. Bubble growth, with interaction of surrounding bubbles, was analyzed by a method of matched asymptotic expansions [21J].

Kinetic theory analyses of evaporation were presented [101J, 109J]. The paradoxical inverted temperature profile between opposing evaporating and condensing surfaces was shown to be stable [19J]. Evaporation in the contact line region of thin films of hexane and hexane with small amounts of octane were studied with an optical interference method [117J]. Small changes in the bulk composition had large influence upon the transport processes near the contact line. The net heat flux and evaporative heat flux crossing the air/water interface of a heated body of water were measured and compared unfavorably with existing correlations [23J]. A two-dimensional analysis was presented for heat and mass transfer in the region of the vapor–gas front of a gas-regulable heat pipe [40J]. Steady evaporation of volatile liquid from a partially filled, open-topped adiabatic container was shown analytically to proceed at substantially lower rates than those predicted by the Stefan (isothermal) model since interface temperatures are depressed [90J]. In a related effort, experiments and numerical modeling with a composite rectangular and circular grid addressed the evaporation of liquid from a thin slot cavity by a fully developed laminar flow over the top of the cavity [91J]. The distribution of local evaporation rate at the liquid surface resembled that in a conventional boundary-layer flow.

## CHANGE OF PHASE—CONDENSATION

A general integral solution procedure was presented for laminar and turbulent film condensation on an isothermal surface, for bodies of arbitrary geometry [21JJ], and a uniform method of analysis for film flow with superposition of various effects (laminar or turbulent transport, gravity and frictional forces, phase transition and variation of film temperature) was developed [10JJ].

Heat transfer with film condensation on horizontal cylinders received considerable attention. Experimental results for a vapor flowing over a single cylinder indicated that the heat transfer by condensation depends substantially on the magnitude of the cross flow [18JJ]. An analytical/numerical study of film condensation over a horizontal cylinder with combined gravity and laminar forced flow was presented, including solutions in the merging flow region controlled by both driving forces [7JJ]. Film condensation heat transfer on horizontal tube banks was investigated experimentally for both the case of a flowing vapor [17JJ] and that of a stationary vapor with variable condensate flow rate [16JJ]; the ranges of dimensionless parameters were determined within which heat transfer was essentially governed by either the condensate flow rate, the vapor velocity, or the combined action of both factors. Experimental data were obtained for heat transfer with condensation of steam on horizontal wire-wrapped tubes; these results were compared to the performance of smooth tubes [24JJ]. The effects of surface tension were considered in an analysis of heat transfer in laminar film condensation on a horizontal cylinder [15JJ] and in film condensation on tubes with finely fluted fins [1JJ].

Flow pattern data during forced convection condensation of refrigerants R-12 and R-22 inside a horizontal tube were presented [26JJ], as were data on the heat transfer coefficients for these substances flowing through an annulus passage [28JJ]. Experimental results were presented for the flow patterns of condensing steam inside horizontal tubes [22JJ]. All of the horizontal flow pattern correlations tested failed in predicting the wavy-slug transition; the results of adiabatic (gas–liquid) flow in upwardly inclined tubes appear to provide some explanation for this behavior.

The dynamic behavior of a boundary layer (either laminar or turbulent) with condensation along a flat plate was studied both experimentally and numerically [19JJ]; the results were compared to those for the somewhat analogous case of a boundary layer with wall suction. Experiments on laminar film condensation heat transfer on several kinds of downward-facing horizontal surfaces were reported [29JJ]; these results have application to electric devices containing a volatile liquid in a casing.

An approximate relation for the heat transfer coefficient for a fully turbulent falling film at high Prandtl number was derived [4JJ], as was a nonlinear two-wave equation for long waves on the surface of vertical falling films [3JJ]; these waves can exert a significant influence on the heat transfer. Modeling and experimental results were presented for film condensation heat transfer on a general cylindrical surface in the presence of a nonuniform electrostatic field [11JJ]. The problem of simultaneous transient condensation and melting of a vertical surface was investigated using a Nusselt-type analysis [9JJ].

Condensation from multicomponent mixtures to surfaces was analyzed for the case where the mixture included a small amount of noncondensable gas [19JJ] and for the specific case of isopropanol–water mixtures [8JJ].

Dropwise condensation curves were measured for the condensation of propylene glycol on a PTFE-coated surface [27JJ]. The values of the heat transfer coefficient were found to be much smaller than for steam condensing on an oleic acid-promoted copper surface, and the transition mode from dropwise to film-type condensation was quite different.

When a superheated stream flows over a subcooled surface, a sufficiently high supersaturation ratio may initiate homogeneous nucleation in the boundary layer. An analysis for this case was presented [2JJ]; it was found that boundary-layer nucleation always reduces vapor mass transfer to the wall. In laminar flow this deficit is more than compensated by deposition on the wall of nucleated particles, whereas in turbulent flow the net mass transfer decreases, in part because of the diffusion of once-nucleated particles across the boundary layer. Numerical solutions for heat and mass transfer to a free droplet growing through condensation were obtained for droplet Reynolds numbers of about 100 [25JJ]. The effect on transport mechanisms of a condensing droplet subject to contamination with insoluble monolayer surfactants was examined theoretically [5JJ]. The 'monophase boundary-layer approximation' (an alternative approach to classical nucleation theory) was used to analyze the irreversible condensation of a vapor in a binary mixture (the dominant component being inert), free-convective, laminar boundary layer [23JJ]; the findings were applied to an air–water vapor mixture in contact with a vertical isothermal surface at cryogenic temperature.

Other studies of condensation heat transfer included a review of recent results pertaining to nuclear reactor transients [12JJ]; a discussion of condensation in vacuum systems [20JJ]; experimental results on frost formation in finned air coolers [6JJ]; and an experimental investigation of heat transfer from steam/air mixtures to a retort pouch laminate, with particular application to packaging food products [13JJ].

## CHANGE OF PHASE—FREEZING AND MELTING

New solution methods continue to be developed for freezing phase change problems. Conformal mapping methods were used to construct explicit solutions for a general Stefan moving-boundary problem [22JM]. An integral approach was found to agree with exact solutions to one-dimensional phase-change problems when $Ste = 5$ [29JM]. Reference [47JM] included crystal growth kinetics. A solution method was developed in which the solution for one phase was obtained using an inverse analysis providing the solution for the other phase was known [12JM]. The effects of isotropic and anisotropic radiation scattering were determined with results given for sapphire [38JM]. Two approximate analytic solutions were obtained for one-dimensional solidification with Newton cooling [19JM]. An approximate solution valid for small Stefan numbers combines the heat balance integral method and time dependent perturbation theory [5JM]. A numerical procedure was developed to model freezing of a liquid phase-change material around a suddenly immersed solid such as a cylinder, sphere or slab [39JM]. Reference [21JM] discussed the conservation laws obeyed by systems containing point defects, dislocations and domain boundaries. Reference [53JM] remarked on the formulation and qualitative behavior or hyperbolic Stefan problems.

Freezing in binary solutions was considered by refs. [55JM, 56JM] in which linear stability analysis was applied to determine the time of first marginal instability as a function of cooling rate for a sodium chloride solution. Reference [26JM] analyzed a similar problem. Analysis and experiments were presented in ref. [23JM] in which the fastest solid growth rate was found to occur when the sodium chloride concentration was 0.9%. Numerical solutions and experiments were performed to evaluate the effectiveness of freezing out one component of a mixture on a rotating, scraped drum [16JM]. A macroscopic numerical model was demonstrated to be especially convenient as it does not require tracking of the interface [1JM]. The theory of binary solid interface motion was used to show that vapor phase transport governs the problem [34JM].

Solidification in forced convective flows included an analytical and experimental study of frost growth on a flat plate with various droplet wetting angles [49JM]. Reference [46JM] described the appropriate dimensionless parameters to use in similar problems. A perturbation solution was used to analyze the freezing and remelting of a liquid flowing parallel to a cool flat plate [8JM]. Experimental results for water freezing inside a pipe showed that the ice layer forms a periodic pattern [20JM]. A numerical study illustrated the shape of the solid layer formed on a cold cylinder in crossflow [7JM]. A simple model and some experimental measurements showed that growth around a single tube is nearly identical to growth around the tubes in an array until 80% of the flow area is blocked by solid [27JM].

Three experimental papers considered the effect of natural convection on the freezing process. The effects on microstructural defects were examined for cadmium–copper alloys [42JM]. Freezing paraffin in a rotating cylinder redistributed the voids and accelerated the freezing process [33JM]. The effect of axisymmetric rotation on the freezing of aluminum–copper alloys was also investigated [41JM].

Solidification in Cartesian, cylindrical or spherical castings was analyzed subject to convective–radiative boundaries [6JM]. A new embedding technique was used to study the solidification within a long cylindrical mold [17JM, 18JM]. A finite element method was applied to a two-dimensional freezing problem that does not include natural convection found in corresponding experiments [35JM]. Another finite-element method was applied to the solidification of magnesium alloy castings [52JM]. Numerical models were employed to simulate the solidification in continuous cast round or square cross-section billets [50JM].

Crystal growth was characterized by reviewing the relevant heat and mass transfer processes governing the transport [4JM]. An analytical model was used to describe the growth of silicon crystals [28JM] and a two-dimensional finite-element model was developed to simulate the growth of gallium arsenide crystals [9JM].

Rapid solidification by melt spinning was investigated experimentally by several investigators to determine the thermal history during ribbon formation [24JM], to measure surface heat flux using a photocalorimetric technique [15JM] and to determine the effect of air jets [3JM]. An experimental study of the freezing of aerosolized aluminum–lead alloy melts was conducted in a nitrogen gas environment [51JM].

Melting adjacent to a heated surface was investigated experimentally in refs. [13JM, 14JM] where gallium was melted and solidified on a horizontal plate. An experimental and numerical study was reported in which natural convection in the melt governed the interface around a heated vertical cylinder [37JM]. Reference [25JM] measured heat transfer enhancements of a factor of five when longitudinal fins were attached to a heated vertical cylinder. A finite-difference numerical study investigated the melting process around a horizontal cylinder where solid subcooling was found to have a significant effect of the melting rate [40JM]. A quasi-three-dimensional solution was obtained for a variable temperature pipe buried in a semi-infinite solid phase-change material [57JM].

Melting inside a vertical rectangular cavity was investigated experimentally and numerically for *n*-octadecane [2JM]. Melting within a horizontal cylinder was measured [43JM] and the effect of the liquid film between the solid and the wall was analyzed using a two-dimensional numerical model [44JM]. An extension of these studies evaluated the effect of internal geometry on the heat removal of an encapsulated phase-change material [45JM]. An experimental study of melting in an inclined cylinder with an aspect ratio near four showed that the horizontal position was best and that the results did not change appreciably until the cylinder axis was within 15° of vertical [54JM].

A hot body melting its way through a solid has been observed using a horizontal heated cylinder and *n*-octadecane [31JM, 32JM]. The fluid motion in the cavity was driven more by the movement of the cylinder than by natural convection currents. An immiscible liquid melting its way through a solid was considered theoretically as an approximation to molten iron melting through the earth's mantle [36JM].

Melting caused by microwave heating of a dielectric material was solved as a boundary value problem [30JM]. Argon-ion laser cutting through silicon was investigated where the propagation of the melt front was controlled by the scan speed, not the laser power [48JM]. A numerical solution was obtained for laser welding which described the size, geometry and motion of the liquid pool [10JM]. Carbon dioxide and YAG lasers were used to cut and weld carbon and stainless-steels and the differences between penetration welding and conduction welding were described [11JM].

## RADIATION IN PARTICIPATION MEDIA AND SURFACE RADIATION

In this review, the research in the area of radiation in participating media is described first, followed by the papers on surface radiation. There are a number of papers which are of common interest to both areas. These and other related studies are included at the end. Some attempt is made to include the works dealing with the radiative properties, e.g. nongray gas absorption, anisotropic scattering, and surface properties, but only a small sample of the information that is available is included. There are also many related research fields in which radiative transfer is studied, e.g. atmospheric sciences, aerosol research, remote sensing, combustion diagnostics. Since the intent here is not to review all of radiative transfer research, the focus is toward those works that deal with radiation heat transfer, although exceptions are made where appropriate.

*Radiation in participating media*

The research papers have been grouped into the following topics for the purposes of the review: one-dimensional media studies, studies in multidimensions, radiation combined with other modes of heat transfer, flame radiation, gas radiation, and scattering media.

(*a*) *One-dimensional media studies.* A wide variety of solution methods is chosen to study the radiative transfer in one-dimensional media. Unless otherwise noted, all the papers deal with one-dimensional, plane parallel media. The Galerkin method is used to obtain the heat flux, the intensity distribution, and the divergence of radiative heat flux in an absorbing, emitting, isotropically scattering sphere with diffuse reflecting, and emitting boundaries [117K]. The Galerkin method is used again to consider a sphere with space-dependent albedo [118K]. Modifications to the matrix operator method for solving the equation of transfer in planar media are proposed. An algorithm for calculating the reflection operator in a semi-infinite medium is developed and used for other optical depths also, reducing the computation time [68K]. Matrix-vector relationships for computing the internal intensity field in emitting and multiply scattering medium are formulated [125K]. Two scaling relations (one for scattering with highly forward peak, and the other for those cases when the scattering is not so peaked) are presented for the Monte Carlo method, to reduce the computation time [9K]. The $F_N$ method is discussed [56K] and modified to solve some benchwork problems [39K]. Results for isotropically scattering spheres and cylinders are given, using the integral transformation techniques and the $F_N$ method [104K]. A $n$-flux method, which uses a power series approach to deal with the directional dependence of radiation, is presented and recommended for its possibility of choosing $n$ independent of the overall dimensions [60K]. Comparisons of the biangular reflectance of an absorbing and isotropically scattering medium, obtained with a discrete ordinate method and the actual data, are presented [94K].

A number of other solution methods is also utilized. A modified diffusion approximation is used to obtain the radiation characteristics of a plane layer of strongly scattering medium [111K]. Improvement on the accuracy of the diffusion approximation for the optically thin problems, is proposed by including the exact formulation of the integrated intensity at the interfaces [5K]. The finite analytical method, used to reduce the nonlinearity in fluid flow and convection calculations, is applied to radiation in absorbing, emitting, and gray medium with good accuracy [105K]. An anisotropically scattering layer with position-dependent albedo is analyzed by expanding the albedo in a Legendre polynomial series [21K]. Two sets of experimental data on attenuation in water, are compared with the solutions obtained using a finite-difference scheme similar to the $S_n$ method [49K]. Numerical results for the radiation transfer by a finite, inhomogeneously emitting layer [97K], and reflection from scattered radiation in dispersive media [127K], are obtained by using the Padé approximation. A spherical harmonics formulation, which can be used for extreme forward-peaked scattering, is developed for a slab [129K]. In studying the effect of boundary reflection on the resulting temperature distribution and the heat flux, ref. [109K] uses the projection method, for which convergence is guaranteed. A linear systems method is used to solve some radiative transfer problems in a plane parallel layer [43K]. For the integrals arising in the solution of radiative transfer, involving an exponential integral function and exponentials, ref. [116K] presents numerical techniques and expressions for improved accuracy. To study the unsteady radiation field in an optically thick medium, ref. [38K] uses the Laplace time transform of the intensity in a conservative-unsteady problem and the intensity in the corresponding non-conservative-steady problem. Unsteady heat propagation by radiation is considered, and the solution is shown to be self-similar [89K].

The following papers seek to solve the integral equation resulting from radiative transfer in one-dimensional layers. The integral equation for a gray, emitting, absorbing and scattering layer with reflecting boundaries, is solved by a collocation method, using Chebyshev polynomials as basis functions [110K]. A mathematical consideration of an infinite, purely scattering layer (isotropic), looks at the Neumann solution with the theory of singular integrals of the Cauchy type [96K]. The searchlight problem in radiative transfer is considered by removing the singular components before numerically taking the inverse Fourier transforms [103K]. Results in a finite layer are also obtained by using the integral transformation technique and the $F_N$ method [34K]. Singularity subtraction and the Gauss quadrature are used to obtain a system of linear equations to solve the singular Fredholm integral equation, describing the transfer in isotropically scattering layer [28K]. A two-step method to solve the Fredholm integral equation of the second kind, requires taking the first-order Taylor series expansion of the Kernel, and then using the collocation method [22K].

The next four papers consider the radiative transfer in one-dimensional media to obtain radiation property data, by using the solutions in conjuction with experimental data. The extinction coefficient and the solid thermal conductivities of glass fiber insulations are obtained from calorimetric measurements [92K]. The four-flux model solution of radiative transfer and the classical theory of lattice vibration, are combined with reflectance measurements of ceramic materials to yield the thermal radiation properties [67K]. Study of the sensitivity on the measurement errors, when using the multiple-scattering inversion methods to obtain the properties, shows that the method can be ill conditioned [82K]. Reference [51K] numerically tests another inverse method, this one using pulsed multiple-scattering experiments with the azimuth- and time-dependent one-dimensional solution, and shows that the scattering albedo, and the asymmetry factor, and perhaps a third parameter, could be obtained from as little as three azimuth angle measurements.

(*b*) *Studies in multidimensions.* Some of the papers on multidimensional radiative transfer also consider other modes of heat transfer. Such works are then included in the following section. Investigations in two-dimensional radiative transfer are reviewed first, followed by three-dimensional transfer in the next paragraph. Reference [40K] presents numerical solutions for two-dimensional, azimuthally symmetric, steady-state equation of transfer. Collimated laser incidence into a finite thickness, linear anisotropically scattering, cylindrical medium, is considered [27K]; numerical results are presented for the source function, heat flux, and the intensity at the boundaries. Reference [29K] models a uniform collimated incidence into a two-dimensional rectangular medium. A numerical solution is obtained by solving a set of algebraic equations resulting from singularity subtraction and quadrature formula. The results show that a one-dimensional solution is a good approximation except near the wall. Another study in two-dimensional rectangular geometry considers an enclosure of gray medium with internal heat generation [131K]. The solution obtained from a point allocation technique, shows that both the optical thickness and the enclosure geometry affect the resulting temperature distribution, while the average heat transfer to the boundaries is primarily affected by the enclosure geometry. Limiting expressions for the scattering contribution to the geometric-mean transmittance in a multi-dimensional absorbing and anisotropically scattering medium are presented [130K]; by using the kernel substitution technique, closed form expressions for selected two-dimensional geometries are also presented.

Three-dimensional radiative transfer is considered in the following four papers. Exact expressions for the radiative flux density and the energy source term are developed for absorbing, emitting medium in a box-shaped enclosure [101K]. The resulting numerical results are compared with data from a large scale experimental furnace. Alternative, but equivalent, exchange factors for the zonal analysis are developed in ref. [61K]. The advantage with the new formulation is that these exchange factors can be experimentally measured for different geometries. Scattering medium in a planar geometry, with inhomogeneities in the $x$, $y$ and $z$ directions is considered [69K]. For the general problem of intensity field incident from above and a surface below, the technique proposed in ref. [69K] uses the spatial Fourier transforms and extends the matrix-operator theory developed for one-dimensional planar layer analysis. Reference [77K] considers inhomogeneous, anisotropically scattering media in a three-dimensional rectangular enclosure, by the first and the third spherical harmonics approximation. The purpose is to be able to model furnaces, and the numerical results are compared with those based on the Hottel's zone method.

(*c*) *Radiation combined with other modes of heat transfer*. In many heat transfer applications, one often finds more than one mode of heat transfer; phase changes may also be taking place. Since such situations arise in a variety of applications, it is likely that the review of research papers in this section is not complete. This section is organized to deal with radiation/conduction with possible phase change first, followed by radiation coupled with forced convection, and lastly the coupling with natural convection.

Transient response by combined conduction and radiation heat transfer in porous, highly scattering, semitransparent, high temperature material to intense solar irradiation is studied [72K] using the two-flux method. The numerical results show that the radiation is an important component even for optically thick layers (optical depth $> 100$). It is in fact, the dominant mode of heat transfer in the front third of a layer, and the location of the maximum temperature is in the interior of the layer. Analysis of the combined conduction/radiation in a gas within a cylindrical enclosure with reflecting boundaries, uses the zone method and the weighted sum of gray gases model, to include the radiation [57K]. The axial and the radial gas temperature distribution, and the wall heat flux and temperatures, are then presented for either the temperature specified or the heat flux specified boundary condition. Thermal conductive/radiative modeling of one- and two-dimensional structural elements is the subject of ref. [4K]. Apparent thermal conductivity of evacuated $SiO_2$–aerogel tiles is determined by guarded hot plate measurements [99K]. Combined radiation/conduction through multilayer insulation, with spacers that scatter or absorb, is studied both numerically and experimentally [78K]. The next two papers deal with the unsteady response of liquid layers exposed to incident radiation. Reference [53K] shows that the absorption of the liquid is a more important factor than whether the incident radiation is collimated or diffuse. Reference [52K] considers collimated incidence onto a liquid layer seeded with fine particles and shows that for the conditions under study, scattering is negligible. References [86K, 88K] consider phase changes associated with radiative transfer. The effect of anisotropic scattering on the melting of semi-infinite, semi-transparent media is such that a forward scattering fosters melting while backward scattering retards it [86K]. Theory of evaporation of water droplets suspended in air when there is radiation incident, including the infrared participation of the evaporated water, is discussed in ref. [88K].

Radiation coupled with forced convection also received much attention. A very thorough experimental and numerical study of the thermal conditions in an irradiated, slowly moving liquid layer, is presented in ref. [50K]. A one-dimensional planar radiation model is coupled with laminar three-dimensional convection. The experimental and the numerical models both show a stably stratified upper layer, a core region of roughly uniform temperature, and a thin bottom layer of large, unstable temperature gradient. Similar geometry of a liquid layer in motion—molten salt in a gravity-driven flow—is analyzed [128K]; an optical depth of two is recommended for optimum solar collector efficiency. Process fluid in mixed channel flow (forced and free convection) is irradiated through an upper enclosure which holds a transparent fluid [18K]; the velocity and the temperature fields of both the fluids are numerically obtained. The results show that the lower flow section is strongly affected by the optical thickness of the absorbing fluid. Reference [106K] considers fully developed laminar and turbulent flow of real gases in a cylindrical enclosure where the radiation is included by the zone method. Experimental and theoretical studies of the thermal radiation in two-phase flow show that the condensed phase radiation is dominant, compared to the gaseous component [59K]. The calculation of radiative–convective heat exchange in hypersonic flow about a body is examined [93K]. In particular, the effect of using several models of optical properties of the gaseous medium in a compressed layer, is estimated. Reference [65K] obtains a modified local heat transfer coefficient of a plate fin which transfers heat to the surrounding fluid by radiation and convection.

Radiation coupled with natural convection is the topic of the next papers. References [31K, 7K] are concerned with stability analysis which includes scattering and natural convection. Reference [31K] seeks a realistic base flow solution in a vertically stratified layer for stability analysis; the first order spherical harmonics ($P-1$) approximation is used to include the radiation. Reference [7K] considers the effect of anisotropic scattering on the stabilizing influence of thermal radiation. The scattering is included by using an extended Eddington approximation, and the results show that the critical Rayleigh number and wave number are reduced. Reference [108K] presents experimental heat transfer results of convective–radiative transfer from a horizontal finned tube with sidewall/floor interactions. The effect on the heat transfer is the greatest with the sidewall/floor interaction, and the reduction can be up to 40%.

(*d*) *Flame radiation.* Since it would be difficult to review all the papers in the area of combustion research, only those which explicitly deal with radiation heat transfer in or from flames, are mentioned. Since flames often include scattering particles as well as participating nongray gases, some related papers may also be found in the following two sections. References [123K, 124K] utilize a three-dimensional formulation to determine the incident radiant heat flux on a cylinder that is engulfed in flames. Reference [126K] inverts the infrared emission measurements from a flame to determine the spatial temperature distribution. Reference [83K] presents results from instantaneous, monochromatic infrared radiation measurements from combustion flames of a 4-stroked, direct injection, no swirl diesel engine. The measurements show a continuous thermal emission by the soot and gas bands at 1.9, 2.9, and 4.2 $\mu$m. References [48K, 76K] both consider obtaining radiation properties of soot radiation in flames. Noting that the thermal radiation intensity from flares is more accurately modeled when the flame source is considered as a surface, ref. [30K] considers the jet diffusion flame from flare stacks. Reference [23K] reports on total and spectral flame radiation measurements made in a tubular-can combustor. Reference [87K] reports on using yttrium–beryllium oxide thermocouple coatings for flame temperature measurements.

(*e*) *Gas radiation.* Radiative exchange in gaseous media is characterized by the highly spectral nature of gaseous absorption. Of the many papers that deal with the properties of nongray gases, only the ones that deal with common combustion gases are considered here. Reference [115K] presents a semi-empirical, total line shape model for water vapor. References [17K, 46K] present measurements and calculations for the bandstrength and the linewidths of CO. For the $CO_2$ 4.3 $\mu$m band, ref. [24K] presents measured absorptivity in a $O_2$–methane flame at 2900 K; refs. [63K, 25K] report on the temperature dependence of the absorption in the far wing of the band; ref. [19K] considers the spectral line shapes for the band from experimental measurements. $CO_2$ line positions and the strengths in the 1200–1430 $cm^{-1}$ region are also reported [119K]. References [16K, 15K] report narrow band parameters based on the Elsasser model as well as the correlations for Edwards wide band model for acetylene and methane.

With the nongray gas properties, heat transfer analyses can be performed. Reference [107K] tests the validity of the narrow band models and the random statistical models for $CO_2$ and $H_2O$ when calculating the temperature and the heat flux distribution for coupled radiation and conduction. Reference [47K] applies the total transmittance nonhomogeneous radiation model to methane combustion, and shows that this method is about 500 times faster than using a narrow band model and still is within 10% accuracy. Reference [54K] reports on modification of the expressions relating the surface temperature and the heat fluxes in an enclosure with isothermal gas, to obtain direct expressions for the heat flux which can be numerically calculated. In different applications ref. [90K] recommends a solar energy receiver–thruster with a rocket propellent of $H_2$ gas with alkali metal vapors for volumetric gas absorption.

(*f*) *Scattering media.* Many of the papers already reviewed, consider radiative transfer analysis in scattering media. This section includes the studies on scatterings separate from a heat transfer analysis. Since scattering is such a widely studied subject, only a small selection of the works dealing with scattering is included here. Notably, some of the detailed scattering analyses and the size distribution retrieval work are not included. Reference [26K] examines the Dirac delta approximation to the Mie calculations of large dielectric spheres. Reference [75K] recommends an experimental procedure to determine the scattering similarity parameter from *in situ* measurements within a cloud. It is not possible to distinguish experimentally between the forward scattering component and the transmitted beam, but for spherical particles Mie theory can be used to calculate a correction. Reference [13K] considers the correction for nonspherical particles, and finds that although oblate spheroids are similar to equal-area spheres, the correction factor for prolate spheroids can be as much as 20% less then the equal-area spheres. Reference [1K] reports on the calculations and experimental data on scattering from large dielectric cylinders. Reference [6K] finds that for large conducting spheres with rough surface, the scattering cross section calculated can be significantly different than if the surface is smooth. Reference [44K] presents a simple analytical method to approximating Mie scattering, which is an extension of the Rayleigh–Debye approximation. A theoretical method for predicting scattering from random aggregates is tested on latex spheres [62K]. Optical constants of soots in the 0.5–0.75 $\mu$m range are obtained from polarized angular reflectance measurements [8K]. Reference [55K] presents the single scattering properties of sodium mist from Mie calculations. Anisotropic scattering in insulations made from randomly oriented fibers is investigated theoretically, and used to optimize the fiber for minimum heat flux [20K]. Reference [2K] considers the regularity of the radiation from two-phase media, e.g. gas–particle systems, bounded by reflecting surfaces.

*Surface radiation*

The research papers dealing with view factor calculations are presented first, followed by the papers on surface exchange. Reference [35K] describes an algorithm for calculating the view factor, by using Hottel's crossed string method, in an enclosure bounded by arbitrary polygons in the plane. Reference [71K] considers the same kind of boundaries, but looks at the computational savings from transforming the surface integrals into line integrals. Reference [102K] compares three computer algorithms used to compute view factors. Reference [36K] considers calculating the view factors for large, sparse structures when curved surfaces may be present. With the appropriate view factors, energy exchange between surfaces can be calculated, but some ambiguities may need to be cleared up [112K]. A transparent enclosure with diffuse and collimated incidence is analyzed to study the absorption of solar energy in a building space [74K]. Reference [80K] considers convection shields for radiative cooling which have high transmittance in the 8–13 $\mu$m wavelength range. Reference [66K] evaluates the effect of radiant transfer to the walls and ceilings, from hot stove and chimney pipes, in simulated overfire conditions.

A number of papers concern the surface exchange in cavities and screens. Reference [58K] presents an exact, closed-form reconstruction algorithm for the temperature distribution of a blackbody from spectral measurements. Reference [84K] numerically computes the bandlimited effective emissivity of nonisothermal diffuse radiators, and shows that the nonisothermality causes only a small deviation of integrated emissivity for a detector a little distance away from the cavity. Reference [10K] considers the emissivities of isothermal and nonisothermal cylindro-inner-cones. Reference [122K] obtains a single equation for the spherical cavity radiation conductivity with a general specular-diffuse surface. Reference [91K] considers the transient temperature field of a cavity with cooled walls and an aperture that is permeable to radiation, to model a receiver of thermal solar tower plant. Reference [95K] utilizes optico-geometric functions to compute heat losses through a system of finite screens. Reference [121K] proposes the construction of a photoelectric apparatus for light model ing, to determine the geometric and the radiation properties of semitransparent screens.

*Other related studies*

There are a number of papers that discuss the instrumentation needed for experimentation. Reference [85K] shows that the resolution, in photodiode array Fourier transfrom spectroscopes, can be improved by adding dispersing optical elements. The integrating sphere is the topic of the next three papers [113K, 37K, 41K]. Reference [113K] discusses the possibility of increasing the detector signal by adding elliptic flux concentrators, when the field of view is limited. Reference [37K] discusses possible misinterpretations when using an integrating sphere. Reference [41K] uses an integrating sphere with a Fourier transform infrared spectroscope to make reflection and emission measurements. The radiation detector is the topic of the next three papers [100K, 32K, 12K]. Reference [100K] discusses using sodium salicylate as a combined fluorescent and reflective coating on a photomultiplier tube to extend the range of the detector into the near infrared. Reference [32K] discusses the signal to noise advantage of a resonant bolometer. Reference [12K] considers the ideal coating for radiometric detectors—low reflectance, independent of wavelength and direction—and shows that the coating thickness is a critical parameter. Reference [45K] is a general paper that discusses the theory and implications of an integrating nephelometer which is used to make scattering measurements. Reference [70K] analyzes a transient calorimeter used to measure the total hemispherical emittance, and shows the importance of rigorously evaluating the heat loss through the thermocouple leads.

This last group of papers includes radiation in combination with various other effects, mostly as a boundary condition. References [14K, 3K, 79K] deal with radiation effects encountered while measuring thermal properties. Reference [14K] accounts for the radiant energy penetration when finding the thermal diffusivity of layered and porous polymers by the flash technique. Reference [3K] discusses a similar experimental setup for determining the thermal diffusivity of liquids, by heating the front surface of a cell with radiation. Reference [79K] is a summary article of the discussions in a workshop during the 9th Thermophysical Properties Conference, on the topic of the effect of radiation on thermal transport measurements. Reference [11K] discusses an application where one can achieve refrigeration by using reverse-biased semiconductor diodes. Reference [73K] predicts an improved performance when liquid droplets, rather than solid surfaces are used as radiators for cooling in space; an experimental evaluation of the properties of Dow 705 fluid shows that the weight would be about 10 times less when the temperature range is 275–335 K. Reference [64K] studies the transient response of water subject to intense, focused laser pulses of nanosecond duration. Reference [33K] considers the transient response of the temperature distribution of a sphere, with directed heat flux and radiative cooling boundary conditions. Reference [98K] considers the same type of boundary conditions on a rotating hollow cylinder, and shows that quasi-steady temperatures are achieved within one revolution. Reference [42K] numerically solves the heat conduction in a semi-infinite layer with boundary heating and radiative cooling. Reference [81K] considers the application of infrared radiation to drying films, and shows that the internal heating due to the penetration of radiation has significant effects on the drying rate and the temperatures. Reference [120K] considers the response of transluscent materials to high energy radiation fluxes, and concludes that the heat exchange process depends on whether the external radiation is diffuse or collimated. Reference [114K] considers the temperature rise of a surface subject to moving heat sources, radiative cooling to the environment, and convective cooling to the lubricating oil, and concludes that the effect of radiation is negligible.

## NUMERICAL METHODS

The use of numerical methods for heat transfer is very common. In general, the papers dealing with the application of a numerical technique to a particular problem are reviewed in the appropriate application category. The papers mentioned in this section are primarily concerned with the numerical method rather than with the application used to illustrate it.

A literature survey of numerical heat transfer for 1982–83 has been published [50N]. The progress of numerical heat transfer has been reviewed in ref. [51N], where some suggestions for future work are offered.

Heat conduction still continues to be the main testing ground for new formulations. Nine different numerical methods for the solution of three-dimensional heat conduction have been compared in the respect of their performance on a common problem [53N]. A finite-difference scheme has been proposed for the heat conduction equation [33N]. Reference [4N] describes a new explicit scheme for heat conduction. Some numerical algorithms for one-dimensional heat conduction are compared in ref. [28N]. A control-volume finite-element method using a nine-node quadratic element is developed [46N]. A collocation technique is described for the solution of the Laplace equation [7N]; it is suitable for implementation on a personal computer.

Unsteady heat conduction problems have been solved by the use of boundary-fitted coordinates for multiconnected arbitrary-shaped domains [54N]. The question of numerically solving hyperbolic heat conduction is discussed in ref. [21N]. The use of direct and indirect boundary integral methods is evaluated in refs. [3N, 2N]. The boundary element method is discussed in ref. [57N]. The effect of stringent boundary conditions on the solution of heat conduction is investigated in ref. [10N]. Numerical modeling of heat conduction in sand castings has been studied in refs. [11N, 12N]. Reference [22N] describes a new self-adaptive grid method.

A two-dimensional inverse conduction problem is solved by the method of dynamic programming [8N]. A finite-element formulation for the inverse problem is given in ref. [56N]. The Stefan problem with multiple free boundaries is solved in ref. [14N], while ref. [45N] presents a new implicit solution procedure for the problem. An efficient algorithm has been developed for problems with melting and solidification [27N]. An unconditionally stable finite-difference scheme has been proposed for conduction with phase change [39N]. Multidimensional moving boundary problems have been treated by coordinate transformation [23N]. Reference [24N] describes a stochastic modeling of transient heat flow through walls.

Considerable research effort has been directed towards the formulation of convection and diffusion so as to produce an accurate and stable numerical scheme. A streamline-upwind finite-element method for convection-dominated flows has been developed and applied [35N, 36N]. A monotone streamline-upwind method has been proposed [47N]. Reference [15N] proposes a generalized Galerkin method for convection–diffusion problems. Finite-difference and Galerkin techniques have been compared by applying them to the combined convection–diffusion problem resulting from the propagation of pollutants from a line source [49N]. A potential and stream function analysis has been presented for the convection–diffusion problem [55N]. Reference [52N] describes a solution scheme for the convection–diffusion equation, while ref. [37N] presents exact and approximate solutions for the equation. The problem of convection and diffusion has been solved by the boundary element technique [26N]. A new explicit scheme has been proposed for the problem [18N]. Reference [43N] introduces a control-volume finite-element method using quadrilateral elements, while ref. [40N] employs the multigrid technique for the convection–diffusion equation. The flux-corrected transport method has been compared with other schemes in ref. [34N]. Reference [38N] presents a critical evaluation of seven discretization schemes for the convection–diffusion problem.

Prediction of convective heat transfer requires the calculation of the underlying fluid flow. A significant part of the literature is devoted to the numerical methods for the calculation of fluid flow. An adaptive grid technique has been developed for parabolic flow problems [1N]. For compressible gas flow with chemical reaction, an optimized implicit scheme for the gas flow has been proposed [13N]. Reference [41N] describes a multilevel multigrid technique for recirculating flow. A coupled strongly implicit procedure has been formulated for the calculation of velocity and pressure [58N]. Further performance characteristics of marching methods for elliptic equations have been described [48N]. For laminar forced convection, a boundary integral equation method has been presented [44N].

A new cubic spline alternating direction implicit method has been employed to predict natural convection in a cavity [31N]. A formulation for the Navier–Stokes equations using a coupled solution of velocity and vorticity has been described [19N]. Reference [32N] uses velocity and vorticity as variables for solving mass transfer equations. A residual method of finite differencing has been presented for the solution of elliptic fluid flow [5N]. A control-volume finite-element method has been developed for the solution of the Navier–Stokes equations [42N]; the method uses equal-order interpolation for velocity and pressure. Reference [9N] describes continuation techniques for a penalty approximation for fluid flow. A family of stable algorithms has been developed for the solution of the generalized Boussinesq equation by a finite-element approximation [20N].

Matters concerning boundary conditions are dealt with in some papers. Reference [25N] describes a finite-element procedure for buoyancy driven flows with cyclic boundary conditions. A new type of boundary condition in convective heat transfer problems has been proposed in ref. [17N]. Reference [16N] discusses errors arising in convective heat transfer problems in connection with boundary conditions of the third kind.

Comparisons of different methods provide useful guidance in selection of an appropriate method. A comparative analysis of numerical methods for hypersonic re-entry flows has been presented [6N]. Reference [30N] gives the results of a comparison of pressure–velocity coupling solution algorithms. A comparative study has been made of various grid generation techniques in connection with a parabolized Navier–Stokes code [29N].

## TRANSPORT PROPERTIES

Research in heat transfer properties includes precise scientific measurements and the expeditious determination of engineering values for industrial application or special materials.

For thermal conductivity and diffusivity a number of new experimental techniques are described. A new design [12P] simultaneously measures thermal conductivity and diffusivity of unconsolidated materials by the transient hot-wire method. For liquids, a novel precision resistance-measuring scheme yields absolute conductivities [36P]; for thin films, ref. [15P] presents results obtained by an AC calorimetric method and [19P] a new technique for simultaneously measuring thermal conductivity and heat capacity. Fibers are the focus of two studies. The first [32P] examines carbon fibers in the range 3–300 K; the second [16P] the effect of misoriented short fibers upon the thermal conductivity of a composite. A dispersion of fully penetrable spheres is examined for effective thermal conductivity [50P], and ref. [43P] reports thermal diffusivity information of partially crystalline polymers. Continuing the study of specialized materials, ref. [41P] reports apparent thermal conductivity of evacuated $SiO_2$–aerogel tiles under variation of radiative boundary conditions; ref. [25P] gives results for iron–titanium powders; ref. [22P] indicates the variation of thermal conductivity with density for polyurethane foam using a guarded hotplate; and ref. [28P] records the thermal conductivity of multicomponent saturated refrigerants.

For gases at high pressure, ref. [37P] employs a Pitzer-type generalized correlation for predicting thermal conductivities. For liquid and vapor hydrocarbon systems (pentanes and heavier) at low pressures the normal boiling point and specific gravity correlate the thermal conductivity [38P]. For multicomponent dense gas mixtures, ref. [47P] obtains an approximate formula for computing the heat conduction coefficient. Additional studies examine the thermal conductivity of specific systems: a semi-theoretical equation relates conductivity to volumetric foam density [24P]; an extended correlation technique allows thermal conductivity predictions to be made for coal-derived liquids and petroleum fractions [4P]; ref. [13P] examines the effective thermal conductivity of a suspension; and ref. [31P] measures the thermal conductivity of alumina and silicon carbide in the range 4–300 K.

Diffusion coefficients are calculated in two works: ref. [51P] considers certain dilute binary gaseous systems and employing several asymmetric potentials predicts, for the temperature range 195–400 K, diffusion and thermal diffusion factors; ref. [3P] calculates the coefficient of self diffusion for steam over the pressure range 0.07–27 bar using a theoretical model. A technique for simultaneously determining solute diffusion coefficient and partial pressure is described in ref. [54P].

For electrical conductors, ref. [53P] describes a pulse-heating method for measuring heat capacities from room temperature to 1300 K and gives results for zirconium. For amorphous metal in the range 1.5–10 K, ref. [23P] also uses a pulse technique requiring a small sample and yielding results for copper within ± percent. The specific heat of ultrafine particles of silver, prepared by the gas evaporation technique, appears in ref. [34P].

A concern with systems undergoing pliable change during heat transfer leads to the consideration of the molar latent entropy change as a more fundamental rationale for the thermodynamic generalizations employed in two-phase heat transfer [44P]. The need to predict the thermal regime in arctic offshore structures led to an investigation of the latent heat of frozen saline coarse-grained soil [52P].

Precise viscosity measurements continue to flow from well-known sources. Results are reported for sulphur hexafluoride up to 100 bar using a capillary-flow viscometer [18P] and for light and heavy water and their mixtures by the oscillating viscometer [20P]. An empirical correlation using available experimental saturated liquid viscosity data is presented for 10 refrigerants [45P]. For measuring liquid viscosities a vibrating sphere yields density as well [14P], while ref. [7P] utilizes an automated falling-cylinder, high-pressure laser-Doppler viscometer.

Velocity of sound measurements are reported for argon gas up to $10^3$ bar [21P] and in reactive liquids at high pressure and temperature [42P].

A number of papers are focused sharply upon the needs of certain technical endeavors. Thus the calculation of transport properties of mixtures encountered in synthetic fuels process design are discussed in ref. [49P] and mass/heat transfer aspects of anaerobic reactor [33P]. Nuclear engineering activities provide the impetus to consider the thermal conductivity of simulated radioactive waste glass [40P], the measurement of the thermal conductivity of liquid urania [11P] and lithium-containing ceramic breeder material [48P], the thermal properties of stabilized zirconia [9, 29P], and the role of organic coolants for nuclear reactors [39P]. In the textile and fiber areas a comparison is made of the heat and mass (water) transport through cotton and polypropylene [10P]. The thermal insulation properties of 12 fabrics in high-intensity heat exposure were tested in ref. [5P] and the effect of free water in fibrous insulating materials on thermal and physical properties examined in ref. [30P]. Rocket propulsion systems cause the thermal transport properties of ammonium perchlorate to be examined [46P]. The efficacy of metallized plastic sheeting in providing thermal protection is studied in ref. [8P]. The influence of soil tillage on its thermal properties is measured as having a 20% effect on the thermal conductivity using the line source heat-probe method [35P].

In the area of building materials *in situ* measurements of $u$-values for a built structure are obtained by recording heat flows and temperature differences over a period of days and calculating the $u$-value as the quotient of means [27P]. For insulated sandwich panels penetrated by structural members a simple method is presented of calculating the theoretical $u$-value to account for the losses caused [26P].

Measurements on several special systems involve a radiant heat flux apparatus for measuring the thermal response of polymeric materials to high temperatures [17P]. The thermal conductivity of several evacuated load-bearing porous insulations at temperatures between 300 and 650 K [6P], and the analysis of heat transfer during freezing of slab-shaped food commodities [2P]. An inverse method of thermophysical properties and heat fluxes is given in ref. [1P].

## HEAT TRANSFER APPLICATIONS—HEAT PIPES AND HEAT EXCHANGERS

Heat transfer applications range widely across a variety of technical fields embracing analysis and testing, modeling and design, heat exchange enhancement and optimization, including individual influences as well as overall performance. Considerable interest continues to be shown toward extended surfaces for improving heat transfer and the heat pipe.

Computer techniques are used to analyze shell-and-tube exchangers [72Q]; multipass heat exchanger networks [64Q]; transient, three-dimensional single-phase flow in nuclear reactor rod bundles [18Q]; the dynamics of transient states of the counterflow heat regenerator [110Q]; and the optimization of heat transfer equipment [66Q].

The electrical enhancement of heat transfer is considered [17Q] for a gas–solid suspension heat exchanger utilizing such a field and in ref. [51Q] where resonant oscillation of drops is induced. For an extended surface, ref. [102Q] determines its temperature distribution for a nonuniform heat transfer coefficient. With optimization as the goal, a number of studies consider specific systems: annular fins with variable thermal parameters [68Q]; arrays of longitudinal, rectangular fins in convective heat transfer [10Q]; choking and optimization of extended surface arrays [56Q]; natural convection and radiation heat transfer from highly populated pin fin arrays [92Q]; and longitudinally-finned cross-flow tube banks and their hydrothermal characteristics [90Q]. A combined analysis and optimization of extended heat transfer surfaces is given in ref. [48Q]. For rectangular fins protruding from a vertical rectangular base, a three-part study [60Q, 61Q, 62Q] reports the optimal fin separation and thermal performance for this configuration. For compact heat exchangers, ref. [86Q] considers the effect of contact resistance in the composite construction used in semiconductor cooling systems; ref. [52Q] treats the efficacy of turbulence promoters; and ref. [95Q] models an offset-strip-fin type exchanger for use at low Reynolds number. In a two-part study [32Q, 33Q] the hydro-thermal performance of finned tube bundles and typical air cooler finned tubes are examined.

The use of finned surfaces for systems undergoing phase change receives consideration by a number of investigators. An analytical model for predicting condensate retention on horizontal integral-fin tubes is presented in ref. [82Q]; the effect of fin spacing on the performance of such a configuration in condenser service is covered in ref. [111Q] and the prediction of the condensation coefficient in ref. [108Q]. Other investigations explore condensation enhancement of vertical spiral double fin tubes with drainage gutters [97Q] and heat transfer coefficients for a vertical fluted-plate refrigerant condenser [101Q]. Two boiling papers consider the optimum use of longitudinal fins of rectangular profiles in boiling liquids [14Q], and surface tension effects on convective boiling in compact heat exchangers with offset strip fins [23Q].

The fouling of heat exchangers is the focus of some investigators. Estimating friction factors in a fouled annulus [67Q]; the causes and effects of sedimentation in condensers and heat exchangers [100Q]; a simulation procedure for chemical reaction fouling in heat exchangers [35Q]; a high-intensity ultrasonic method of scale and deposit removal [75Q]; and a general discussion of the problem [16Q] all address this aspect of heat transfer equipment.

For heat exchangers, ref. [80Q] considers the transient response of the parallel flow type, ref. [113Q] calculates the temperature fields in cross-flow including the effects of inlet non-uniformities and ref. [57Q] seeks to characterize the 'thermo-hydraulically efficient' exchanger surface. Specific influences on exchanger performance are considered by ref. [76Q]—viscosity induced non-uniform flow in laminar flow; ref. [50Q]—turbulators in fire tube boilers; ref. [3Q]—unsteady-state transfer and mixing due to flow twisting; ref. [40Q]—the effect of manufacturing inaccuracies and deformation of tube bundles; and ref. [27Q]—two-phase flow in exchangers and pipelines. For compact heat exchangers, single-blow transient testing of surfaces is discussed [63Q], construction of and measurements with extremely compact, cross-flow types is described [96Q] and the general nature and purpose of such devices [52Q].

For plate exchangers, ref. [11Q] discusses the temperature distribution in parallel channels; ref. [12Q] the temperature distribution in a four channel exchanger; and ref. [34Q] the effect of corrugation inclination angle on exchanger performance. To evaluate and coordinate experimental studies of such exchangers, ref. [46Q] proposes a mathematical model. The design of a plate-type evaporator for heat pumps is described by ref. [45Q].

The use of porous materials joins three studies. In a two-part investigation, refs. [37Q, 38Q] examine the improvement in efficiency by the use of such material in a shell and tube design and a single tube-shell and tube exchanger; ref. [22Q] considers the effect of a porous layer on the hydrodynamic behavior of the coolant.

The design of exchangers receives consideration [55Q] through a mathematical analysis governed by a single similitude criterion. Other papers stressing design are directed toward specific applications: refrigerant exchanger [93Q] and steam generator [13Q].

Solid–gas exchangers are investigated in the form of 'raining bed' exchangers for high temperatures [19Q] and an experimental study of the high temperature performance of a pebble bed exchanger [112Q].

Studies stressing the chemical aspects of exchangers include the modeling of an exchanger in which phase changes are possible in both multicomponent streams [106Q]; a novel processing technique combining separation of a mixture into its components with heat transfer [59Q]; the thermal character of a heat exchanger–chemical reactor with coolant in cross-flow [47Q]; and a single fluid, multi-pass exchanger and combustor for low-heating-value gas [28Q].

Specialized exchangers are studied for nuclear reactors: very high-temperature gas-cooled reactor in cross-flow [98Q]; and heat removal in fast reactor cores [114Q]. Oil is the medium of interest in ref. [107Q]—optimum exchanger design for crude oil stabilization; and ref. [83Q]—experimental performance of an oil–air exchanger. Evaporative cooling exchangers are considered by simulation [109Q] analyzed for the packed bed, recirculated-liquid gas cooler–humidifier [58Q]. Air–molten salt direct-contact exchange is examined in ref. [15Q]; a scraper to augment condensation heat transfer is reported [65Q] and the role of the exchanger in power systems is generally discussed in ref. [39Q].

Research on the heat-pipe or thermosyphon continues to attract a high level of interest. The modeling of such a system is considered by ref. [42Q] for a closed-loop type including the Soret effect and by ref. [24Q] for the transient operating characteristics of a low-temperature device. A method of analysis is given for exchangers involving the principle by ref. [49Q]; a variable area one- and two-phase steady-state loop in ref. [77Q]; and a heat-pipe thermodynamic cycle in ref. [53Q]. Mixed boundary conditions for the loop syphon is considered by ref. [43Q].

The stability of these systems is treated in a number of studies. Steady-state behavior and stability thresholds for a closed two-phase type is investigated in ref. [29Q]; oscillatory instability in closed-loops by ref. [25Q]; complex oscillations in ref. [44Q]; and throughflow effects and the effect of motion onset in refs. [118Q, 117Q], respectively. Measurements of working fluid distribution within the wick are reported [87Q] and natural convection in the concentric tube system is treated by ref. [94Q]. The toroidal configuration is the focus of ref. [81Q] for high Graetz and Grashof numbers; ref. [84Q] for the inclined device and the steady-state velocity; and ref. [85Q] for known heat flux. Discrete influences or special circumstances mark the following works: improving maximum heat transfer for axially grooved pipes [9Q]; two-phase operation for fluid near the critical point [41Q]; double-wall artery, high capacity pipe [74Q]; effect of liquid plug in vapor channel [78Q]; design of air–water, co-axial exchanger [5Q]; and a water–air, gravity assisted exchanger [4Q]; low-temperature systems [105Q]; and use in a metallurgical furnace [26Q]. The device is reviewed from its inception in 1973 to the present with its many applied forms [79Q].

Regenerator performance is predicted using a nonlinear analogy method [7Q, 8Q] and the Galerkin method applied to solve the symmetric and balanced counter-flow problem [6Q]. Experiments are performed [69Q] in order to determine the thermal stage performance for the device in semi-continuous operation. Quick design and evaluation [31Q], approximate methods for evaluation efficiency in periodic operation [30Q], and the effect of flow-through capacity on the hydro-thermal performance of a Stirling engine type [71Q] conclude the work on this device.

For heat transfer in tubes, attention is directed toward the augmentation of laminar flow exchange by wire coil inserts [104Q], correlations for oscillations in long, sodium-heated, steam-generating tubes [103Q], impedance heating [54Q], and the measurement of heat and mass transfer from humid air to a horizontal tube in a false bank [36Q]. Tube assemblies are examined for the influence of surface roughness on heat flow and drag for crossflow [116Q]; for conditions of laminar axial, transverse and inclined flow [2Q]; and under conditions of turbulent inclined flow [1Q]. Correlations for heat flow and pressure drop for in-line and staggered banks are suggested [115Q]. Proper selection, inspection, maintenance, and failure analysis for HVAC heat transfer coils are discussed in ref. [88Q]. A review of North American usage for estimating refrigerant-side heat transfer and pressure drop for direct expansion coils is given [99Q] and a cost-estimating method provided for double-pipe and multi-tube exchangers with bare tubes and external-longitudinally-finned tubes [73Q].

Shell and tube exchangers are treated in a review on current practice for shell-side two-phase heat transfer [89Q], a prediction method for pressure drop in the instance of roughened tubes and smooth shell surface [20Q], and the determination of shell-side heat transfer coefficients by the naphthalene sublimation technique [70Q, 91Q]. The characteristics of dry cooling towers for condensate cooling are considered by ref. [21Q].

## HEAT TRANSFER APPLICATIONS—GENERAL

A large number of papers has been published on heat transfer occurring in specific areas of engineering activity. They are scattered in many journals. Approximately one-half of those known to us have been included in this section of the review and are discussed with the aim of providing a feeling for the various fields of engineering activity in which heat transfer is encountered.

A considerable number of papers deal with *metal and polymer processing*. A good fraction of them are analytical. The temperature fields are calculated for the heating [54S] and cooling [62S] of steel casting because of the pronounced effect which it has on the microstructure of the steel. Friction welding is modeled [27S] and unipolar induction heating is considered [58S] as well as electromagnetic turbulent stirring in furnaces [61S] and impedance pipe heating [38S]. Models for the analysis [45S] and experimental results [18S] are reported for polymer molding. Differences up to 30°C in the cavity surface temperature have been observed in cyclic injection moldings [2S]. Several models describing the effect of heat transfer on the spinning of glass fibers were examined [44S] and experiments established heat transfer in the heating of molten glass banks agitated by jets [9S].

Heat transfer in *chemical processing* is discussed in a number of papers dealing with topics like mathematical modeling used in the scaling of fixed-bed [24S] and agitated [41S] reactors. The penetration theory is used to study heat transfer in stirred reactors [40S, 42S] with immersed heating elements. Heat transfer in boiling of contaminated sulphuric acid [65S] is discussed and a number of papers [49S, 56S] deals with heating and devolatilation and with freezing of coal.

*Ground heat transfer studies* included methods to calculate the daily soil heat flux [31S] and the subsurface temperature distribution [46S] and provide a model to calculate shallow soil heat extraction [43S] as well as the use of geologic formations for seasonal thermal energy storage [64S]. Greenhouse heating by underground pipes has been analyzed [4S]. Surface heat flow measurements at hot spots of the Kilauea volcano in Hawaii [22S] were used to locate magma deposits. The growth and decay of ice on the Lawrence river [30S] and the undulation of water on an icy Siberean surface [29S] were modeled and described as well as flow and temperature distribution in aquifers [53S] and in wells [5S].

Modeling results of *heat transfer in buildings* were compared with experimental results for two Dutch dwellings [1S] and included the effects of wind direction on the energy consumption [12S]. Building envelopes using new energy efficient materials were optimized [34S] for heating and cooling load. The effect of phase-change component materials in thermal storage walls on their thermal performance is investigated [13S] by a time-dependent analysis. The use of transparent films to transmit solar and reflect infrared radiation in greenhouses is discussed [6S].

Several papers deal with heat transfer in *nuclear power plants* and some for *coal-fired power plants.* A survey compares results of computer codes with experiments and plant operation to study natural circulation cooling in pressurized water reactors [7aS]. Heat transfer from a partially uncovered reactor core was modeled [63S]. The temperature distribution in fuel rods [59S] and scaling criteria in nuclear reactors [35S] were also considered. An analysis studied the performance of coal-fired power plant spray-cooling systems [52S].

The spreading of *fire* in buildings and in nature was studied by analysis and experiments for a fire plume impinging on a ceiling [68S] or moving through several rooms [33S]. The spread of forest fires [37, 20S] was analyzed. The onset of a firestorm [11S] is postulated to require the pre-existence of a swirl.

Experiments and analysis in *bioengineering* considered the temperature distribution in the heart [3S] and in the head [51S] caused by blood flow.

Thermal insulation of *garments* was measured during wear trials [32S] and during burning [50S].

Survey papers described the pioneering contributions of Luikov [48S] and of Sherwood [15S, 17S] to heat and mass transfer research in *drying.* Other contributions deal with wood [55S, 21S], fibrous sheet material [37S], paper [19S] and humid sandstone [66S].

Three papers are examples of studies on heat transfer in *combustion engines.* Two [67S, 25S] deal with diesel engines and one [57S] with gas turbines.

*Fusion power plants* will experience extreme conditions for heat transfer. These are discussed in papers like [8S, 10S, 26S].

A mathematical model for simulation of industrial *refrigeration* plants is tested against experimental data [57S].

Papers concerned with *aerospace* applications include computer results for the Knudsen layer of a highly cooled blunt body in rarified flow at Mach number 26 [14S] which differ markedly from previous calculations and a detailed heat transfer analysis [59S] to determine the temperature limitations for the thermal control system of a space shuttle payload.

Examples of papers in the field of *electrical engineering* describe experiments on a rotating test rotor simulating superconducting generator cooling [23S], on heat loading of components in multi-megawatt ion sources [47S] and on turbulent convective heat transfer in forced cooled underground electric transmissions using oil [28S].

## SOLAR ENERGY

The energy loss mechanisms are analyzed for a parabolic dish/cavity receiver configuration and it was found that varying the concentrator rim angle and cavity geometry can greatly affect the cavity power profile without a large effect on system efficiency [18T]. A semi-empirical equation was developed for the heat loss factor for a tubular absorber with a concentric glass cover, employed as the target of a linear solar concentrator [6T]. A study of the interaction between concentrated solar radiation and a honeycomb matrix or a bed of particles cooled by a gas shows evidence of overheating of the solid near the irradiated surface [31T]. A thermal analysis of a V-trough solar concentrator shows that this design is more efficient and provides higher temperatures than a flat-plate collector [1T]. A 1.5 × CPC type collector described and tested in detail exhibits an optical and thermal behavior which make it an excellent candidate for thermal applications up to 100°C [10T].

Testing of a set of Sanyo STC-CU 250 evacuated tubular collectors and subsequent data reduction demonstrated that large variations in thermal performance characteristics can result among a collector type taken from a production batch [32T]. An investigation is reported of heat transfer between the glass absorber tubes of an all-glass evacuated collector and fluid-in-metal manifolds designed for heat extraction from the tubes [39T].

The performance of a flat-plate solar collector combining a selective surface on the absorber plate and a plastic honeycomb in the air gap can be improved by leaving an air gap of about 10 mm between the plate and the honeycomb [19T]. A theoretical analysis of the regimes of convective heat transfer in a horizontal solar converter shows that beehive-type designs can minimize convective losses by maintaining a conductive regime at Rayleigh numbers as high as $10^6$ [14T].

Analytical approximations of the temperatures within a flat-plate collector at a moment $t = 0$, are derived. They are expressed as functions of the time-varying behavior of the solar flux, the ambient temperature and the fluid outlet and inlet temperatures [24T]. A discrete-gradient algorithm is used to identify the parameters in a one-node and two-node capacitance model of a flat-plate collector [20T]. An analytical solution is presented of a matrix differential equation for heat removal from an absorber plate with a serpentine tube [38T]. The effects of noncontinuous bonding of the energy removal tube to the absorber plate of a flat-plate collector are analyzed [11T]. An analytical study of the laminar heat transfer in the ducts of a solar collector indicates that the use of an average Nusselt number for the constant wall temperature boundary condition in a radially lumped solution predicts efficiency factors that are within 6% of those obtained using a more detailed calculation procedure [37T]. It is shown that the multiple-pass air heater performs well for low flow rates and large plate lengths but for small plate lengths and high flow rates, the addition of cover plates does not affect the performance of two- or three-pass air heaters [15T].

An interferometric technique was used to study coupled convective heat transfer for an inclined solar collector [25T]. An experimental study provides data for convective heat transfer coefficients on the front surface of a free-standing array of solar collectors mounted on a flat roof and exposed to the wind [28T]. Studies of collectors operating in a wind tunnel indicate that recent empirical relations for calculating top losses provide good estimates at low wind speeds but underestimate the top loss for wind speeds greater than about $1\,\mathrm{m\,s^{-1}}$ [13T].

A simplified simulation method for solar thermosyphon collectors was developed using the Hottel–Bliss–Whillier theory for the absorber, Close's model of a thermally stratified tank, and a newly defined loop resistance relation [21T]. A numerical simulation model for thermosyphon solar water heaters has been developed and used to study the characteristics of vertical and horizontal tank thermosyphon systems [30T]. In a side-by-side comparison of a pressurized and a nonpressurized solar water heating thermosyphon system, it was found that the nonpressurized system had the higher daily average efficiency [35T]. An integral compact solar water heater proved to have high collection efficiency. However, it also proved to have high losses during the period when there was no incident solar flux [36T].

Steady-state calculations prove that only little sophistication in design and technology of solar collectors is required with favorable weather conditions but that unfavorable weather conditions require collectors with technological refinements [17T]. A study implies that the sophistication and expense involved in a searching for and implementing optimal variable collector flow rate strategies for single-pass, open-loop solar thermal energy systems may not be worth the effort [16T]. The benefits of using phase-change slurries as enhanced heat transfer/storage working fluids in solar energy and waste heat utilization systems are investigated [26T]. Numerical simulation and experimental measurement are used to examine the performance of a greenhouse-type solar timber dryer that dries about $5\,\mathrm{m^3}$ of timber from green to equilibrium in about three weeks [34T]. A thermodynamic analysis of a solar zeolite refrigeration system showed that the system performance depends primarily on the solar collector type and the zeolite absorption properties [8T].

An analytical and numerical study of the thermal and fluid flow effects of heat rejection to the surface layer of a salt-gradient solar pond, by means of a recirculating thermal discharge, is carried out [23T]. The use of an empirical transmittance function in the modeling of a solar pond was found to improve the results of the modeling [2T]. An analytic solution is presented that calculates the heat loss from the bottom of a solar pond to a soil that contains a moving water table [22T].

Measurements performed for the 1981–1982 heating season showed that the solar collection efficiency was 64% and the solar fraction was 0.40 for a passive solar modular house located in Knoxville, Tennessee [33T]. The thermal performance of three walls, a 40-cm-thick concrete wall, an 8-cm-thick hard paraffin wall and an 8-cm-thick soft paraffin wall, was monitored for a three-year period [5T]. A quantitative assessment is presented of the extent to which massive building envelopes can increase solar heating fractions by moderating the storage and the release of solar gain [12T]. A computer model of a general integral collection–storage passive solar component was created to be compatible with the transient system program TRNSYS and was used to develop and verify the simpler monthly performance prediction method [40T]. An efficient method is presented for the computer analysis in the frequency domain of multizone passive solar buildings [3T].

The transient thermal response of a rock bed with no net fluid flow is examined following all-day charging and the results indicate that natural convection may occur in the upper regions of the bed [4T]. A three-dimensional numerical model for seasonal heat storage in the ground using vertical heat exchanger pipes is presented [29T]. An analytical and numerical study demonstrates that the harvesting of solar energy by a solar collector installation with temporary storage can be maximized by the proper selection of the daily regime of operation [9T].

Analytical and experimental studies were performed for night sky radiators as a function of power dissipation, surface properties and water vapor pressure [27T]. Three models of spectral direct irradiance of the sun at groundlevel are found to be in satisfactory agreement with experimental measurements, although their behavior is quite different in the absorption bands [7T].

## PLASMA HEAT TRANSFER AND MHD

Papers in plasma heat transfer are primarily concerned with heat transfer in arcs and applications such as thermal plasma processing of materials.

The results of a two-dimensional analysis of free burning arcs in argon (100–400 A) show good agreement with experimental data. The importance of energy transfer due to electron convection currents is demonstrated [28U]. Radial temperature profiles in radiation-dominated, wall-stabilized arcs are calculated by using equations derived from the first two moments of the radiative transfer equation for determining radiation losses [31U]. A transient two-dimensional analysis of forced convection-stabilized arcs (gas-blast circuit breakers) shows good agreement with experiments for the upstream region of steady-state arcs in nitrogen and hexafluoride [34U]. A previously described method for computing radial temperature distributions in wall-stabilized arcs is applied to the treatment of D-line emission from a sodium arc lamp [32U]. Different methods for measuring electron densities in a $SF_6$ arc are in good agreement indicating departures from LTE due to a demixing effect [48U]. Experimental data indicate that the gas dynamics of vortex-stabilized plasma guns control their energy transfer, electric performance, and service life [40U]. The presence of metal vapor in an argon arc plasma at the $p = 1$ atom leads in the anode region to a temperature decrease, a significant reduction of the electric field, and a large increase of the electrical conductivity [9U].

An improved relaxation method for measuring gas temperatures in arc plasmas is described, based on different relaxation times of density and electron temperature after arc interruption [41U]. Based on a numerical solution of the radiation transfer equation, temperature determination in high-pressure plasmas is possible in cases where no optically thin lines are available [47U]. A new procedure has been developed for determining the line broadening at the axis of an optically thick arc discharge, and the influence of the radial variation of the line broadening on the plasma temperature is determined for the case of symmetric self-reversal [22U]. Temperature measurements in nitrogen seeded, nonequilibrium argon plasmas, using the intensity distributions of the $N_2^+$ first negative bands, show that at lower pressures, the rotational temperatures are much lower than the vibrational and electron temperatures. At higher pressures they assume the same values since LTE is attained [42U]. By combining the technique of statistical spectroscopy with a probabilistic theory of radiative transport, a new method has been developed for evaluating the radiative power emitted from a thermal plasma by spectral lines [12U]. A new, simple elliptical Abel inversion is described for calculating spatial distributions of electron densities in elliptically shaped plasmas [20U].

Thermodynamic and transport properties of hydrogen and copper plasmas are reported for temperatures from 5000 to 60,000 K and pressures from 1 to $10^4$ atm [27U]. Measurements of the thermal conductivity of hydrogen above 4500 K with electric arcs must take deviations from LTE into account [38U]. Simple and accurate expressions for the electrical conductivity in steady-state weakly and highly ionized plasmas are in good agreement with exact numerical calculations [30U]. Computer models are introduced for calculating the ambipolar diffusion coefficient and the reactive thermal conductivity of a two-temperature argon plasma containing higher ionized species [7U]. The nonlinear heat conductivities of a dilute plasma in a magnetic field deviate markedly from the linear theory prediction as the Debye length increases [17U]. A theoretical investigation of plasmas contaminated by various metal vapors shows the importance of the first ionization of these contaminants on the plasma properties [2U]. The theory of thermal diffusion in ionized gases is reconsidered taking into account quantal effects and effects caused by dynamic shielding [35U].

In connection with heat and mass transfer studies of particles injected into thermal plasmas, a new integral mean diffusivity is introduced for calculating mass transfer rates from such particles [43U]. The ambipolar diffusion coefficients in a nitrogen thermal plasma for $4000 \leqslant T \leqslant 15{,}000$ K depend on actual population number densities encountered and not only on temperature [4U]. The electrical conductivity of partially ionized monatomic gases has been calculated for a wide range of electron temperatures and degrees of ionization. Knowledge of the electrical conductivity allows for easy determination of electron mobility and diffusion coefficients in plasmas [16U].

The average cooling energy of electrons emitted from an arc cathode root and the effective work function are strongly dependent on the temperature and the electric field at the location of electron emission [29U]. Studies of the effect of anode vapor (Cu) on the anode region of a high-intensity argon arc show a flattening of the current density distribution which will also affect the heat flux distribution at the anode [15U]. Modeling of the transport phenomena in the anode region of high-intensity arcs indicates that nitrogen arcs tend to form highly constricted anode arc roots in contrast to argon arcs [52U]. An improved heat conduction model is proposed which provides better predictions of the anode voltage drops for electric discharges in dielectric liquids, as for example, in EDM machining [6U]. Cooling of the expanding metal plasma emitted from the cathode spot of a vacuum arc leads to a strong variation of the electrical conductivity across the thermal boundary layer [13U].

At the boundary between a hot and cold plasma, a double layer structure is formed on the hot-plasma side with a potential difference given approximately by $\phi_{DL} \sim T_{eh}/2e$ where $T_{eh}$ is the hot electron temperature and $e$ the elementary charge [21U]. Experimental studies of heat and mass transfer between a plasma jet and a permeable wall cooled by injection of a two-phase flow show that the temperature of the wall undergoes self-induced oscillation due to a shift of the vaporization zone [1U]. A numerical analysis of thermal plasma flow in a pipe indicates that the velocity and energy fields are different from ordinary pipe flow and vary characteristically depending on the state in the pipe and the initial conditions [23U, 24U]. The heat flux to the wall of a water-cooled tube carrying a thermal argon plasma flow changes little with cold gas injection upstream of the location where heat flux measurement were taken [25U]. A correlation for heat transfer between a hydrogen plasma jet and the walls of a cylindrical channel represents the data within 22% [54U].

Computer experiments show the relative importance of various effects on the motion and on heat and mass transfer of a particle injected into a thermal plasma [44U]. The motion of a small spherical particle injected into a thermal plasma may be affected by a number of effects which are not present in an ordinary gas [45U]. The results of heat and mass transfer studies of particles in thermal plasma flows indicate that convective heat transfer coefficients have to be modified due to strongly varying transport properties. In addition, particle heat transfer under noncontinuum conditions is governed by individual contributions from the species in the plasma and by particle charging effects [33U]. Plasma–particle interactions in r.f. induction plasmas are considered using argon at $p = 1$ atm as the plasma gas interacting with copper and alumina particles. Substantial local cooling rates are found for high particle injection rates [46U]. Heat transfer to a copper particle immersed into an argon plasma is substantially affected by the change of the transport coefficients due to copper vapor, except for cases of very high plasma temperatures [10U]. Heat transfer to particles injected into plasmas at reduced pressures ($p < 1$ atm) is severely reduced due to the Knudsen effect [11U].

Theoretical studies of the plasma-activated chemical vapor deposition (PCVD) process, used for the preparation of optical fibers, indicate that the static deposition profile of silica can be computed by considering convection, radiation and diffusion processes inside the glass tube [51U]. Investigations of the pyrolytic decomposition of methane in a plasma indicate that an excess of hydrogen causes a decrease in the overall rate constants for the methane decomposition [14U]. Natural phosphate may be dissociated in a thermal plasma and in this way concentrated phosphorus fertilizer may be produced [36U]. Plasma heat transfer and chemical reactivity are important for an understanding of the surface effects on solids and liquids for refining, nitriding, etc. [3U]. Modeling of plasmas, calculation of plasma transport properties, and mixing of plasmas with cold gases are discussed in the context of plasma–particle momentum and heat transfer. In addition, experimental data are presented and compared with analytical results [19U]. The successful generation and processing of fine powders in thermal plasmas is directly linked to the understanding of heat and mass transfer processes [55U].

Two different numerical approaches are used for modeling the flow and temperature fields in an inductively coupled plasma. The results show that the method may have a substantial influence on the stability and the convergence of the solution [37U]. Investigations of the phenomenon of exploding wires indicate that for energies $E > E_e$ ($E_e$ is the energy density required for complete vaporization), explosive vaporization occurs, resulting in a high-temperature plasma [50U]. During the explosion phase, plasma temperatures may exceed 10 eV. A super high density ($n_e = 5 \times 10^{22}\,\mathrm{cm}^{-3}$), high temperature ($T_e \approx 400$ eV) plasma can be produced by an aluminum wire explosion [18U]. The gas heating of the neutral molecules in a glow to spark transition in air and nitrogen gives rise to a neutral depopulation in the core of the discharge [5U]. The heat transfer coefficient from a flowing hydrogen microwave plasma to the plasma discharge tube wall increases with increasing flow rate and pressure and is independent of the absorbed power of the mircowave plasma [8U]. A heated three-chamber pneumatic shock tube is a convenient instrument for investigating a dense plasma composed of various chemical elements over a wide range of parameters [26U].

Low Prandtl number MHD convection studies about a heated semi-infinite horizontal flat plate reveal downstream of the leading edge an unusual structure [53U]. Studies of the spectral emission from MHD combustion gas mixed with pulverized coal ($0.38 < \lambda < 2.7\,\mu$m) revealed many lines of K, Li, Na, Rb, and Ca, but no emission from coal-ash particles was observed [39U]. The combined effects of free forced convection on the flow of an incompressible conducting visco-elastic fluid between two horizontal insulated parallel walls are considered with linear axial temperature variation under the influence of a uniform transverse magnetic field [49U].

## BOOKS

R. I. Soloukhin and N. H. Afgan, *Measurement Techniques in Heat and Mass Transfer*. Hemisphere, Washington, DC (1985).

S. Kakac and R. Viskanta (Editors), *Natural Convection*. Hemisphere, Washington, DC (1985).

Xue-jun Chen and T. Nejat Vezirogulu (Editors), *Two-phase Flow and Heat Transfer: China–U.S. Progress*. Hemisphere, Washington, DC (1985).

A. Zukauskas and J. Ziugzda (Edited by G. F. Hewitt), *Heat Transfer of a Cylinder in a Crossflow* (translated from Russian). Hemisphere, Washington, DC (1985).

B. F. Armaly and A. F. Emery (Editors), *HTD-Vol. 49, Radiation Heat Transfer*. ASME Order Dept., New York (1985).

S. Oktay and R. J. Moffat (Editors), *HTD-Vol. 48, Heat Transfer in Electronic Equipment—1985*. ASME Order Dept., New York (1985).

P. J. Bishop (Editor), *HTD-Vol. 41, Heat Transfer in Buildings and Structures*. ASME Order Dept., New York (1985).

W. M. Rohsenow, J. P. Hartnett and E. N. Ganic (Editors), *Handbook of Heat Transfer*, 1st Vol., *Fundamentals*, 2nd Vol., *Applications*. McGraw-Hill, New York (1985).

J. Sucec, *Heat Transfer*. Brown, Dubuque, IA (1985).

Jasbir Singh and B. V. Badger, *Heat Transfer Fluids and Systems for Processs and Energy Applications*. Marcel Dekker, New York (1985).

S. M. Shenkman, J. E. O'Brien, I. S. Habib and J. A. Kohler, *HTD-Vol. 43, Advances in Enhanced Heat Transfer—1985*. ASME Order Dept., New York (1985).
J. T. Pearson and J. B. Kitto, Jr. (Editors), *HTD-Vol. 44, Two-phase Heat Exchanger Symposium*. ASME Order Dept., New York (1985).
G. K. Law, Y. Jaluria, W. W. Yuen and K. Miyasaks, *HTD-Vol. 45, Heat Transfer in Fire and Combustion Systems*. ASME Order Dept., New York (1985).
V. Dembovský, *Plasma Metallurgy, The Principles*. Elsevier, Amsterdam (1985).

## CONDUCTION

1A. A. A. Aleksashenko, Optimal control in solution of certain inverse heat-conduction problems, *Pwr Engng* **23**(1), 98 (1985).
2A. N. M. Alnajem and M. N. Özişik, Direct analytical approach for solving linear inverse heat conduction problems, *J. Heat Transfer* **107**(3), 700 (1985).
3A. N. M. Alnajem and M. N. Özişik, On the solution of three-dimensional inverse heat conduction in finite media, *Int. J. Heat Mass Transfer* **28**(11), 2121 (1985).
4A. V. W. Antonetti and M. M. Yovanovich, Enhancement of thermal contact conductance by metallic coatings: theory and experiment, *J. Heat Transfer* **107**(3), 513 (1985).
5A. N. Araki, K. Kobayasi and M.-A. Ochi, Measuring thermal diffusivity of liquids by stepwise heating (the second report, heat loss characteristics and measurements on molten salts), *Heat Transfer—Japan. Res.* **14**(1), 56 (1985).
6A. N. Araki and K. Natsui, Measuring thermal diffusivity of liquids by stepwise heating (the first report, principle of measuring method and theoretical analysis of errors), *Heat Transfer—Japan. Res.* **14**(1), 36 (1985).
7A. E. A. Artyukhin, Experimental design of measurements for the solution of coefficient-type inverse heat-conduction problems, *J. Engng Phys.* **48**(3), 372 (1985).
8A. J. Baker-Jarvis and R. Inguva, Heat conduction in heterogeneous materials, *J. Heat Transfer* **107**(1), 39 (1985).
9A. B. T. F. Chung, M. M. Kermani, M. J. Braun, J. Padovan and R. C. Hendricks, Heat transfer in thermal barrier coated rods with circumferential and radial temperature gradients, *J. Engng Gas Turbine Pwr* **107**(1), 135 (1985).
10A. R. M. Clever and A. T. Wassel, Three-dimensional transient heat conduction in a multilayer medium, *J. Spacecraft Rockets* **22**(2), 211 (1985).
11A. T. W. Davies, Transient conduction in a plate with counteracting convection and thermal radiation at the boundaries, *Appl. Math. Modell.* **9**(5), 337 (1985).
12A. O. V. Dikhtiyevskiy, A variational method for solving the two-dimensional problem of heat conduction with a finite-size internal source, *Heat Transfer—Sov. Res.* **16**(4), 81 (1985).
13A. L. Ercoli, P. A. A. Laura, R. O. Grossi and G. Sanchez Sarmiento, Unsteady thermal field in bars of doubly connected cross section with heat generation, *Nucl. Engng Des.* **88**(3), 377 (1985).
14A. J. I. Frankel, B. Vick and M. N. Özişik, Flux formulation of hyperbolic heat conduction, *J. appl. Phys.* **58**(9), 3340 (1985).
15A. J. C. Friedly, Transient response of a coupled conduction and convection heat transfer problem, *J. Heat Transfer* **107**(1), 57 (1985).
16A. S. M. Ghiaasiaan, A. T. Wassel, J. L. Farr, Jr. and S. M. Divakaruni, Heat conduction in nuclear fuel rods, *Nucl. Engng Des.* **85**(1), 89 (1985).
17A. S. C. Huang, Unsteady-state heat conduction in semi-infinite regions with mixed-type boundary conditions, *J. Heat Transfer* **107**(2), 489 (1985).
18A. F. W. Jones and M. E. Ertman, Heat flow through thermally anisotropic media: a numerical method and its application to an area of the southwest Scottish Highlands, *Geologie en Mijnbouw* **64**(3), 251 (1985).
19A. Y. Kawashima and K. Nishimoto, A method for analyzing the thermal conduction problems by a dual difference equation, *Bull. J.S.M.E.* **28**(237), 444 (1985).
20A. K. Kawashimo, K. Morikawa and E. Nemoto, Mathematical analysis of nonlinear unsteady heat conduction (1st report, general fundamental idea), *Bull. J.S.M.E.* **28**(244), 2341 (1985).
21A. Yu. M. Kolyano, V. I. Gromovyk and Ya. T. Karpa, Heat-conduction problem for a plate with a square cut, *J. Engng Phys.* **48**(2), 233 (1985).
22A. Z.-B. Kuang and S. N. Atluri, Temperature field due to the moving heat source: a moving mesh finite element analysis, *J. appl. Mech.* **52**(2), 274 (1985).
23A. A. A. Kulkarni and K. G. Narayankhedkar, Measurement of equivalent thermal conductivity of multi-layer insulations, *Indian J. Technol.* **23**(1), 13 (1985).
24A. H. L. Kuntz and N. D. Perriera, Oscillatory conductive heat transfer for a fiber in an ideal gas, *J. Heat Transfer* **107**(1), 52 (1985).
25A. U. H. Kurzweg, Enhanced heat conduction in fluids subjected to sinusoidal oscillations, *J. Heat Transfer* **107**(2), 459 (1985).
26A. G. R. McGee, M. H. Schankula and M. M. Yovanovich, Thermal resistance of cylinder–flat contacts: theoretical analysis and experimental verification of a line-contact model, *Nucl. Engng Des.* **86**(3), 369 (1985).
27A. M. D. Mikhailov and M. N. Özişik, Unified solutions of heat diffusion in a finite region involving a surface film of finite heat capacity, *Int. J. Heat Mass Transfer* **28**(5), 1039 (1985).
28A. P. L. Mills, S. S. Lai and M. P. Dudukovic, Solution methods for problems with discontinuous boundary conditions in heat conduction and diffusion with reaction, *Ind. Engng Chem. Fund.* **24**(1), 64 (1985).
29A. T. Miura, J. Fukai and S. Ohtani, Measurement of thermal diffusivities at a continuous heating rate, *Heat Transfer—Japan. Res.* **13**(1), 20 (1984).
30A. A. M. Mujahid and M. Abdulaziz, Periodic heat transfer in triangular fins, *Heat Technol.* **3**(1), 61 (1985).
31A. A. K. Naghdi, Heat conduction in a rectangular parallelopiped with multiple cylindrical cavities, *J. Heat Transfer* **107**(2), 491 (1985).
32A. A. K. Naghdi, Heat transfer in a rectangular plate fin with inner circular boundaries, *Trans. Can. Soc. mech. Engrs* **9**(1), 11 (1985).
33A. E. Nemoto and K. Kawashimo, Analysis of unsteady state problems in nonlinear heat conduction materials, (1st report, one-dimensional exponential models of $x$ = constant), *Bull. J.S.M.E.* **28**(241), 1459 (1985).
34A. R. Pakula and R. Sigel, Self-similar expansion of dense matter due to heat transfer by nonlinear conduction, *Phys. Fluids* **28**(1), 232 (1985).
35A. E. Ya. Rapoport, Optimization of two-dimensional processes of nonstationary heat conduction, *Pwr Engng* **23**(1), 76 (1985).
36A. C. Rogers and R. Sawatsky, Heat conduction in an inhomogeneous half-space subject to a nonlinear boundary condition. Application of Bergman-type series, *Int. J. Engng Sci.* **23**(4), 415 (1985).
37A. J. Saint Jean Paulin, Study of the evolution of temperature in the core of high voltage electric cable, *Int. J. Engng Sci.* **23**(8), 839 (1985).
38A. D. D. Sayers and M. C. Potter, Effect of curvature and torsion on the temperature distribution in a helix, *J. appl. Mech.* **52**(3), 529 (1985).

39A. R. Singh, N. S. Saxena and D. R. Chaudhary, Simultaneous measurement of thermal conductivity and thermal diffusivity of some building materials using the transient hot strip method, *J. Phys. D: appl. Phys.* **18**(1), 1 (1985).
40A. E. M. Sparrow and A. T. Prata, Effect of circumferential conduction on the critical radius of insulation for forced convection crossflow, *J. Heat Transfer* **107**(4), 960 (1985).
41A. L. N. Tao, Analyticity of solutions on the heat equation with nonlinear boundary conditions, *J. Mech. appl. Math.* **38**(3), 447 (1985).
42A. T. Tsukada, S. Noguchi and K. Yanagi, Contact heat transfer between spherical and plane surfaces with microirregularities, *J. Japan Soc. Lubrication Engrs* **30**(1), 60 (1985).
43A. Y. Tsukamoto and Y. Seguchi, Shape optimization problem for minimum volume fin, *Heat Transfer—Japan. Res.* **1**(1), 1 (1984).
44A. M. Ueda, M. Kinugawa and Y. Hara, Heat conduction through a layered pressure vessel wall, *Hitachi Zosen Tech. Rev.* **46**(2), 68 (1985).
45A. Yu. V. Vidin, On eigenvalue calculation in some hollow cylinder heat conduction problems, *Sov. Aeronaut.* **28**(2), 138 (1985).
46A. D. W. Yarbrough, T. W. Tong and D. L. McElroy, Use of fine powders for high thermal resistance, *High Temp. Sci.* **19**(2), 213 (1985).
47A. F. Yoshikawa and M. Tanaka, A boundary element analysis of steady-state heat-conduction problems in axisymmetric bodies, *Heat Transfer—Japan. Res.* **13**(4), 51 (1985).
48A. W. Y. D. Yuen, On the heat transfer of a moving composite strip compressed by two rotating cylinders, *J. Heat Transfer* **107**(3), 541 (1985).

## CHANNEL FLOW

1B. L. A. Abdel-Latif, H. Peeken and J. Benner, Thermohydrodynamic analysis of thrust-bearing with circular pads running on bubbly oil (BTHD-theory), *J. Tribol. Technol.* **107**(4), 527 (1985).
2B. R. S. Amano, A numerical study of laminar and turbulent heat transfer in periodically corrugated wall channel, *J. Heat Transfer* **107**(3), 564 (1985).
3B. O. A. Arnas, M. A. Ebadian and H. C. Topakoglu, Convective heat transfer in annular tubes carrying radioactive slurry, *Heat Technol.* **3**(2), 47 (1985).
4B. G. S. Barozzi and G. Pagliarini, A method to solve conjugate heat transfer problems—the case of fully developed laminar flow in a pipe, *J. Heat Transfer* **107**(1), 77 (1985).
5B. R. Bhargava and M. Rani, Numerical solution of heat transfer in micropolar fluid flow in a channel with porous walls, *Int. J. Engng Sci.* **23**(4), 409 (1985).
6B. B. F. Blackwell, Numerical solution of the Graetz problem for a Bingham plastic in laminar tube flow with constant wall temperature, *J. Heat Transfer* **107**(2), 466 (1985).
7B. V. A. Bruk, Nonisothermal quasistationary gas flow in tubes, *High Temp.* (English translation of *Teplofiz. Vysok. Temp.* **23**(2), 262 (1985).
8B. R. Budwig, S. Tavoularis and S. Corrsin, Temperature fluctuations and heat flux in grid-generated isotropic turbulence with streamwise and transverse mean-temperature gradients, *J. Fluid Mech.* **153**, 441 (1985).
9B. A. S. Buevich and A. I. Filippov, Transfer phenomena accompanying oscillations in a two-component medium, *J. Engng Phys.* (English translation of *Inzh.-Fiz. Zh.*) **48**(2), 158 (1985).
10B. N. I. Buleev and G. A. Zinina, Kinetic model for turbulent transfer in fluid flows, *J. appl. Mech. Tech. Phys.* **26**(1), 42 (1985).
11B. B. Carpenter and G. M. Homsy, The effect of surface contamination on thermocapillary flow in a two-dimensional slot, part 2—partially contaminated interfaces, *J. Fluid Mech.* **155**, 429 (1985).
12B. C.-Y. Chang and C.-F. Lin, Convective transfer in a rectangular duct with heterogenous and homogeneous reactions of arbitrary order, *Chem. Engng Jl, Lausanne* **30**(3), 147 (1985).
13B. D. R. Chenoweth and S. Paolucci, Gas flow in vertical slots with large horizontal temperature differences, *Phys. Fluids* **28**(8), 2365 (1985).
14B. C. Chiranjivi and C. V. Raghavaiah, Developing laminar flow forced convective heat transfer in short elliptical channels, *Indian J. Technol.* **23**(6), 223 (1985).
15B. B. R. Clayton and Y. S. M. Morsi, Determination of principal characteristics of turbulent swirling flow along annuli, part 2—measurement of turbulence components, *Int. J. Heat Fluid Flow* **6**(1), 31 (1985).
16B. M. C. M. Cornelissen and C. J. Hoogendoorn, Forced convection heat transfer to supercritical helium, *Appl. scient. Res.* **42**(2), 161 (1985).
17B. M. J. S. de Lemos and A. Sesonske, Turbulence modeling in combined convection in mercury pipe flow, *Int. J. Heat Mass Transfer* **28**(6), 1067 (1985).
18B. R. Doo, C. M. Rodkiewicz and R. N. Gupta, Development of transient temperatures in a thrust bearing, *J. Tribol. Technol.* **107**(2), 280 (1985).
19B. I. L. Dunin, V. V. Ivanov and V. V. Savenko, Radiative-convective cooling of fluids in pipes with allowance for axial heat flow, *Pwr Engng* (English translation of *Izv. Akad. Nauk SSR, Energetika i Transport*) **23**(1), 93 (1985).
20B. N. M. Galin, F. I. Mashlenko and V. V. Raz'nyak, Heat transfer in turbulent liquid flow in annular channels with a moving internal wall, *High Temp.* (English translation of *Teplofiz. Vysok. Temp.*) **23**(2), 297 (1985).
21B. R. G. Galiullin and G. G. Khalimov, Experimental study of heat transfer in a tube with large-amplitude resonance oscillations, *Sov. Aeronaut.* (English translation of *Izv. VUZ, Aviat. Tekh.*) **28**(2), 15 (1985).
22B. B. Gecim and W. O. Winer, Transient temperatures in the vicinity of an asperity contact (84-Trib-15), *J. Tribol. Technol.* **107**(3), 333 (1985).
23B. J. C. Gottifredi and A. F. Flores, Extended Leveque solution for heat transfer to non-Newtonian fluids in pipes and flat ducts, *Int. J. Heat Mass Transfer* **28**(5), 903 (1985).
24B. P. Gray and W. Kordylewski, Dynamic aspects of spontaneous ignition—thermal runaway induced by increasing ambient temperature, *Proc. R. Soc.* **A**(1811), 257 (1984).
25B. R. Gregorig, Above for the correction factor $k = (Pr_b/Pr_w)^p$ which considers influence of temperature dependent physical characteristics of fluids on convective heat transfer (in German), *Wärme- u. Stoffübertr.* **19**(3), 235 (1985).
26B. J. R. Greig, R. E. Pechacek and M. Raleigh, Channel cooling by turbulent convective mixing, *Phys. Fluids* **28**(8), 2357 (1985).
27B. E. M. Greitzer, R. W. Paterson and C. S. Tan, An approximate substitution principle for viscous heat conducting flows, *Proc. R. Soc.* **A**(1820), 163 (1985).
28B. B. Sturm, U. Grigull and H. Schmucker, Fluid flow and heat transfer of liquid mercury in wetted and nonwetted tubes (in German), *Wärme- u. Stoffübertr.* **19**(3), 217 (1985).
29B. A. M. Grishin and V. B. Nemirovskii, Nonsteady flow and heat transfer of polymerizing liquids in a long

tubular reactor, *J. appl. Mech. Tech. Phys.* **26**(1), 64 (1985).
30B. E. Harada, M. Toda, M. Kuriyama and H. Konno, Heat transfer between wall and solid–water suspension flow in horizontal pipes, *J. Chem. Engng—Japan* **18**(1), 33 (1985).
31B. J. P. Hartnett and M. Kostic, Heat transfer to a viscoelastic fluid in laminar flow through a rectangular channel, *Int. J. Heat Mass Transfer* **28**(6), 1147 (1985).
32B. H. Herwig, An asymptotic theory that accounts for the effects of variable properties in momentum and heat transfer problems, *Forsch. Ing.* **51**(6), 186 (1985).
33B. H. Herwig, The effect of variable properties on momentum and heat transfer in a tube with constant heat flux across the wall, *Int. J. Heat Mass Transfer* **28**(2), 423 (1985).
34B. G.-J. Hwang and M.-J. Lin, Natural convection effects on laminar heat transfer in the thermal entrance region of horizontal isothermal tubes, *Chung-kup King C'eng Hsueh K'an* (*J. Chin. Inst. Engrs*) **8**(4), 343 (1985).
35B. E. Ibe and S. Uchida, Water radiolysis model in a circulating flow system with a boiling region and its application to hydrogen alternate water chemistry of boiling water reactors, *Nucl. Sci. Engng* **90**(2), 140 (1985).
36B. K. P. Ivanov, A. A. Karpov, A. K. Orlov and V. Ya. Rivkind, Liquid flow in a slot, *Heat Transfer—Sov. Res.* **16**(3), 63 (1984).
37B. R. W. Johnson and B. E. Launder, Local Nusselt number and temperature field in turbulent flow through a heated, square-sectioned U-bend, *Int. J. Heat Fluid Flow* **6**(3), 171 (1985).
38B. E. K. Kalinin and G. A. Dreitser, Unsteady convective heat transfer for turbulent flows of gases and liquids in tubes, *Int. J. Heat Mass Transfer* **28**(2), 361 (1985).
39B. S. R. Kennon and G. S. Dulikravich, The inverse design of internally cooled turbine blades (84-GT-7), *J. Engng Gas Turbine Pwr* **107**(1), 123 (1985).
40B. Ye. M. Khabakhpasheva and G. I. Yefimenko, Structure of a turbulent flow in a plane diffuser, *Heat Transfer—Sov. Res.* **16**(2), 1 (1984).
41B. A. A. Khalatov and A. N. Borroto, Optimal geometries of screw-type swirl promoters with axial ducts, *Heat Transfer—Sov. Res.* **16**(5), 107 (1985).
42B. Y.-K. Kim, Heat transfer from the wall of a packed tube to an air–solid suspension flow and pressure drop, *Forsch. Ing.* **51**(4), 122 (1985).
43B. Y. Komiyama, F. Mikami, K. Okui and T. Hori, Laminar forced convection heat transfer in curved channels of rectangular cross section, *Heat Transfer—Japan. Res.* **13**(3), 68 (1984).
44B. M. Kumari and G. Nath, Unsteady compressible boundary layer swirling flow in a nozzle and a diffuser, *Int. J. Engng Sci.* **23**(7), 759 (1985).
45B. U. H. Kurzweg and L. Zhao, Experimental observations on enhanced heat transfer in fluids subjected to high frequency oscillations, *Ching Hua Ta Hsueh Hsueh Pao* (*J. Ching Hua Univ.*) **25**(1), 52 (1985).
46B. G. Kushida, H. Yamashita and R. Izumi, Study on three-dimensional flow and heat transfer in miter-bend (2nd report, analysis of heat transfer in laminar region), *Bull. J.S.M.E.* **28**(243), 1992 (1985).
47B. G. Kushida, H. Yamashita and R. Izumi, Study on three-dimensional flow and heat transfer in miter-bend (3rd report, effects of Reynolds number and aspect ratio), *Bull. J.S.M.E.* **28**(243), 2000 (1985).
48B. C. Laohakul, C. Y. Chan, K. Y. Look and C. W. Tan, On approximate solutions of the Graetz problem with axial conduction, *Int. J. Heat Mass Transfer* **28**(3), 541 (1985).
49B. A Lawal and A. S. Mujumdar, Laminar flow and heat transfer in power-law fluids flowing in arbitrary cross-sectional ducts, *Numer. Heat Transfer* **8**(2), 217 (1985).
50B. J.-B. Lee, H. A. Simon and J. C. F. Chow, Buoyancy in developed laminar curved tube flows, *Int. J. Heat Mass Transfer* **28**(3), 631 (1985).
51B. C. L. Merkle, A. Gulati and Y.-H. Choi, Effect of strong heat addition on the convergence of implicit schemes, *A.I.A.A. Jl* **23**(6), 847 (1985).
52B. E. Naito, Laminar heat transfer in the entrance region between parallel plates with uniform wall temperature, *Heat Transfer—Japan. Res.* **13**(3), 92 (1984).
53B. N. Pazooki and S. K. Loyalka, Heat transfer in a rarefied polyatomic gas—I. Plane parallel plates, *Int. J. Heat Mass Transfer* **28**(11), 2019 (1985).
54B. B. V. Perepelitsa, Properties of large-scale structures in the turbulent flow of water and weak polymer solution, *Heat Transfer—Sov. Res.* **16**(2), 27 (1984).
55B. V. N. Popov and N. E. Petrov, Calculation of heat transfer and flow resistance in the turbulent pipe flow of cooled carbon dioxide in the super critical region, *High Temp.* (English translation of *Teplofiz. Vysok. Temp.*) **23**(2), 255 (1985).
56B. C. Prakash and Y.-D. Liu, Analysis of laminar flow and heat transfer in the entrance region of an internally finned circular duct, *J. Heat Transfer* **107**(1), 84 (1985).
57B. C. Prakash and P. Renzoni, Effect of buoyancy on laminar fully developed flow in a vertical annular passage with radial internal fins, *Int. J. Heat Mass Transfer* **28**(5), 995 (1985).
58B. P. Ranganathan and R. Viskanta, Heat transfer through a rectangular solid with a gas-filled cylindrical hole, *Numer. Heat Transfer* **8**(4), 469 (1985).
59B. V. B. Repin, Heat transfer associated with viscous two-dimensional channel flow in a transverse acoustic field, *Fluid Dynam.* **20**(3), 369 (1985).
60B. W. Roetzel and J. Ahrendts, Derivation of the energy equation for single phase flowing fluids (in German), *Wärme- u. Stoffübertr.* **19**(3), 203 (1985).
61B. E. N. Saburov and Yu. L. Leukhin, Aerodynamics and heat exchange of a swirled stream in a cylindrical channel, *J. Engng Phys.* (English translation of *Inzh.-Fiz. Zh.*) **48**(3), 259 (1985).
62B. V. Scirocco, R. Devienne and M. Lebouche, Ecoulement laminaire et transfert de chaleur pour un fluide pseudo-plastique dans la zone d'entrée d'un tube, *Int. J. Heat Mass Transfer* **28**(1), 91 (1985).
63B. V. I. Shcherbinin and F. R. Shklyar, Radiative–convective heat transfer in turbulent flow of gases in a flat duct, *Heat Transfer—Sov. Res.* **16**(5), 113 (1985).
64B. Y. I. Shvets, I. E. Virozub, V. F. Vishnyak, N. M. Kondak, V. N. Panchenko and G. A. Frolov, Friction and heat transfer in the turbulent flow of a compressible gas in a plane channel, *J. Engng Phys.* (English translation of *Inzh.-Fiz. Zh.*) **48**(1), 12 (1985).
65B. I. B. Simanovskii, Steady-state and oscillatory convection motions in a side-heated two-layer system, *High Temp.* (English translation of *Teplofiz. Vysok. Temp.*) **23**(2), 251 (1985).
66B. V. M. Simonis, Ye. V. Uspuras and P. S. Poskas, Conversion of data and heat transfer and drag of annuli with rough inner tube for purposes of prediction of hydraulic and thermal behavior of completely rough annuli and tube bundles, *Heat Transfer—Sov. Res.* **16**(6), 60 (1984).
67B. M. M. Sorour, M. B. Madi and M. S. El-Beshbeeshy, Thermal equilibrium of two-phase gas–liquid bubbly flow in a vertical heated annulus, *Appl. scient. Res.* **42**(4), 319 (1985).
68B. E. M. Sparrow and D. R. Otis, Jr., Ductflow heat transfer at a smooth wall which faces a wall covered

by protuberances, *Int. J. Heat Mass Transfer* **28**(7), 1317 (1985).
69B. E. M. Sparrow, P. C. Stryker and C. A. C. Altemani, Heat transfer and pressure drop in flow passages that are open along their lateral edges, *Int. J. Heat Mass Transfer* **28**(4), 731 (1985).
70B. V. I. Subbotin, V. I. Deev, A. Pridantsev, V. K. Andreev, V. V. Arkhipov, V. N. Novikov, A. N. Savin and V. V. Solodovnikov, Heat transfer and hydrodynamics in cooling channels of super-conducting devices, *Cryogenics* **25**(5), 261 (1985).
71B. Y. Sudo, K. Miyata, H. Ikawa, M. Ohkawara and M. Kaminaga, Experimental study of differences in single-phase forced-convection heat transfer characteristics between upflow and downflow for narrow rectangular channel, *J. nucl. Sci. Technol.* **22**(3), 202 (1985).
72B. R. Taleyarkhan, M. Podowski and R. T. Lahey, Jr., An instability analysis of ventilated channels, *J. Heat Transfer* **107**(1), 175 (1985).
73B. S.-W. Tsai and H.-M. Yeh, Study of the separation efficiency in horizontal thermal diffusion columns with external refluxes, *Can. J. chem. Engng* **63**(3), 406 (1985).
74B. D. Valougeorgis and J. R. Thomas, Jr., $F//N$-method in kinetic theory: II. Heat transfer between parallel plates, *Transport Theory statist. Phys.* **14**(4), 497 (1985).
75B. J. V. Vilemas and V. M. Simonis, Heat transfer and friction of rough ducts carrying gas flow with variable physical properties, *Int. J. Heat Mass Transfer* **28**(1), 59 (1985).
76B. P.-L. Viollet, Experimental study and numerical modeling of density currents resulting from thermal transients in a non-rectilinear pipe flow, *Electricité de France, Bulletin de la Direction des Etudes et Recherches*, Ser. B: Reseaux Electriques, *Materials Electriques* **2**, 33 (1985).
77B. B. W. Webb and S. Ramadhyani, Conjugate heat transfer in a channel with staggered ribs, *Int. J. Heat Mass Transfer* **28**(9), 1679 (1985).
78B. V. A. Yefimov, Simulation of mass transfer between cells in rod bundles in the case of longitudinal flow through such bundles, *Heat Transfer—Sov. Res.* **16**(1), 75 (1984).
79B. K. Y. Zhou and H. H. Bau, On the stability and flow reversal of pressure-driven flow in an asymmetrically heated U-shaped tube, *J. Heat Transfer* **107**(1), 112 (1985).

## BOUNDARY-LAYER AND EXTERNAL FLOWS

1C. S. Aiba, Heat transfer around a circular cylinder near a plane surface, *J. Heat Transfer* **107**(4), 916 (1985).
2C. O. O. Ajayi and A. Falade, Time-dependent Stokes flow induced by instantaneous sources, *J. appl. Mech.* **52**(3), 718 (1985).
3C. C. E. Andraka and T. E. Diller, Heat-transfer distribution around a cylinder in pulsating crossflow, *J. Engng Gas Turbine Pwr* **107**(4), 976 (1985).
4C. A. Ansari and S. Morris, The effects of a strongly temperature-dependent viscosity on Stokes' drag law—experiments and theory, *J. Fluid Mech.* **159**, 459 (1985).
5C. F. Anselmet and R. A. Antonia, Joint statistics between temperature and its dissipation in a turbulent jet, *Phys. Fluids* **28**(4), 1048 (1985).
6C. K. A. Antonopoulos, Heat transfer in tube assemblies under conditions of laminar axial, transverse and inclined flow, *Int. J. Heat Fluid Flow* **6**(3), 193 (1985).
7C. D. A. Ashworth, J. E. LaGraff, D. L. Schultz and K. J. Grindrod, Unsteady aerodynamic and heat transfer processes in a transonic turbine stage (85-GT-128), *J. Engng Gas Turbine Pwr* **107**(4), 1022 (1985).
8C. W. Asrar and A. H. Nayfeh, Nonparallel stability of heated two-dimensional boundary layers, *Phys. Fluids* **28**(5), 1263 (1985).
9C. D. E. Avery, Experimental aerodynamic heating to simulated space shuttle tiles in laminar and turbulent boundary layers with variable flow angles at a nominal Mach number of 7, *NASA Tech. Paper* 2307, 48 (1985).
10C. D. E. Avery, P. A. Kerr and A. R. Wieting, Experimental aerodynamic heating to simulated shuttle tiles, *J. Spacecraft Rockets* **22**(4), 417 (1985).
11C. A. Balakrishnan, W. C. Davy and C. K. Lombard, Real-gas flowfields about three-dimensional configurations, *J. Spacecraft Rockets* **22**(1), 46 (1985).
12C. H. F. Bauer, Mass transport in a two-dimensional diffusor or confusor, *Wärme- u. Stoffübertr.* **19**(2), 167 (1985).
13C. B. J. Bayly, Heat transfer from a cylinder in a time-dependent cross flow at low Peclet number, *Phys. Fluids* **28**(12), 3451 (1985).
14C. P. G. Berardi and A. Pozzi, Unsteady momentum and energy boundary layers in laminar flat plate flow, *Int. J. Heat Mass Transfer* **28**(1), 101 (1985).
15C. R. Bhargava and M. Rani, Heat transfer in micropolar boundary layer flow near a stagnation point, *Int. J. Engng Sci.* **23**(12), 1331 (1985).
16C. S. P. Bhattacharyya and M. Abbas, On the stability of a hot rotating layer of micropolar fluid, *Int. J. Engng Sci.* **23**(3), 371 (1985).
17C. A. Binder, W. Foerster, H. Kruse and H. Rogge, Experimental investigation into the effect of wakes on the unsteady turbine rotor flow, *J. Engng Gas Turbine Pwr* **107**(2), 458 (1985).
18C. M. F. Blair, Heat transfer in the vicinity of a large-scale obstruction in a turbulent boundary layer, *J. Propul. Pwr* **1**(2), 158 (1985).
19C. V. V. Bogolepov and I. I. Lipatov, Locally three-dimensional laminar flows, *J. appl. Mech. Tech. Phys.* **26**(1), 24 (1985).
20C. A. J. Chambers, R. A. Antonia and L. Fulachier, Turbulent Prandtl number and spectral characteristics of a turbulent mixing layer, *Int. J. Heat Mass Transfer* **28**(8), 1461 (1985).
21C. Y.-M. Chen, Heat transfer of a laminar flow passing a wedge at small Prandtl number—a new approach, *Int. J. Heat Mass Transfer* **28**(8), 1517 (1985).
22C. R. K. Cheng and T. T. Ng, Conditional Reynolds stress in a strongly heated turbulent boundary layer with premixed combustion, *Phys. Fluids* **28**(2), 473 (1985).
23C. D. M. Cooper, R. L. Jaffe and J. O. Arnold, Computational chemistry and aeroassisted orbital transfer vehicles, *J. Spacecraft Rockets* **22**(1), 60 (1985).
24C. M. De Salve and B. Panella, Interaction between a liquid jet and a wall at high temperatures, *Termotecnica, Milan* **39**(2), 61 (1985).
25C. M. G. Dunn, Turbine heat flux measurements—influence of slot injection on vane trailing edge heat transfer and influence of rotor on vane heat transfer (84-GT-175), *J. Engng Gas Turbine Pwr* **107**(1), 76 (1985).
26C. D. E. Florence, Aerothermodynamic design feasibility of a Mars aerocapture vehicle, *J. Spacecraft Rockets* **22**(1), 74 (1985).
27C. R. L. Frederick, Heat transfer correlation for the laminar boundary layer with uniform wall heat flux, *Int. J. Mech. Engng Ed.* **13**(4), 289 (1985).
28C. K. Fukui and M. Nakajima, Unstable stratification effects on turbulent shear flow in the wall region, *Int. J. Heat Mass Transfer* **28**(12), 2343 (1985).
29C. R. Gaugler, Review and analysis of boundary layer transition data for turbine application, *NASA Tech. Memo* 86880 (1985).

30C. R. Germerdonk and N. N. Nguyen, Increase of the local heat transfer coefficient by 'convection vive' phenomenon, *German chem. Engng* **8**(2), 81 (1985).
31C. E. A. Gershbein and S. V. Peigin, Three-dimensional multicomponent boundary layer on a catalytic surface near the critical point, *High Temp.* **23**(3), 415 (1985).
32C. Yu. P. Golovachev and N. V. Leont'eva, Circulation flow at the front surface of a sphere in a supersonic wake, *Fluid Dynam.* **20**(3), 459 (1985).
33C. V. N. Golubkin, On the asymptotic theory of the three-dimensional flow of a hypersonic stream of radiating gas around a body, *J. appl. Math. Mech.* **47**(4), 493 (1983).
34C. L. J. Grubka and K. M. Bobba, Heat transfer characteristics of a continuous, stretching surface with variable temperature, *J. Heat Transfer* **107**(1), 248 (1985).
35C. K. Haga and Y. Kikuchi, Experimental investigation of coolability degradation by fission gas release into flowing sodium in a fuel pin bundle, *Nucl. Technol.* **70**(2), 220 (1985).
36C. J. C. Han, J. S. Park and C. K. Lei, Heat transfer enhancement in channels with turbulence promoters, *J. Engng Gas Turbine Pwr* **107**(3), 628 (1985).
37C. G. K. Hargrave, M. Fairweather and J. K. Kilham, Turbulence enhancement of stagnation point heat transfer on a body of revolution, *Int. J. Heat Fluid Flow* **6**(2), 91 (1985).
38C. H. P. Hodson, Boundary-layer transition and separation near the leading edge of a high-speed turbine blade (84-GT-179), *J. Engng Gas Turbine Pwr* **107**(1), 127 (1985).
39C. N. G. Hogg and H. M. Stommel, The heton, an elementary interaction between discrete baroclinic geostropic vortices, and its implications concerning eddy heat-flow, *Proc. R. Soc.* **A**(397), 1 (1985).
40C. J. T. Howe, Introductory aerothermodynamics of advanced space transportation systems, *J. Spacecraft Rockets* **22**(1), 19 (1985).
41C. P. Huerre and P. A. Monkewitz, Absolute and convective instabilities in free shear layers, *J. Fluid Mech.* **159**, 151 (1985).
42C. J. O. Ilegbusi and D. B. Spalding, An improved version of the $k$–$W$ model of turbulence, *J. Heat Transfer* **107**(1), 63 (1985).
43C. N. K. Jain, Variation of heat transfer coefficient by radiative fluid injection in brick-lined regenerators, *Reg. J. Energy Heat Mass Transfer* **7**(2), 111 (1985).
44C. Y. Kamotani, J. K. Lin and S. Ostrach, Effect of destabilizing heating on Goertler vortices, *J. Heat Transfer* **107**(4), 877 (1985).
45C. K. Kataoka, Optimal nozzle-to-plate spacing for convective heat transfer in nonisothermal, variable-density impinging jets, *Drying Technol.* **3**(2), 235 (1985).
46C. Y. Kawaguchi, K. Suzuki and T. Sato, Heat transfer promotion with a cylinder array located near the wall, *Int. J. Heat Fluid Flow* **6**(4), 249 (1985).
47C. A. V. Kazakov, M. N. Kogan and V. A. Kuparev, Stability of the subsonic boundary layer during heating of the surface of a flat plate near the leading edge, *Fluid Dynam.* **20**(3), 394 (1985).
48C. M. D. Kim and C. H. Lewis, Three-dimensional nonequilibrium viscous flow over the shuttle orbiter with catalytic surface effects, *J. Spacecraft Rockets* **22**(2), 97 (1985).
49C. M. N. Kiselev, V. P. Motulevich and E. D. Sergievskii, Effect of the directed blowing and suction on characteristics of the laminar boundary layers, taking account of the negative pressure gradient, *Tekhnicheskikh Nauk* **4**, 94 (1985).
50C. S. A. Korpela, On the viscous dissipation in the boundary layer of a high Prandtl number fluid in laminar flow over a flat plate, *Z. angew. Math. Phys.* **36**(4) 624 (1985).
51C. A. M. Lapin and O. Yu. Tsvelodub, Mass transfer in the flow of a thin wavy film of liquid, *J. appl. Mech. Tech. Phys.* **26**(2), 230 (1985).
52C. A. M. Lindemann, Turbulent Reynolds analogy factors for nonplanar surface microgeometries, *J. Spacecraft Rockets* **22**(5), 581 (1985).
53C. K. F. Loughlin, M. A. Abul-Hamayel and L. C. Thomas, The surface rejuvenation theory of wall turbulence for momentum, heat and mass transfer–application to moderate and high Schmidt (Prandtl) fluids, *A.I.Ch.E. Jl* **31**(10), 1614 (1985).
54C. V. I. Maron and V. N. Nikolaevskii, Dissipative heating in shear flow of the asthenosphere, *Fluid Dynam.* (English translation of *Izv. Akad. Nauk SSR, Mekh. Zhidkosti Gaza*) **20**(2), 212 (1985).
55C. E. Marumo, K. Suzuki and T. Sato, Turbulent heat transfer in a flat plate boundary layer distributed by a cylinder, *Int. J. Heat Fluid Flow* **6**(4), 241 (1985).
56C. S. McAlees, Jr. and R. C. Maydew, Aerothermodynamic design of high speed rockets, *J. Spacecraft Rockets* **22**(3), 309 (1985).
57C. S. McHale and J. F. Richardson, Heat transfer from immersed surfaces to aqueous liquids, *Chem. Engng Sci.* **40**(11), 2154 (1985).
58C. C. G. Miller III, J. R. Micol and P. A. Gnoffo, Laminar heat-transfer distributions on biconics at incidence in hypersonic-hypervelocity flows, *NASA Tech. Paper* 2213, 144 (1985).
59C. V. P. Motulevich, E. D. Sergiyevskiy, S. V. Zhubrin and L. K.-J. Lukosiavicius, Analysis of skin friction and heat transfer in the boundary layer of a turbulent flow, *Heat Transfer—Sov. Res.* **16**(4), 99 (1985).
60C. D. G. Motwani, U. N. Baitonde and S. P. Sukhatme, Heat transfer from rectangular plates inclined at different angles of attack and yaw to an air stream, *J. Heat Transfer* **107**(2), 307 (1985).
61C. A. Narumi, S. Kato, K. Terada and R. Izumi, Forced heat convection in turbulent flow over a flat plate of a finite width, *Heat Transfer—Japan. Res.* **13**(3), 17 (1984).
62C. R. J. Nowak, C. W. Albertson and L. R. Hunt, Aerothermal tests of 12.5 degree cone at Mach 6.7 for various Reynolds numbers, angles of attack, and nose shapes, *NASA Tech. Paper* 2345, 88 (1985).
63C. I. Owen and D. J. Ryley, Flow of thin liquid films around corners, *Int. J. Multiphase Flow* **11**(1), 51 (1985).
64C. S. Paolucci, Heat transfer during the early expansion of gas in pressurized vessels, *Int. J. Heat Mass Transfer* **28**(8), 1525 (1985).
65C. B. Pathangey and S. Kovenklioglu, Effect of chemical reaction on particle to gas heat transfer, *Chem. Engng Sci.* **40**(7), 1205 (1985).
66C. W. R. C. Phillips, On vortex boundary layers, *Proc. R. Soc.* **A**(1819), 253 (1985).
67C. S. Polat, A. S. Mujumdar and W. J. M. Douglas, Heat transfer distribution under a turbulent impinging jet—a numerical study, *Drying Technol.* **3**(1), 15 (1985).
68C. W. J. Priddy and F. J. Bayley, Effects of free stream turbulence on the distribution of heat transfer around turbine blade sections, *Int. J. Heat Fluid Flow* **6**(3), 181 (1985).
69C. R. Rajasekaran and M. G. Palekar, Viscous dissipation effects of mixed convection about a rotating sphere, *Int. J. Engng Sci.* **23**(8), 789 (1985).
70C. S. T. Revankar and P. C. Chakravarti, Effects of transpiration on flow past impulsively started plate, *A.I.Ch.E. Jl* **31**(11), 1923 (1985).
71C. W. Rodi and G. Scheuerer, Calculation of heat transfer to convection-cooled gas turbine blades, *J. Engng Gas Turbine Pwr* **107**(3), 620 (1985).

72C. N. A. Rubtsov and N. N. Ponomarev, Heat transfer in a laminar boundary layer of an absorbing emitting and scattering gas on a permeable plate, *Heat Transfer—Sov. Res.* **16**(3), 104 (1984).

73C. E. Ruckenstein and A. Ramagopal, Anomalous heat transfer and drag in laminar flow of viscoelastic fluids, *J. Non-Newtonian Fluid Mech.* **17**(2), 145 (1985).

74C. K. Rued and S. Wittig, Free-stream turbulence and pressure gradient effects on heat transfer and boundary layer development on highly cooled surfaces, *J. Engng Gas Turbine Pwr* **107**(1), 54 (1985).

75C. R. San Jose, J. L. Casanova, R. E. Viloria and J. Casanova, Evaluation of the turbulent parameters of the unstable surface boundary layer outside Businger's range, *Atmos. Envir.* **19**(10), 1555 (1985).

76C. C. D. Scott, Effects of nonequilibrium and wall catalysis on shuttle heat transfer, *J. Spacecraft Rockets* **22**(5), 489 (1985).

77C. J. L. Shideler, G. L. Webb and C. M. Pittman, Verification tests of durable thermal protection system concepts, *J. Spacecraft Rockets* **22**(6), 598 (1985).

78C. J. L. Shinn and J. J. Jones, Chemical nonequilibrium effects on flowfields for aeroassisted orbital transfer vehicles, *J. Spacecraft Rockets* **22**(1), 54 (1985).

79C. P. Singh and S. A. Raj, Analytical study of laminar boundary layers with non-uniform main stream velocity and wall temperature, *J. Non-Equilibrium Thermodynam.* **10**(4), 287 (1985).

80C. B. M. Smolsky, L. A. Sergeyeva and V. L. Sergeyev, Investigation of the unsteady-state heat transfer in the region of a stagnation point in plane and axisymmetric flows, *Int. J. Heat Mass Transfer* **28**(1), 7 (1985).

81C. D. J. Song, S. Swaminathan and C. H. Lewis, High-altitude effects on three-dimensional nonequilibrium viscous shock-layer flows, *J. Spacecraft Rockets* **22**(6), 614 (1985).

82C. E. M. Sparrow and G. T. Geiger, Local and average heat transfer characteristics for a disk situated perpendicular to a uniform flow, *J. Heat Transfer* **107**(2), 321 (1985).

83C. H. S. Takhar and V. M. Soundalgekar, Flow and heat transfer of a micropolar fluid past a continuously moving plate, *Int. J. Engng Sci.* **23**(2), 201 (1985).

84C. D. A. Throckmorton and L. C. Hartung, Shock-interaction-induced heat transfer to the orbiter wing lower surface, *J. Spacecraft Rockets* **22**(5), 516 (1985).

85C. N. Tokuda, A convection Stefan problem by Lagrange–Burmann expansions (I) small time solution, *J. Phys. Soc. Japan* **54**(12), 4513 (1985).

86C. G. J. VanFossen, Jr. and R. J. Simoneau, Preliminary results of a study of the relationship between free stream turbulence and stagnation region heat transfer, *NASA Tech. Memo* 86884, 15 (1985).

87C. E. P. Volchkov, S. V. Semyonov and V. I. Terekhov, The end wall boundary layer in a vortex chamber, *Heat Transfer—Sov. Res.* **16**(5), 1 (1985).

88C. G. D. Walberg, A survey on aeroassisted orbit transfer, *J. Spacecraft Rockets* **22**(1), 3 (1985).

89C. C. Y. Wang, Stagnation flow on the surface of a quiescent fluid—an exact solution of the Navier–Stokes equations, *Q. appl. Math.* **43**(2), 215 (1985).

90C. J. H. Wang, H. F. Jen and E. O. Hartel, Airfoil heat transfer calculation using a low Reynolds number version of a two-equation turbulence model (84-GT-261), *J. Engng Gas Turbine Pwr* **107**(1), 60 (1985).

91C. T. Wang, T. W. Simon and J. Buddhavarapu, Heat transfer and fluid mechanics measurements in transitional boundary layer flows, *J. Engng Gas Turbine Pwr* **107**(4), 1007 (1985).

92C. W. L. Wells, Heating measurements on space shuttle orbiter models with differentially deflected elevons, *J. Spacecraft Rockets* **22**(2), 126 (1985).

93C. S. L. Yelistratov, Experimental investigation of forced-convection heat transfer to a sphere at low Reynolds numbers, *Heat Transfer—Sov. Res.* **16**(6), 71 (1984).

94C. V. P. Zabolotskii, P. S. Roganov and E. V. Shishov, Influence of outer flow turbulence level on heat transfer and friction in the turbulent boundary layer, *Sov. Aeronaut.* (English translation of *Izv. VUZ, Aviat. Tekh.*) **28**(1), 23 (1985).

95C. G. P. Zigmantas, Transfer of heat from a plate to a flow exhibiting perturbations, *Heat Transfer—Sov. Res.* **16**(3), 25 (1984).

96C. E. V. Zoby and A. L. Simmonds, Engineering flowfield method with angle-of-attack applications, *J. Spacecraft Rockets* **22**(4), 398 (1985).

97C. A. Zukauskas, R. Ulinskas and P. Daunoras, Influence of surface roughness on the heat transfer and drag of tube banks in crossflow, *Heat Technol.* **3**(2), 1 (1985).


## FLOW WITH SEPARATED REGIONS


1D. S. Aiba, Heat transfer around a circular cylinder near a plane surface, *J. Heat Transfer* **107**(4), 916 (1985).

2D. C. E. Andraka and T. E. Diller, Heat transfer distribution around a cylinder in pulsating crossflow (85-GT-67), *J. Engng Gas Turbine Pwr* **107**(4), 976 (1985).

3D. R. A. Antonia, On a heat transport mode for a turbulent plane jet, *Int. J. Heat Mass Transfer* **28**(10), 1805 (1985).

4D. W. Aung, A. Baron and F.-K. Tsou, Wall independency and effect of initial shear-layer thickness in separated flow and heat transfer, *Int. J. Heat Mass Transfer* **28**(9), 1757 (1985).

5D. V. R. Borovskiy, L. M. Mishnayevskiy and V. A. Shelimanov, Heat transfer to and from slender moving cylinders, *Heat Transfer—Sov. Res.* **16**(6), 121 (1984).

6D. R. J. Goldstein, M. K. Chyu and R. C. Hain, Measurement of local mass transfer on a surface in the region of the base of a protruding cylinder with a computer-controlled data acquisition system, *Int. J. Heat Mass Transfer* **28**(5), 977 (1985).

7D. A. M. Gorray, C. B. Watkins and S. Aung, Turbulent heat transfer computations for rearward-facing steps and sudden pipe expansions, *J. Heat Transfer* **107**(1), 70–76 (1985).

8D. E. J. Hall and R. H. Pletcher, Application of a viscous–inviscid interaction procedure to predict separated flows with heat transfer, *J. Heat Transfer* **107**(3), 557 (1985).

9D. T. Igarashi, Heat transfer from a square prism to an air stream, *Int. J. Heat Mass Transfer* **28**(1), 175 (1985).

10D. Yu. N. Kuznetsov and V. E. Lipatov, A study of high-performance convective surfaces for viscous fluids, *High Temp.* **6**(1), 31 (1985).

11D. L. Makkonen, Heat transfer and icing of a rough cylinder, *Cold Reg. Sci. Technol.* **10**(2), 105-116 (1985).

12D. D. L. R. Oliver, T. E. Carleson and J. N. Chung, Transient heat transfer to a fluid sphere suspended in an electric field, *Int. J. Heat Mass Transfer* **28**(5), 1005 (1985).

13D. V. V. Orlov, V. V. Ovchinnikov, N. N. Mukhina and V. M. Karsten, Investigation of turbulence and heat transfer in a separating flow behind a step, *Heat Transfer—Sov. Res.* **16**(2), 58 (1984).

14D. T. Ota and H. Nishiyama, Fouling effects of geothermal water scale upon heat transfer around an elliptic cylinder, *Wärme- u. Stoffübertr.* **19**(1), 93 (1985).

15D. A. M. Pavlyuchenko, Heat transfer on axisymmetric rocket nose cones with separationless and separated flows, *Heat Transfer—Sov. Res.* **16**(4), 115 (1985).

16D. T. M. Shih and A. L. Ren, Combined convection and radiative recirculating flows in enclosures, *Numer. Heat Transfer* **8**(2), 149 (1985).

17D. F. T. Smith, F. R. S. and J. W. Elliott, On the abrupt turbulent reattachment downstream of leading-edge laminar separation, *Proc. R. Soc.* **A**(1820), 1 (1985).

18D. E. M. Sparrow and G. T. Geiger, Heat transfer at the base of a cylindrical cavity oriented perpendicular to a freestream flow, *Int. J. Heat Mass Transfer* **28**(12), 2353 (1985).

19D. E. M. Sparrow and F. Samie, Heat transfer and pressure drop results for one- and two-row arrays of finned tubes, *Int. J. Heat Mass Transfer* **28**(12), 2247 (1985).

20D. J. C. Vogel and J. K. Eaton, Combined heat transfer and fluid dynamic measurements downstream of a backward-facing step, *J. Heat Transfer* **107**(4), 922 (1985).

21D. A. Zukauskas and R. Ulinskas, The efficiency parameters for heat transfer in tube banks, *High Temp.* **(6)**1, 19 (1985).


## HEAT TRANSFER IN POROUS MEDIA


1DP. N. Afzal, Two-dimensional buoyant plume in porous media: higher-order effects, *Int. J. Heat Mass Transfer* **28**, 2029 (1985).

2DP. G. F. Barreto, G. Donsi, A. Lancia and G. Volpicelli, Modelling of heat transfer between a slugging fluidized bed and immersed vertical probes, *Powder Technol.* **41**, 41 (1985).

3DP. A. Bejan and K. R. Khair, Heat and mass transfer by natural convection in a porous medium, *Int. J. Heat Mass Transfer* **28**, 909 (1985).

4DP. H.-J. Bock and J. Schweinzer, Heat transfer on horizontal internals in gas/solid pressure fluidized beds, *Chem.-Ing.-Tech.* **57**, 486 (1985).

5DP. P. Bondi, Thermo-hygrometric transients in heat transfer measurements with a hot-box apparatus, *Termotecnica* **39**(2), 57 (1985).

6DP. Yu. A. Buevich and E. B. Perminov, Stationary exchange between an infiltrated granular bed and a body immersed in it, *J. Engng Phys.* **48**, 26 (1985).

7DP. R. Chandran and J. C. Chen, A heat transfer model for tubes immersed in gas fluidized beds, *A.I.Ch.E. Jl* **31**, 244 (1985).

8DP. B. C. Chandrasekhara, Mixed convection in the presence of horizontal impermeable surfaces in saturated porous media with variable permeability, *Wärme- u. Stoffübertr.* **19**, 195 (1985).

9DP. B. C. Chandrasekhara and P. M. S. Namboodiri, Influence of variable permeability in combined free and forced convection about inclined surfaces in porous media, *Int. J. Heat Mass Transfer* **28**, 199 (1985).

10DP. S. H. Chang and S. H. Kim, Derivation of a dryout model in a particle debris bed with the drift-flux approach, *Nucl. Sci. Engng* **91**, 404 (1985).

11DP. T. C. Chawla, D. R. Pedersen and W. J. Minkowycz, Governing equations for heat and mass transfer in heat-generating porous beds—I. Coolant boiling and transient void propagation, *Int. J. Heat Mass Transfer* **28**, 2129 (1985).

12DP. T. C. Chawla, D. R. Pedersen and W. J. Minkowycz, Governing equations for heat and mass transfer in heat-generating porous beds—II. Particulate melting and substrate penetration by dissolution, *Int. J. Heat Mass Transfer* **28**, 2137 (1985).

13DP. P. Chen and D. C. T. Pei, A model of heat transfer between fluidized beds, and immersed surfaces, *Int. J. Heat Mass Transfer* **28**, 675 (1985).

14DP. T.-M. Chiu and E. N. Ziegler, Liquid holdup and heat transfer coefficient in liquid-solid and three-phase fluidized beds, *A.I.Ch.E. Jl* **31**, 1504 (1985).

15DP. Y. K. Chuah and V. P. Carey, Analysis of boiling heat transfer and two-phase flow in porous media with non-uniform porosity, *Int. J. Heat Mass Transfer* **28**, 147 (1985).

16DP. J. Ciborowski and J. Kopec, Mechanism of mass transfer from an immersed surface to a high mass capacity fluidized bed, *Chem. Engng J.* **31**(2), 63 (1985).

17DP. D. J. Close, J. G. Symons and R. F. White, Convective heat transfer in shallow, gas-filled porous media: experimental investigation, *Int. J. Heat Mass Transfer* **28**, 2371 (1985).

18DP. P. Crausse, G. Bacon and C. Langlais, Experimental and theoretical study of simultaneous heat and moisture transfer in a fibrous insulant, *J. Therm. Insul.* **9**, 46 (1985).

19DP. P. R. Dawson and D. F. McTigue, A numerical model for natural convection in fluid-saturated creeping porous media, *Numer. Heat Transfer* **8**, 45 (1985).

20DP. C. Delvosalle and J. Vanderschuren, Gas-to-particle and particle-to-particle heat transfer in fluidized beds of large particles, *Chem. Engng Sci.* **40**, 769 (1985).

21DP. A. G. Dixon, Thermal resistance models of packed-bed effective heat transfer parameters, *A.I.Ch.E. Jl* **31**, 826 (1985).

22DP. V. I. Drobyshevich and V. A. Kirillov, Mathematical model for the description of heat and mass transfer inside a porous granule in the presence of phase transitions, *J. appl. Mech. Tech. Phys.* **26**, 58 (1985).

23DP. S. I. Pereira Duarte, O. M. Martinez, O. A. Ferretti and N. O. Lemcoff, Theoretical prediction of heterogeneous one-dimensional heat transfer coefficients for fixed-bed reactors, *A.I.Ch.E. Jl* **31**, 868 (1985).

24DP. E. R. G. Eckert, R. J. Goldstein, A. I. Behbahani and R. Hain, Boiling in an unconstricted granular medium, *Int. J. Heat Mass Transfer* **28**, 1187 (1985).

25DP. J. Escott, Design considerations for fluid-bed dryers, *Proc. Engng London* **66**(10), 77 (1985).

26DP. D. K. Gartling and C. E. Hickox, Numerical study of the applicability of the Boussinesq approximation for a fluid-saturated porous medium, *Int. J. Numer. Meth. Fluids* **5**, 995 (1985).

27DP. H. Glaser and Y.-K. Kim, Heat transfer from the wall of a tube packed with spheres to a stream of air containing particulate matter and the associated pressure drop, *Chem.-Ing.-Tech.* **57**, 524 (1985).

28DP. N. S. Grewal, T. K. Cheung and S. C. Saxena, Heat transfer between horizontal finned tubes and a gas-solid fluidized bed, *Ind. Engng Chem. Proc. Des. Dev.* **24**, 458 (1985).

29DP. M. Hasan and A. S. Mujumdar, Transpiration-induced buoyancy effect around a horizontal cylinder embedded in a porous medium, *Int. J. Energy Res.* **9**(2), 151 (1985).

30DP. M. Hasatani, N. Arai and K. Hori, Drying of granular particles in a multistage inclined fluidized bed with mechanical vibration, *Drying Technol.* **3**, 39 (1985).

31DP. H. Hattori and J. R. Howard, Gas-to-gas heat recovery using fluidized bed technology, *J. Heat Recovery Syst.* **5**, 535 (1985).

32DP. C. R. B. Hoerger and W. F. Phillips, Limitations of the single-phase model for solid–gas heat transfer in packed beds, *J. Heat Transfer* **107**, 260 (1985).

33DP. J. T. Hong, C. L. Tien and M. Kaviany, Non-Darcian effects on vertical-plate natural convection in porous media with high porosities, *Int. J. Heat Mass Transfer* **28**, 2149 (1985).

34DP. C. T. Hsu and P. Cheng, The Brinkman model for natural convection about a semi-infinite vertical plate in a porous medium, *Int. J. Heat Mass Transfer* **28**, 683 (1985).

35DP. A. K. A. Juma and J. F. Richardson, Heat transfer to cylinders from segregating liquid–solid fluidised beds, *Chem. Engng Sci.* **40**, 687 (1985).

36DP. F. A. Kamke and J. B. Wilson, Analysis of a rotary dryer: drying of wood particles, *For. Prod. J.* **35**(9), 32 (1985).

37DP. R. S. Kane and R. Pfeffer, Heat transfer in gas–solids drag-reducing flow, *J. Heat Transfer* **107**, 570 (1985).

38DP. M. Kaviany, Laminar flow through a porous channel bounded by isothermal parallel plates, *Int. J. Heat Mass Transfer* **28**, 851 (1985).

39DP. Y. Kawase and J. J. Ulbrecht, New approach for heat and mass transfer in granular beds based on the capillary model, *Ind. Engng Chem. Fund.* **24**, 115 (1985).

40DP. V. L. Khitrik, Distribution of mean temperatures of a porous material and coolant in a channel with a porous insert, *J. Engng Phys.* **48**, 301 (1985).

41DP. H. S. Kim and S. I. Abdel-Khalik, Convective cooling of simulated core debris beds, *Nucl. Technol.* **69**, 268 (1985).

42DP. S. Kimura and A. Bejan, Natural convection in a stably heated corner filled with porous medium, *J. Heat Transfer* **107**, 293 (1985).

43DP. J. Kubie, Heat transfer between gas fluidized beds and immersed surfaces, *Int. J. Heat Mass Transfer* **28**, 1345 (1985).

44DP. P. S. Kuts and N. N. Grinchik, Phenomenological approach to the problems on non-isothermal drying, sorption and filtration under incomplete saturation conditions, *Heat Technol.* **3**(2), 102 (1985).

45DP. J. Levec and R. G. Carbonell, Longitudinal and lateral dispersion in packed beds, part I: Theory, *A.I.Ch.E. Jl* **31**, 581 (1985).

46DP. J. Levec and R. G. Carbonell, Longitudinal and lateral thermal dispersion in packed beds, part II: Comparison between theory and experiment, *A.I.Ch.E. Jl* **31**, 591 (1985).

47DP. J. S. Marshall and V. K. Dhir, Effect of overlying liquid layer on dryout heat flux measurements, *Nucl. Sci. Engng.* **91**, 109 (1985).

48DP. O. G. Martynenko, V. G. Leitsina, V. V. Levdansky and N. V. Pavlyukevich, The kinetic model of one-component gas flow during evaporation in a porous layer, *Drying Technol.* **3**, 483 (1985).

49DP. E. I. Mezlyakov and P. G. Kuntsevskiy, Transient filtration and heat transfer in a geothermal rock fracture produced by hydraulic fracturing, *Heat Transfer—Sov. Res.* **16**(3), 138 (1984).

50DP. M. A. Minkin and S. P. Dmitrieva, Computer-aided mathematical modeling of the steam-thaw process of permafrost, *Soil Mech. Foundation Engng* **22**(2), 73 (1985).

51DP. W. J. Minkowycz, P. Cheng and C. H. Chang, Mixed convection about a nonisothermal cylinder and sphere in a porous medium, *Numer. Heat Transfer* **8**, 349 (1985).

52DP. T. F. Morse, C. Y. Wang and J. W. Cipolla, Jr., Laser-induced thermophoresis and particulate deposition efficiency, *J. Heat Transfer* **107**, 155 (1985).

53DP. S. Motakef and M. A. El-Masri, Liquid diffusion in fibrous insulation, *J. Heat Transfer* **107**, 299 (1985).

54DP. K. Muroyama and L.-S. Fan, Fundamentals of gas–liquid–solid fluidization, *A.I.Ch.E. Jl* **31**, 1 (1985).

55DP. D. A. Nield and D. D. Joseph, Effects of quadratic drag on convection in a saturated porous medium, *Phys. Fluids* **28**, 995 (1985).

56DP. V. N. Novakovskii, Analytical method for calculating nonstationary heat exchange in soil with a pipeline, *Pwr Engng* **23**(1), 139 (1985).

57DP. A. Ohhashi, K. Momonoi and H. Harada, Characteristics of longitudinal dispersion of liquid in fluidized bed biofilm reactor, *Doboku Gakkai Rombun Hokokushu* **357**(II-3), 247 (1985).

58DP. B. Palancz, Modeling and simulation of heat and mass transfer in a packed bed of solid particles having high diffusion resistance, *Comput. chem. Engng* **9**, 567 (1985).

59DP. B. Palancz, Simulation of heat and mass transfer in a finite porous medium using orthogonal collocation method, *Wärme- u. Stoffübertr.* **19**, 229 (1985).

60DP. D. Polisevski, Steady convection in porous media—I. The solutions and their regularity, *Int. J. Engng Sci.* **23**, 733 (1985).

61DP. D. Polisevski, Steady convection in porous media—II. The case of low Rayleigh numbers and asymptotic expansions, *Int. J. Engng Sci.* **23**, 741 (1985).

62DP. D. Polisevski, Steady convection in porous media—III. The structure of the solutions, *Int. J. Engng Sci.* **23**, 751 (1985).

63DP. I. Pop, J. K. Sunada, P. Cheng and W. J. Minkowycz, Conjugate free convection from long vertical plate fins embedded in a porous medium at high Rayleigh numbers, *Int. J. Heat Mass Transfer* **28**, 1629 (1985).

64DP. D. Poulikakos, Departure from the Darcy model in boundary layer natural convection in a vertical porous layer with uniform heat flux from the side, *J. Heat Transfer* **107**, 716 (1985).

65DP. D. Poulikakos, On buoyancy induced heat and mass transfer from a concentrated source in an infinite porous medium, *Int. J. Heat Mass Transfer* **28**, 621 (1985).

66DP. D. Poulikakos, Onset of convection in a horizontal porous layer saturated with cold water, *Int. J. Heat Mass Transfer* **28**, 1899 (1985).

67DP. D. Poulikakos, The effect of a third diffusing component on the onset of convection in a horizontal porous layer, *Phys. Fluids* **28**, 3172 (1985).

68DP. D. Poulikakos and A. Bejan, The departure from Darcy flow in natural convection in a vertical porous layer, *Phys. Fluids* **28**, 3477 (1985).

69DP. V. Prasad and F. A. Kulacki, Natural convection in porous media bounded by short concentric vertical cylinders, *J. Heat Transfer* **107**, 147 (1985).

70DP. W. Prins, T. P. Casteleijn, W. Draijer and W. P. M. van Swaaij, Mass transfer from a freely moving single sphere to the dense phase of a gas fluidized bed of inert particles, *Chem. Engng Sci.* **40**, 481 (1985).

71DP. V. D. Rao, P. K. Sarma and G. J. V. J. Ragu, Biot's variational method to fluidized-bed coating on thin plates, *J. Heat Transfer* **107**, 258 (1985).

72DP. A. A. Raptis and C. P. Perdikis, Oscillatory flow through a porous medium by the presence of free convective flow, *Int. J. Engng Sci.* **23**, 51 (1985).

73DP. D. A. S. Rees and D. S. Riley, Free convection above a near horizontal semi-infinite heated surface embedded in a saturated porous medium, *Int. J. Heat Mass Transfer* **28**, 183 (1985).

74DP. D. S. Riley and D. A. S. Rees, Non-Darcy convection from arbitrarily inclined heated surfaces in saturated porous media, *Q. Jl Mech. appl. Math.* **38**, 277 (1985).

75DP. D. U. Ringer and A. S. Mujumdar, Analysis of aerodynamics and heat transfer in vibro-fluidized beds, *Drying Technol.* **2**, 449 (1983–84).

76DP. E. Saatdjian and J. F. Large, Heat transfer simulation in a raining packed bed exchanger, *Chem. Engng Sci.* **40**, 693 (1985).

77DP. M. Saberian-Broudjenni, G. Wild, N. Midoux and J. C. Charpentier, Contribution à l'étude du transfert de chaleur à la paroi dans les réacteurs à lit fluidisé gaz–solide à faible vitesse de liquide, *Can. J. chem. Engng* **63**, 553 (1985).

78DP. S. C. Saxena and V. L. Ganzha, Dependence of heat transfer coefficient for immersed surfaces in a gas fluidized bed on pressure, *Powder Technol.* **44**, 115 (1985).

79DP. S. C. Saxena and A. Mathur, Hydrodynamic and heat-transfer studies in fine particle gas-fluidized beds, *Energy* **10**, 57 (1985).

80DP. D. C. Shaw and R. A. Dawe, Effects of a vertical discontinuity in a porous medium on a plane convection plume at high Rayleigh numbers, *Int. J. Heat Mass Transfer* **28**, 789 (1985).

81DP. V. A. Shul'chishin, N. B. Rashkovskaya and L. G. Domracheva, Calculating circulation and heat-transfer rates for a drying apparatus containing a fluidized bed of inert material, *J. appl. Chem. U.S.S.R.* **58**(3), 505 (1985).

82DP. W. T. Simpson, Drying wood: a review. I, *Drying Technol.* **2**, 235 (1983–84).

83DP. I. S. Suh, G. T. Jin and S. D. Kim, Heat transfer coefficients in three phase fluidized beds, *Int. J. Multiphase Flow* **11**, 255 (1985).

84DP. M. Syamlal and D. Gidaspow, Hydrodynamics of fluidization: prediction of wall to bed heat transfer coefficients, *A.I.Ch.E. Jl* **31**, 127 (1985).

85DP. H. R. Thomas, Modeling two-dimensional heat and moisture transfer in unsaturated soils, including gravity effects, *Int. J. numer. analyt. Meth. Geomech.* **9**, 573 (1985).

86DP. T. W. Tong, D. L. McElroy and D. W. Yarbrough, Transient conduction and radiation heat transfer in porous thermal insulations, *J. therm. Insul.* **9**, 13 (1985).

87DP. T. W. Tong and E. Subramanian, A boundary-layer analysis for natural convection in vertical porous enclosures—use of the Brinkman-extended Darcy model, *Int. J. Heat Mass Transfer* **28**, 563 (1985).

88DP. I. Toovey and J. Dayan, Analytical solution for the heat transfer problem of fluid flowing through a packed bed of porous solids, *J. Heat Transfer* **107**, 713 (1985).

89DP. O. V. Trevisan and A. Bejan, Natural convection with combined heat and mass transfer buoyancy effects in a porous medium, *Int. J. Heat Mass Transfer* **28**, 1597 (1985).

90DP. K. S. Udell, Heat transfer in porous media considering phase change and capillarity—the heat pipe effect, *Int. J. Heat Mass Transfer* **28**, 485 (1985).

91DP. K. Vafai, R. L. Alkire and C. L. Tien, Experimental investigation of heat transfer in variable porosity media, *J. Heat Transfer* **107**, 642 (1985).

92DP. V. Vesely, M. Soldat, J. Cermak, A. Mrnkova and M. Kralova, Measurement of heat transfer coefficients in a fluidized bed furnace operating under steady-state conditions, *Chemicky Prum.* **35(60)**(8), 399 (1985).

93DP. C. K. Wei, H. T. Davis, E. A. Davis and J. Gordon, Heat and mass transfer in water-laden sandstone: convective heating, *A.I.Ch.E. Jl* **31**, 1338 (1985).

94DP. K. Yoshikawa, H. Kajiyama, T. Okamura, S. Kabashima, H. Yamasaki, S. Shioda, M. Yamada, T. Yokota, M. Ishimura, K. Nakayama, K. Nakamoto and T. Sasaki, Experimental studies on thermal performance of a pebble bed high-temperature heat exchanger, *J. Heat Transfer* **107**, 722 (1985).

95DP. G.-T. Zhang and F. Ouyang, Heat transfer between the fluidized bed and the distributor plate, *Ind. Engng Chem. Proc. Des. Dev.* **24**, 430 (1985).

## EXPERIMENTAL TECHNIQUES AND INSTRUMENTATION

1E. T. Baba, A. Ono and S. Hattori, Analysis of the operational error of heat flux transducers placed on wall surfaces, *Rev. scient. Instrum.* **56**, 1399 (1985).

2E. V. S. Batalov, Utilization of the thermal strain of solids for determining the constants of internal heat transfer of solid-phase polymers, *J. Engng Phys.* **48**, 64 (1985).

3E. J. W. Baughn, R. K. Takahashi, M. A. Hoffman and A. A. McKillop, Local heat transfer measurements using an electrically heated thin gold-coated plastic sheet, *J. Heat Transfer* **107**, 953 (1985).

4E. G. E. Bodeep, Temperature measurement systems for optical-fiber preform fabrication, *Rev. scient. Instrum.* **55**, 1957 (1984).

5E. V. S. Bogachev, E. T. Brook-Levinson, A. A. Bulavko, V. V. Gil, Yu. M. Dmitrenko, V. L. Dragun, V. I. Kordonsky, V. I. Lemesh, O. G. Lysenko, O. G. Martynenko, L. N. Novichyonok, S. E. Perez Guerra, N. A. Pokryvailo, A. D. Solodukhin, R. I. Soloukhin, N. N. Stolovich, N. A. Fomin, I. V. Khodan and V. K. Shchitnikov, Methods of experimental investigation of heat and mass transfer processes, *Heat Transfer—Sov. Res.* **16**(5), 40 (1985).

6E. K. Bremhorst, Effect of fluid temperature on hot-wire anemometers and an improved method of temperature compensation and linearization without use of small signal sensitivities, *J. Phys. E: scient. Instrum.* **18**, 44 (1985).

7E. H. H. Bruun and C. Tropea, The calibration of inclined hot-wire probes, *J. Phys. E: scient. Instrum.* **18**, 405 (1985).

8E. K. J. Bullock, M. A. Ledwich and J. C. S. Lai, Numerical simulation of transient response of heat transfer from a hot-wire anemometer transducer, *Int. J. Heat Fluid Flow* **6**, 57 (1985).

9E. M. R. Corson, Computer-compatible, self-contained, precision AC resistance bridge suitable for thermometry, *Rev. scient. Instrum.* **56**, 2310 (1985).

10E. T. W. Davies, Static and dynamic response of a hot-wire anemometer, *Int. J. Heat Fluid Flow* **6**, 226 (1985).

11E. Y. Enomoto and S. Furuhama, Study on thin film thermocouple for measuring instantaneous temperature on surface of combustion chamber wall in internal combustion engine, *Bull. J.S.M.E.* **28**(235), 108 (1985).

12E. H. Fiedler, K. Nottmeyer, P. P. Wegener and S. Raghu, Schlieren photography of water flow, *Exp. Fluids* **3**, 145 (1985).

13E. J. R. Frederick, J. N. Zemel and N. Goldfine, Pyroelectric anemometers: experimental geometric considerations, *J. appl. Phys.* **57**, 4936 (1985).

14E. T. Grandke, Theory and application of the laser shadow technique, Part 2, *Exp. Fluids* **3**, 277 (1985).

15E. G. W. Gray, The Clifford Paterson lecture, 1985. Liquid crystals: an arena for research and industrial collaboration among chemists, physicists and engineers, *Proc. R. Soc.* **A402**(1822), 1 (1985).

16E. D. F. Grosjean, B. Sarka and L. P. Goss, Time-resolved temperature measurements in a laboratory flame using the optoacoustic beam-deflection method, *Opt. Lett.* **10**, 324 (1985).

17E. M. Grubic and K. Kemmerle, A precision lock-in amplifier for temperature control in a spacelab calorimetric experiment, *J. Phys. E: scient. Instrum.* **18**, 572 (1985).

18E. L. E. Haseler, H. O. Lorch, M. G. Rao, R. G. Scurloc, F. A. Stevens and D. B. Utton, Rotating cryostats for heat transfer and fluid flow studies on the helium cooling of superconducting generator rotors, *Cryogenics* **25**, 355 (1985).

19E. P. Hesketh, B. Gebhart and J. N. Zemel, Heat transfer model for the pyroelectric anemometer, *J. appl. Phys.* **57**, 4944 (1985).

20E. S. A. Hippensteele, L. M. Russell and F. J. Torres, Local heat transfer measurements on a large scale-model turbine blade airfoil using a composite of a

heater element and liquid crystals, *J. Engng Gas Turbine Pwr* **107**, 953 (1985).
21E. H. A. Hoff, S. J. Rothman and J. N. Mundy, Calibration of an optical pyrometer above 2300°C, *J. Phys. E: scient. Instrum.* **18**, 197 (1985).
22E. G. R. Johnson, E. Marschall and J. H. Esdorn, Improved flow visualization technique for quantitative velocity measurement in small test volumes, *Rev. scient. Instrum.* **56**, 264 (1985).
23E. F. R. A. Jorgensen and M. Zuiderwyk, Two-color pyrometer measurement of the temperature of individual combusting particles, *J. Phys. E: scient. Instrum.* **18**, 486 (1985).
24E. V. V. Kholshchev, Determination of thermal loads of steam generating waterwall tubes (in Russian), *Teploenergetika* **4**, 72 (1985).
25E. Y. A. Kirichenko, R. I. Fedorov, V. V. Tsybulsky and S. I. Boxhidai, Device for investigation of hydrodynamics and heat transfer during cryogenic liquid motion under centrifugal forces, *Cryogenics* **25**, 279 (1985).
26E. L. V. Krishnamoorthy, D. H. Wood, R. A. Antonia and A. J. Chambers, Effect of wire diameter and overheat ratio near a conducting wall, *Exp. Fluids* **3**, 121 (1985).
27E. W. Kuhn and B. DreBler, Experimental investigations on the dynamic behavior of hot-wire probes, *J. Phys. E. scient. Instrum.* **18**, 614 (1985).
28E. A. Lachaine, Thermal analysis by photoacoustic phase measurements: effect of sample thickness, *J. appl. Phys.* **57**, 5075 (1985).
29E. P. C. Lanchester and K. A. Mohammed, A low-power digitally controlled heater power supply for calorimetry, *J. Phys. E: scient. Instrum.* **18**, 499 (1985).
30E. J. C. Lecordier, D. Moreau and P. Paranthoen, Prong-wire thermal interaction effect induced harmonics for the thin-wire resistance thermometer, *J. Phys. E: scient. Instrum.* **18**, 571 (1985).
31E. C. H. Liebert, R. Holanda, S. A. Hippensteele and C. A. Andrachio, High-temperature thermocouple and heat flux gauge using a unique thin film-hardware hot junction, *J. Engng Gas Turbine Pwr* **107**, 938 (1985).
32E. S. P. Logvinenko and O. A. Rossoshanskii, Low-temperature semiconductor resistance thermometer with heat conductor, *Cryogenics* **25**, 249 (1985).
33E. M. B. Long, P. S. Levin and D. C. Fourguette, Simultaneous two-dimensional mapping of species concentration and temperature in turbulent flames, *Opt. Lett.* **10**, 267 (1985).
34E. D. M. Mathews and D. Morris, A monotone-wall heat flow calorimeter, *J. Phys. E: scient. Instrum.* **18**, 1007 (1985).
35E. K. Mathioudakis and F. A. E. Breugelmans, Use of triple hot wires to measure unsteady flows with large direction changes, *J. Phys. E: scient. Instrum.* **18**, 414 (1985).
36E. C. G. Miller, Refinement of an 'alternate' method for measuring heating rates in hypersonic wind tunnels, *A.I.A.A. Jl* **23**, 810 (1985).
37E. K. C. Mills and W. A. Wakeham, Effect of radiation on thermal transport measurements, *High Temp.—High Press.* **17**, 343 (1985).
38E. J. A. Nienaber and A. L. Maddy, Temperature controlled multiple chamber indirect calorimeter-design and operation, *Trans. Am. Soc. agric. Engrs (Gen. Ed.)* **28**(2), 55 (1985).
39E. S. Niksa, R. E. Mitchell, K. R. Hencken and D. A. Tichenor, Optically determined temperatures, sizes, and velocities of individual carbon particles under typical combustion conditions, *Combust. Flame* **60**, 183 (1985).
40E. D. K. Pandey, Response time correlations for chromel-constantan, *J. Phys. E: scient. Instrum.* **18**, 712 (1985).
41E. F. Peters, Schlieren interferometry applied to a gravity wave in a density-stratified liquid, *Exp. Fluids* **3**, 261 (1985).
42E. W. R. C. Phillips, Higher-order response equations for an inclined hot-wire, *J. Phys. E: scient. Instrum.* **18**, 314 (1985).
43E. A. Raman, V. S. Krishnan and R. P. Roy, Directional sensitivity of cylindrical hot-film velocity sensors, *J. appl. Mech.* **52**, 199 (1985).
44E. J. E. Roth, Thin films of fired metal paints as resistance thermometers for heat transfer measurement (in German), *Wärme- u. Stoffübertr.* **19**(4), 305 (1985).
45E. O. Sano and R. Takaki, Simultaneous measurement of velocity and temperature by the use of laser doppler velocimeter, *Phys. Fluids* **28**, 818 (1985).
46E. J. M. Seitzman, G. Kychakoff and R. K. Hanson, Instantaneous temperature field measurements using planar laser-induced fluorescence, *Opt. Lett.* **10**, 439 (1985).
47E. G. S. Settles, Color-coding schlieren techniques for the optical study of heat and fluid flow, *Int. J. Heat Fluid Flow* **6**, 3 (1985).
48E. I. Tomaszkiewicz and S. L. Randzio, A high-pressure and elevated-temperature flow calorimeter, *J. Phys. E: scient. Instrum.* **18**, 92 (1985).
49E. J. Van Dam and H. Janeschitz-Kriegl, Temperature measurement and heat transfer in flowing polymer melts, *Int. J. Heat Mass Transfer* **28**, 395 (1985).
50E. A. R. P. Van Heininghen, W. J. M. Douglas and A. S. Mujmdar, A high sensitivity, fast response heat flux sensor, *Int. J. Heat Mass Transfer* **28**, 1657 (1985).
51E. T. von Weissenfluh, Probes for local velocity and temperature measurements in liquid metal flow, *Int. J. Heat Mass Transfer* **28**, 1563 (1985).
52E. M. D. Walker and M. R. Maxey, A whirling hot-wire anemometer with optical data transmission, *J. Phys. E: scient. Instrum.* **18**, 516 (1985).
53E. M. E. Weill, M. Rhazi and G. Gouesbet, Experimental investigation of oscillatory phenomena produced by a hot wire located near and below a free surface, *J. Phys.* **46**, 1501 (1985).
54E. D. Wilkie, The correlation of engineering data considered, *Int. J. Heat Fluid Flow* **6**, 99 (1985).

## NATURAL CONVECTION—INTERNAL FLOWS

1F. J. R. Abernathey and F. Rosenberger, Time-dependent convective instabilities in a closed vertical cylinder heated from below, *J. Fluid Mech.* **160**, 137 (1985).
2F. S. Acharya, Natural convection in an inclined enclosure containing internal energy sources and cooled from below, *Int. J. Heat Fluid Flow* **6**(2), 113 (1985).
3F. S. Acharya and R. J. Goldstein, Natural convection in an externally heated vertical or inclined square box containing internal energy sources, *J. Heat Transfer* **107**(4), 855 (1985).
4F. S. Acharya and C. H. Tsang, Natural convection in a fully partitioned, inclined enclosure, *Numer. Heat Transfer* **8**(4), 407 (1985).
5F. N. Afzal, Turbulent natural convection in a horizontal fluid layer with volumetric energy sources: an intermediate layer, *Int. J. Heat Mass Transfer* **25**(1), 291 (1985).
6F. O. A. Arnas and M. A. Ebadian, Convective heat transfer in a circular annulus with various wall heat flux distributions and heat generation, *J. Heat Transfer* **107**(2), 334 (1985).
7F. W. Arter, Nonlinear Rayleigh–Bénard convection with square planform, *J. Fluid Mech.* **152**, 391 (1985).

8F. T. Asaeda, N. Tamai and Y. Takahasi, Investigation of convection induced by thermal instability, *Trans. Japan Soc. Civil Engrs* **15**, 541 (1985).
9F. L. F. A. Azevedo and E. M. Sparrow, Natural convection in open-ended inclined channels, *J. Heat Transfer* **107**(4), 893 (1985).
10F. R. F. Babus'Haq, S. D. Probert and M. J. Shilston, Natural convection across cavities: design advice, *Appl. Energy* **20**(3), 161 (1985).
11F. V. A. Batischev, V. V. Kolesov, S. K. Slitinskaya and V. I. Yudovich, Effect of spatial modulation of the temperature distribution on the stability of two-dimensional steady flow in a horizontal layer of a two-component liquid, *J. appl. Mech. Tech. Phys.* **26**(2), 226 (1985).
12F. H. F. Bauer, Heat transport in a liquid column in weightless conditions due to thermal Marangoni, *Numer. Heat Transfer* **8**(1), 81 (1985).
13F. T. L. Bergman, F. P. Incropera and R. Viskanta, A differential model for salt-stratified, double-diffusive systems heated from below, *Int. J. Heat Mass Transfer* **28**(4), 779 (1985).
14F. S. N. Bhattacharyya and A. S. Gupta, Thermoconvective waves in a binary mixture, *Phys. Fluids* **28**(11), 3215 (1985).
15F. V. A. Bogachev, V. M. Yeroshenko, O. F. Synitina and L. A. Yaskin, Measurements of heat transfer to super-critical helium in vertical tubes under forced and mixed convection conditions, *Cryogenics* **25**(4), 198 (1985).
16F. E. W. Bolton and F. H. Busse, Stability of convection rolls in a layer with stress-free boundaries, *J. Fluid Mech.* **150**, 487 (1985).
17F. B. Borkowska-Pawlak and W. Kordylewski, Cell-pattern sensitivity to box configuration in a saturated porous medium, *J. Fluid Mech.* **150**, 169 (1985).
18F. M. E. Braaten and S. V. Patankar, Analysis of laminar mixed convection in shrouded arrays of heated rectangular blocks, *Int. J. Heat Mass Transfer* **28**(9), 1699 (1985).
19F. D. G. Briggs and D. N. Jones, Two-dimensional periodic natural convection in a rectangular enclosure of aspect ratio one, *J. Heat Transfer* **107**(4), 850 (1985).
20F. Yu. A. Buevich, Theory of interfacial convection, *J. Engng Phys.* **48**(2), 163 (1985).
21F. T. Burch, T. Rhodes and S. Acharya, Laminar natural convection between finitely conducting vertical plates, *Int. J. Heat Mass Transfer* **28**(6), 1173 (1985).
22F. F. H. Busse and H. Frick, Square-pattern convection in fluids with strongly temperature-dependent viscosity, *J. Fluid Mech.* **150**, 451 (1985).
23F. J. P. Caltagirone and S. Bories, Solutions and stability criteria of natural convective flow in an inclined porous layer, *J. Fluid Mech.* **155**, 267 (1985).
24F. J. L. Castillo and M. G. Velarde, Marangoni convection in liquid films with a deformable open surface, *J. Colloid Interface Sci.* **108**(1), 264 (1985).
25F. Y. L. Chan and C. L. Tien, A numerical study of two-dimensional laminar natural convection in shallow open cavities, *Int. J. Heat Mass Transfer* **28**(3), 603 (1985).
26F. Y. L. Chan and C. L. Tien, A numerical study of two-dimensional natural convection, *Numer. Heat Transfer* **8**(1), 65 (1985).
27F. C. F. Chen and S. Thangam, Convective stability of variable-viscosity fluid in a vertical slot, *J. Fluid Mech.* **161**(12), 161 (1985).
28F. C. Cianfrini, D. M. Fontana and F. Mattiucci, Natural convection in a cavity with isothermal wall in transient conditions, *Energie Alternative Habitat Territorio Energia* **7**(33), 63 (1985).
29F. J. Pascal Coutier and R. Greif, An investigation of laminar mixed convection inside a horizontal tube with isothermal wall conditions, *Int. J. Heat Mass Transfer* **28**(7), 1293 (1985).
30F. P. G. Daniels, Stationary instability of the buoyancy-layer flow between heated vertical planes, *R. Soc. Proc.* **A**(1820), 145 (1985).
31F. P. G. Daniels, Transition to the convective regime in a vertical slot, *Int. J. Heat Mass Transfer* **28**(11), 2071 (1985).
32F. J. A. Dantzig, Experimental method of measuring energy in the Bénard–Rayleigh problem, *Rev. scient. Instrum.* **56**(5), 740 (1985).
33F. Yu. M. Dashevsky and V. I. Malkovsky, Heat exchange with laminar upflow of supercritical helium in a gravitational field, *Cryogenics* **25**(11), 658 (1985).
34F. C. Dietsche and U. Muller, Influence of Bénard convection on solid–liquid interfaces, *J. Fluid Mech.* **161**(12), 249 (1985).
35F. B. F. Edwards and A. L. Fetter, Onset of oscillations in Rayleigh–Bénard convection: horizontally unbounded slab, *Phys. Fluids* **27**(12), 2795 (1984).
36F. E. M. Eidson, Numerical simulation of the turbulent Rayleigh–Bénard problem using subgrid modelling, *J. Fluid Mech.* **158**, 245 (1985).
37F. O. T. Fang, M. E. Glicksman, S. R. Coriell, G. B. McFadden and R. F. Boisvert, Convective influence on the stability of a cylindrical solid–liquid interface, *J. Fluid Mech.* **151**, 121 (1985).
38F. A. P. Fein, M. S. Heutmaker and J. P. Gollub, Scaling at the transition from quasiperiodicity to chaos in a hydrodynamic system, *Physica Scripta* **T9** (1985).
39F. A. C. Fowler, Fast thermoviscous convection, *Stud. appl. Math.* **72**(3), 189 (1985).
40F. A. C. Fowler, Secular cooling in convection, *Stud. appl. Math.* **72**(2), 161 (1985).
41F. D. Getachew and S. Rosenbalt, Thermocapillary instability of a viscoelastic liquid layer, *A Mech.* **55**(1–2), 137 (1985).
42F. G. Guglielmini, G. Milano and M. Misale, Electronic cooling by natural convection in partially confined enclosures, *Heat Technol.* **3**(3–4), 43 (1985).
43F. M. A. Hassab, The stability of steady convective motion in a vertical slender slot with non-uniform volumetric energy sources and unequal surface temperature, *Int. J. Heat Mass Transfer* **28**(2), 351 (1985).
44F. M. A. Hessami, A. Pollard, R. D. Rowe and D. W. Ruth, A study of free convective heat transfer in a horizontal annulus with a large radii ratio, *J. Heat Transfer* **107**(3), 603 (1985).
45F. J. Y. Holyer, The stability of long steady three-dimensional salt fingers to long-wavelength perturbations, *J. Fluid Mech.* **156**, 495 (1985).
46F. J. M. Hyun, Effect of the Prandtl number on heatup of a stratified fluid in an enclosure, *J. Heat Transfer* **107**(4), 982 (1985).
47F. J. M. Hyun, Thermally-forced stratification build-up in an initially isothermal, continued fluid, *J. Phys. Soc. Japan* **54**(3), 942 (1985).
48F. F. P. Incropera and J. A. Schutt, Numerical simulation of laminar mixed convection in the entrance region of horizontal rectangular ducts, *Numer. Heat Transfer* **8**(6), 707 (1985).
49F. A. D. W. Jones, The stability of buoyancy-driven rolls aligned with a shear flow when the temperature gradient is nonlinear, *Phys. Fluids* **28**(1), 31 (1985).
50F. Y. Kamotani, L. W. Wang, S. Ostrach and H. D. Jian, Experimental study of natural convection in shallow enclosures with horizontal temperature and concentration gradients, *Int. J. Heat Mass Transfer* **28**(1), 165 (1985).

51F. D. R. Kassoy and B. Cotte, The effects of sidewall heat loss on convection in a saturated porous vertical slab, *J. Fluid Mech.* **152,** 361 (1985).

52F. M. Keyhani, F. A. Kulacki and R. N. Christensen, Experimental investigation of free convection in a vertical rod bundle—a general correlation for Nusselt numbers, *J. Heat Transfer* **107**(3), 611 (1985).

53F. D. M. Kim and R. Viskanta, Effect of wall heat conduction on natural convection heat transfer in a square enclosure, *J. Heat Transfer* **107**(1), 139 (1985).

54F. K.-H. Kim and M.-U. Kim, Effect on time-dependent heating on the onset of Rayleigh–Bénard convection, *J. Phys. Soc. Japan* **54**(3), 933 (1985).

55F. S. Kimura and A. Bejan, Natural convection in a differentially heated corner region, *Phys. Fluids* **28**(10), 2980 (1985).

56F. A. G. Kirdyashkin, Gravitational heat convection in a planar inclined layer with adiabatic surfaces and a lateral heat supply, *High Temp.* **23**(1), 104 (1985).

57F. G. H. Knightly and D. Sather, Selection principle for Bénard-type convection, *Arch. Ration. Mech. Anal.* **88**(2), 163 (1985).

58F. S. Kotake and N. Hattori, Combined forced and free convection heat transfer for fully-developed laminar flow in horizontal annuli, *Int. J. Heat Mass Transfer* **28**(11), 2113 (1985).

59F. M. C. Limbourg-Fontaine, G. Petre and J. C. Legros, Texus 8 experiment: effects of a surface tension minimum on thermocapillary convection, *Physico-Chem. Hydrodynam.* **6**(3), 301 (1985).

60F. Y. Maeno, H. Haucke, R. E. Ecke and J. C. Wheatley, Oscillatory convection in a dilute **3H superfluid **4He solution, *J. Low Temp. Phys.* **59**(3–4), 305 (1985).

61F. V. I. Malkovski, Hydrodynamics and heat transfer within an inclined cell immersed in a cooling liquid, *Cryogenics* **25**(1), 37 (1985).

62F. C. L. McTaggart and K. A. Lindsay, Nonclassical effects in the Bénard problem, *SIAM J. appl. Math.* **45**(1), 70 (1985).

63F. R. Monti and G. Mannara, Texus experiment on the convective heat transfer induced by marangoni flows, *Acta astronaut.* **12**(7–8), 511 (1985).

64F. H. Mori, K. Shobu, B. C. So and H. Okamoto, Spectral structure and universality of intermittent chaos, *Physica Scripta* **T9** (1985).

65F. E. Naito, The effect of buoyancy on laminar flow and heat transfer in the entrance region between horizontal parallel plates, *Heat Transfer—Japan. Res.* **13,** 80 (1984).

66F. K. Nandakumar, J. H. Masliyah and H.-S. Law, Bifurcation in steady laminar mixed convection flow in horizontal ducts, *J. Fluid Mech.* **152,** 145 (1985).

67F. V. F. Nicolette, K. T. Yang and J. R. Lloyd, Transient cooling by natural convection in a two-dimensional square enclosure, *Int. J. Heat Mass Transfer* **28**(9), 1721 (1985).

68F. D. G. Osborne and F. P. Incropera, Experimental study of mixed convection heat transfer for transitional turbulent flow between horizontal parallel plates, *Int. J. Heat Mass Transfer* **28**(7), 1337 (1985).

69F. H. Ozoe, K. Fujii, T. Shibata, H. Kuriyama and S. W. Churchill, Three-dimensional numerical analysis of natural convection in a spherical annulus, *Numer. Heat Transfer* **8**(4), 383 (1985).

70F. H. Ozoe, A. Mouri, M. Ohmuro, S. W. Churchill and N. Lior, Numerical calculations of laminar and turbulent natural convection in water in rectangular channels heated and cooled isothermally on the opposing vertical walls, *Int. J. Heat Mass Transfer* **28**(1), 125 (1985).

71F. D. Poulikakos, Natural convection in a confined fluid-filled space driven by a single vertical wall with warm and cold regions, *J. Heat Transfer* **107**(4), 867 (1985).

72F. C. Prakash and Ye-Di Liu, Buoyancy induced flow in a vertical internally finned circular duct, *J. Heat Transfer* **107**(1), 118 (1985).

73F. V. Prasad and F. A. Kulacki, Free convective heat transfer in a liquid-filled vertical annulus, *J. Heat Transfer* **107**(2), 596 (1985).

74F. V. Prasad, F. A. Kulacki and M. Keyhani, Natural convection in porous media, *J. Fluid Mech.* **150,** 89 (1985).

75F. U. Projan and H. Beer, Prandtl number effects on natural convection heat transfer in concentric and eccentric horizontal cylindrical annuli, *Wärme- u. Stoffübertr.* **19**(4), 249 (1985).

76F. K. R. Rajagopal and T. Y. Na, Natural convection flow of a non-Newtonian fluid between two vertical flat plates, *A Mech.* **54**(3–4), 239 (1985).

77F. Y. Renardy and D. D. Joseph, Oscillatory instability in a Bénard problem of two fluids, *Phys. Fluids* **28**(3), 788 (1985).

78F. Y. Renardy and M. Renardy, Perturbation analysis of steady oscillatory onset in a Bénard problem with similar liquids, *Phys. Fluids* **28**(9), 2699 (1985).

79F. N. Riahi, Nonlinear convection in a horizontal layer with an internal heat source, *J. Phys. Soc. Japan* **53**(12), 4169 (1984).

80F. N. Riahi, Nonlinear thermal convection with finite conducting boundaries, *J. Fluid Mech.* **152,** 113 (1985).

81F. A. J. Roberts, An analysis of near-marginal, mildly penetrative convection with heat flux prescribed on the boundaries, *J. Fluid Mech.* **158,** 71 (1985).

82F. H. Saito, I. Tokura and K. Okada, Experimental study on free convection heat transfer from vertically lined horizontal cylinders set between parallel walls, *Bull. J.S.M.E.* **28**(244), 2347 (1985).

83F. Yu. V. Sanochkin, Thermocapillary cell in a horizontal moving liquid layer with heating from above, *J. appl. Mech. Tech. Phys.* **26**(2), 222 (1985).

84F. G. S. R. Sarma, Effects of inter-facial curvature and gravity waves on the onset of thermocapillary convective instability in a rotating liquid layer subjected to a transverse magnetic field, *PhysicoChem. Hydrodynam.* **6**(3), 283 (1985).

85F. W. M. M. Schinkel and C. J. Hoogendoorn, Core stratification effects on natural convection in inclined cavities, *Appl. scient. Res.* **42**(2), 109 (1985).

86F. W. C. Schreiber and S. N. Singh, Natural convection between confocal horizontal elliptical cylinders, *Int. J. Heat Mass Transfer* **28**(4), 807 (1985).

87F. M. Schulte, N. K. Mitra and M. Fiebig, Heat transfer by free convection from a horizontal tube in concentric and eccentric cylindrical annulus (in German), *Wärme- u. Stoffübertr.* **19**(4), 241 (1985).

88F. A. H. Shaaban and M. N. Özişik, Thermal stability of a vertical fluid layer with volumetric energy source, *J. Heat Transfer* **107**(2), 589 (1985).

89F. W. A. Shay and D. H. Schultz, Second-order approximation to natural convection for large Rayleigh numbers and small Prandtl numbers, *Int. J. numer. Meth. Fluids* **5**(5), 427 (1985).

90F. C. Smutek, P. Bontous, B. Roux, G. H. Schiroky, A. C. Hurford, F. Rosenberger and G. de Vahl Davis, Three-dimensional convection in horizontal cylinders: numerical solutions and comparison with experimental and analytical results, *Numer. Heat Transfer* **8**(5), 613 (1985).

91F. E. F. C. Somerscales and M. Kassemi, Electrochemical mass transfer studies in open cavities, *J. appl. Electrochem.* **15**(3), 405 (1985).

92F. M. M. Sorour, M. A. Hassab and F. A. Elewa, Effect of suction on the stability of fluid between horizontal plates at differing temperatures, *Proc. Inst. mech. Engrs, Part C, Mech. Engng Sci.* **199**(2), 145 (1985).
93F. M. M. Sorour, M. A. Hassab and F. A. Elewa, Stability of combined natural and forced cross flow in a vertical slot, *Int. J. Heat Mass Transfer* **28**(5), 987 (1985).
94F. A. C. M. Sousa, G. V. Hadjisophocleous and J. E. S. Venart, Numerical simulation of 3-D laminar free convection in tanks with localized heat sources, *Heat Technol.* **3**(1), 49 (1985).
95F. A. C. M. Sousa, P. R. Wentzell and J. E. S. Venart, Thermal modelling of LPG tanks engulfed in flames, *Heat Technol.* **3**(3–4), 1 (1985).
96F. J. Stastna, Convection and overstability in a viscoelastic fluid layer, *J. Non-Newtonian Fluid Mech.* **18**(1), 61 (1985).
97F. V. Steinberg, G. Ahlers and D. S. Cannell, Pattern formation and wave-number selection by Rayleigh–Bénard convection in a cylindrical container, *Physica Scripta* **T9**, 97 (1985).
98F. M. Takashima and H. Hamabata, The stability of natural convection in a vertical fluid layer having side walls of different temperatures and internal heat generation, *J. Phys. Soc. Japan* **54**(5), 1782 (1985).
99F. Yu. V. Val'tsiferov and V. P. Dronov, Numerical investigation of the convective heat transfer in a thin-walled cylindrical vessel with hemispherical ends with different heat-flux distributions over the contours, *High Temp.* **23**(1), 99 (1985).
100F. S. I. Vybornov and Yu. V. Sanochkin, Thermocapillary cell in a layer of a heavy fluid heated from above, *Fluid Dynam.* **20**(1), 153 (1985).
101F. I. C. Walton, The effect of a shear flow on convection in a layer heated non-uniformly from below, *J. Fluid Mech.* **154,** 303 (1985).
102F. R. O. Warrington, Jr. and R. E. Powe, The transfer of heat by natural convection between bodies and their enclosures, *Int. J. Heat Mass Transfer* **28**(2), 319 (1985).
103F. P. S. Wei and W. H. Giedt, Surface tension gradient-driven flow around an electron beam welding cavity, *Welding J.* **64**(9), 251 (1985).
104F. P. D. Weidman and G. Mehrdadtehranfar, Instability of natural convection in a tall vertical annulus, *Phys. Fluids* **28**(3), 776 (1985).
105F. M. Grae Worster and Alison M. Leitch, Laminar free convection in confined regions, *J. Fluid Mech.* **156,** 301 (1985).
106F. W. Wulbrand and H. Kagermann, The influence of random temperature modulation on the convective instability, *Physica* **131A**(1), 182 (1985).
107F. S. Yanase and K. Kohno, The effect of a salinity gradient on the instability of natural convection in a vertical fluid layer, *J. Phys. Soc. Japan* **54**(10), 3747 (1985).
108F. F. Zangrando and L. A. Bertram, The effect of variable stratification on linear doubly diffusive stability, *J. Fluid Mech.* **151,** 55 (1985).
109F. A. Zebib, A. K. Goyal and G. Schubert, Convective motions in a spherical shell, *J. Fluid Mech.* **152,** 39 (1985).
110F. A. Zebib, G. M. Homsy and E. Meiburg, High Marangoni number convection in a square cavity, *Phys. Fluids* **28**(12), 3467 (1985).
111F. Z. Y. Zhong, K. T. Yang and J. R. Lloyd, Variable property effects in laminar natural convection in a square enclosure, *J. Heat Transfer* **107**(1), 133 (1985).

## NATURAL CONVECTION—EXTERNAL FLOWS

1FF. N. Afzal, Higher order effects in natural convection flow over a uniform flux horizontal surface, *Wärme- u. Stoffübertr.* **19**(3), 177 (1985).
2FF. N. Afzal, Mixed convection plume above a point heat source in a vertical free stream, *Int. J. Heat Mass Transfer* **28**(11), 2043 (1985).
3FF. M. Amaouche and J.-L. Peube, Convection mixte stationnaire autour d'un cylindre horizontal, *Int. J. Heat Mass Transfer* **28**(7), 1269 (1985).
4FF. H. M. Badr, On the effect of flow direction on mixed convection from a horizontal cylinder, *Int. J. numer. Meth. Fluids* **5**(1), 1 (1985).
5FF. M. N. Bui and T. Cebeci, Combined free and forced convection on vertical slender cylinder, *J. Heat Transfer* **107**(2), 476 (1985).
6FF. J. Calman, Convection at a model ice edge, *Johns Hopkins APL Tech. Digest (appl. Phys. Lab.)* **6**(3), 211 (1985).
7FF. M. J. Chamberlain, K. G. T. Hollands and G. D. Raithby, Experiments and theory on natural convection heat transfer from bodies of complex shape, *J. Heat Transfer* **107**(3), 624 (1985).
8FF. S. S. Chawla, Free convection from a torsionally oscillating vertical plane, *Int. J. Engng Sci.* **23**(6), 611 (1985).
9FF. M. M. Elsayed and K. A. Fathalah, Natural convection over a vertical flat plate due to absorption of thermal radiation, *Wärme- u. Stoffübertr.* **19**(2), 121 (1985).
10FF. M. Epstein, G. M. Hauser and R. E. Henry, Thermophoretic deposition of particles in natural convection flow from a vertical plate, *J. Heat Transfer* **107**(2), 272 (1985).
11FF. V. M. Eroshenko, L. I. Zaichik and V. A. Pershukov, Stability of the free-convection boundary layer on a vertical permeable plate, *J. Engng Phys.* **48**(3), 271 (1985).
12FF. S. Ghorbani-Tari and A. J. Ghajar, Improved free convective heat-transfer correlations in the near-critical region, *A.I.A.A. Jl* **23**(10), 1647 (1985).
13FF. M. Hasan and A. S. Mujumdar, Simultaneous mass and heat transfer under mixed convection along a vertical cone, *Int. J. Energy Res.* **9**(2), 129 (1985).
14FF. M. Hasan and A. S. Mujumdar, Simultaneous heat and mass transfer in free convection from a horizontal cylinder, *A.I.A.A. Jl* **23**(10), 1602 (1985).
15FF. M. Hasan and A. S. Mujumdar, Combined heat and mass transfer in free convection about a sphere, *Can. J. chem. Engng* **63**(3), 412 (1985).
16FF. H. Herwig, Asymptotic approach to free-convection flow at maximum density, *Chem. Engng Sci.* **40**(9), 1709 (1985).
17FF. H. Herwig, G. Wickern and K. Gersten, T he influence of variable fluid properties to free convection laminar flows (in German), *Wärme- u. Stoffübertr.* **19**(1), 19 (1985).
18FF. C. T. Hsu and P. Cheng, Effects of upstream geometry on natural convection of a Darcian fluid about a semi-infinite inclined heated surface, *J. Heat Transfer* **107**(2), 283 (1985).
19FF. M.-J. Huang and C.-K. Chen, Effects of surface mass transfer on free convection flow over vertical cylinder embedded in a saturated porous medium, *J. Energy Res. Technol. Trans. Am. Soc. mech. Engrs* **107**(3), 394 (1985).
20FF. M.-J. Huang and C.-K. Chen, Conjugate mixed convection and conduction heat transfer along a vertical circular pin, *Int. J. Heat Mass Transfer* **28**(3), 523 (1985).
21FF. M.-J. Huang, C.-K. Chen and J. W. Cleaver, Vertical circular pin with conjugated natural convection-conduction flow, *J. Heat Transfer* **107**(1), 242 (1985).
22FF. D. B. Ingham, Flow past a suddenly heated vertical plate, *Proc. R. Soc.* **A402**(1822), 109 (1985).

23FF. Y. Jaluria, Interaction of natural convection wakes arising from thermal sources on a vertical surface, *J. Heat Transfer* **107**(4), 883 (1985).
24FF. X. K. Kakatsios, Heat released by a flat plate at various angles of inclination, *Chem.-Ing.-Tech.* **57**(10), 865 (1985).
25FF. J. H. Kim, An analytical mixing model for buoyant jet injected into pipe flow, *J. Heat Transfer* **107**(3), 630 (1985).
26FF. S. Kimura, A. Bejan and I. Pop, Natural convection near a cold plate facing upward in a porous medium, *J. Heat Transfer* **107**(4), 819 (1985).
27FF. K. Kitamura, M. Koike, I. Fukuoka and T. Saito, Large eddy structure and heat transfer of turbulent natural convection along a vertical flat plate, *Int. J. Heat Mass Transfer* **28**(4), 837 (1985).
28FF. A. K. Kolar and V. M. K. Sastri, Numerical and experimental investigations into the upstream transpiration problem in free convection, *Wärme- u. Stoffübertr.* **19**(4), 297 (1985).
29FF. A. A. Kovkova, Singular perturbations in the problem of free convection of high-viscosity fluids on a vertical plate, *Heat Transfer—Sov. Res.* **16**(4), 106 (1985).
30FF. H. Koyama, A. Nakayama, S. Ohsawa and H. Yamada, Theoretical and experimental study of free convection from a vertical frustum of a cone of a finite length, *Int. J. Heat Mass Transfer* **28**(5), 969 (1985).
31FF. S.-C. Lee, K.-L. Wong and C.-K. Chen, The finite element solution of laminar combined convection from a horizontal cylinder, *Comp. Meth. appl. Mech. Engng* **50**(2), 147 (1985).
32FF. J. H. Merkin, Note on the similarity solutions for free convection on a vertical plate, *J. Engng Math.* **19**(3), 189 (1985).
33FF. J. H. Merkin, Free convection above a uniformly heated horizontal circular disk, *Int. J. Heat Mass Transfer* **28**(6), 1157 (1985).
34FF. M. Miyamoto, Y. Katoh, K. Kurima, S. Kurihara and K. Yamashita, Free convection heat transfer from vertical and horizontal short plates, *Int. J. Heat Mass Transfer* **28**(9), 1733 (1985).
35FF. A. Nakayama and H. Koyama, An analysis of turbulent free convection about bodies of arbitrary geometrical configurations, *Wärme- u. Stoffübertr.* **19**(4), 263 (1985).
36FF. S. B. Nasrallah, G. Arnaud et A. Trad, Evaporation en convection naturelle sur une plaque verticale chauffée a flux variable. *Z. angew. Math. Phys.* **36**(1), 105 (1985).
37FF. A. O. Nieckele and S. V. Patankar, Laminar mixed convection in a concentric annulus with horizontal axis, *J. Heat Transfer* **107**(4), 902 (1985).
38FF. R. H. Nilson, Countercurrent convection in a double-diffusive boundary layer, *J. Fluid Mech.* **160,** 181 (1985).
39FF. P. Olson and H. Singer, Creeping plumes, *J. Fluid Mech.* **158,** 511 (1985).
40FF. D. G. Osborne and F. P. Incropera, Laminar, mixed convection heat transfer for flow between horizontal parallel plates with asymmetric heating, *Int. J. Heat Mass Transfer* **25**(1), 207 (1985).
41FF. K. H. Park and V. P. Carey, Analysis of transient natural convection flow near a vertical surface at low Prandtl number, *Numer. Heat Transfer* **8**(3), 317 (1985).
42FF. U. Projahn and H. Beer, Theoretical and experimental study of transient and steady-state natural convection heat transfer from a vertical flat plate partially immersed in water, *Int. J. Heat Mass Transfer* **28**(8), 1487 (1985).
43FF. U. Projahn and H. Beer, Theoretical and experimental studies on steady-state and transient heat transfer behavior as a result of natural convection on a vertical heating surface partially immersed in water, *Chem.-Ing.-Tech.* **57**(9), 808 (1985).
44FF. M. Ramachandran, B. F. Armaly and T. S. Chen, Measurements and predictions of a laminar mixed convection flow adjacent to a vertical surface, *J. Heat Transfer* **107**(3), 636 (1985).
45FF. K. V. Rao, B. F. Armaly and T. S. Chen, Mixed convection plumes arising from a thermal point source, *J. Heat Transfer* **107**(3), 720 (1985).
46FF. P. Razelos, An interferometric investigation of the effect of separation distance and temperature imbalance on natural convection for two horizontal cylinders at moderate Rayleigh numbers, *Wärme- u. Stoffübertr.* **19**(4), 255 (1985).
47FF. H. Saito, I. Tokura and K. Okada, An experimental study on free convection heat transfer from vertically lined horizontal cylinders set between parallel walls, *Bull. J.S.M.E.* **28**(244), 2347 (1985).
48FF. B. Sammakia, V. P. Carey and B. Gebhart, Measurements and calculations of transient mixed convection in air, *Int. J. Heat Mass Transfer* **28**(10), 1837 (1985).
49FF. T. Schulenberg, Natural convection heat transfer below downward facing horizontal surfaces, *Int. J. Heat Mass Transfer* **28**(2), 467 (1985).
50FF. V. I. Semenov, Similar problems of steady-state laminar free convection on a vertical plate, *Heat Transfer—Sov. Res.* **16**(2), 69 (1984).
51FF. D. L. Siebers, R. F. Moffat and R. G. Schwind, Experimental, variable properties natural convection from a large, vertical, flat surface, *J. Heat Transfer* **107**(1), 124 (1985).
52FF. Yu. A. Sokovishin and A. A. Kovkova, Free convection of highly viscous liquid along a vertical finite plate with constant heat flux, *J. Engng Phys.* **48**(1), 46 (1985).
53FF. V. M. Soundalgekar and P. Ganesan, Transient free convection with mass transfer on a vertical plate with constant heat flux, *Int. J. Energy Res.* **9**(1), 1 (1985).
54FF. E. M. Sparrow and L. F. A. Azevedo, Vertical-channel natural convection spanning between the fully-developed limit and the single-plate boundary-layer limit, *Int. J. Heat Mass Transfer* **28**(10), 1847 (1985).
55FF. E. M. Sparrow and L. F. A. Azevedo, Lateral-edge effects on natural convection heat transfer from an isothermal vertical plate, *J. Heat Transfer* **107**(4), 977 (1985).
56FF. E. M. Sparrow and S. S. Kang, Two-dimensional heat transfer and critical radius results for natural convection about an insulated horizontal cylinder, *Int. J. Heat Mass Transfer* **28**(11), 2049 (1985).
57FF. E. M. Sparrow and A. J. Stretton, Natural convection from variously oriented cubes and from other bodies of unity aspect ratio, *Int. J. Heat Mass Transfer* **28**(4), 741 (1985).
58FF. K. Stephan, M. Durst and R. Windisch, Natural convection heat transfer in the near critical region of pure fluids (in German), *Wärme- u. Stoffübertr.* **19**(3), 187 (1985).
59FF. W. E. Stewart, Jr. and J. C. Johnson, Experimental natural convection heat transfer from isothermal spherical zones, *J. Heat Transfer* **107**(2), 463 (1985).
60FF. N. Takenaka, O. Takahashi and I. Michiyoshi, Natural convection heat transfer from a horizontal plate to potassium, *Mem. Fac. Engng, Kobe Univ.* **32,** 145 (1985).
61FF. J. Timma et J.-P. Padet, Etude théorique du couplage convection-conduction en convection libre laminaire sur une plaque plane verticale, *Int. J. Heat Mass Transfer* **28**(6), 1097 (1985).

62FF. M. G. Timol and N. L. Kalthia, Similarity solution of flow past an accelerated vertical infinite plate in the presence of free convection currents, *Reg. J. Energy Heat Mass Transfer* 7(1), 67 (1985).
63FF. A. K. Tolpadi and T. H. Kuehn, Experimental investigation of conjugate natural convection heat transfer from a horizontal isothermal cylinder with a non-isothermal longitudinal plate fin at various angles, *Int. J. Heat Mass Transfer* **28**(1), 155 (1985).
64FF. K. L. Tzuoo, T. S. Chen and B. F. Armaly, Wave instability of natural convection flow on inclined surface, *J. Heat Transfer* **107**(1), 107 (1985).
65FF. S. Wakitani, Non-parallel-flow stability of a two-dimensional buoyant plume, *J. Fluid Mech.* **159,** 241 (1985).
66FF. I. C. Walton, The effect of a shear flow on convection near a two-dimensional hot-patch, *Q. Jl Mech. appl. Math.* **38**(4), 561 (1985).
67FF. G. Wilks, R. Hunt and D. S. Riley, The two-dimensional laminar vertical jet with positive or adverse buoyancy, *Numer. Heat Transfer* **8**(4), 449 (1985).
68FF. M. F. Young and T. Ozel, Mixed free and forced convection from a short vertical cylinder placed in a laminar horizontal flow, *J. Heat Transfer* **107**(1), 250 (1985).

## CONVECTION FROM ROTATING SURFACES

1G. M. M. M. Abou-Ellail and S. M. Morcos, Influence of cylinder rotation on turbulence modeling of flow and heat transfer in an annulus, *Heat Technol.* 3(3–4), 90 (1985).
2G. S. P. Bhattacharyya and M. Abbas, On the stability of a hot rotating layer of micropolar fluid, *Int. J. Engng Sci.* **23**(3), 371 (1985).
3G. J. W. Chew, Computation of convection laminar flow in rotating cavities, *J. Fluid Mech.* **153,** 339 (1985).
4G. J. W. Chew, Computation of forced laminar convection in rotating cavities, *J. Heat Transfer* **107**(2), 277 (1985).
5G. J. W. Chew, Effect of frictional heating and compressive work in rotating axisymmetric flow, *J. Heat Transfer* **107**(4), 984 (1985).
6G. B. Farouk, Mixed convective flows around a slowly rotating isothermal sphere, *J. Heat Transfer* **107**(2), 431 (1985).
7G. N. C. Ghosh, Thermal effect on the transverse vibration of high-speed rotating anisotropic disk, *J. appl. Mech.* **52**(3), 543 (1985).
8G. K. M. Iskaov and V. A. Trushin, Effect of rotation on heat transfer in the radial cooling channels or turbine blades, *Thermal Engng* **32**(2), 93 (1985).
9G. J. Jimenez and M. G. Velarde, Thermoconvective instability of a rotating viscoelastic fluid layer heated from below, *J. Non-Equil. Thermodynam.* **10**(4), (1985).
10G. C. W. Lee and H. N. Chang, Examination of immobilized cells in a rotating packed drum reactor for the production of ethanol from D-glucose, *Enzyme Microbial Tech.* 7(11), 561 (1985).
11G. A. M. Morrison and C. Fiscina, Effects of spin and mass addition on high-angle-of-attack re-entry, *J. Spacecraft Rockets* **22**(1), 68 (1985).
12G. M. R. Muller and J. N. Burch, An experimental study of the behavior of transient isolated convection in a rigidly rotating fluid, *Exp. Fluids* **3**(1), 17 (1985).
13G. S. Neti, A. S. Warnock, E. K. Levy and K. S. Kannan, Computation of laminar heat transfer in rotating rectangular ducts, *J. Heat Transfer* **107**(3), 575 (1985).
14G. J. M. Owen, J. R. Pincombe and R. H. Rogers, Source-sink flow inside a rotating cylindrical cavity, *J. Fluid Mech.* **155,** 233 (1985).
15G. J. Pecheux et C. Boutin, Etude d l'ecoulement laminaire de deux liquides non miscibles entre deux disques coaxiaux tournanent en sens contraires, *Z. angew. Math. Phys.* **36**(2), 238 (1985).
16G. R. Rajasekaran and M. G. Palekar, Viscous dissipation effects on mixed convection about a rotating sphere, *Int. J. Engng Sci.* **23**(8), 789 (1985).
17G. R. Shimada, S. Kumagai and T. Takeyama, Enhancement of heat transfer from a rotating cylinder by means of surface projections, *Heat Transfer—Japan. Res.* **13**(3), 1 (1984).
18G. R. Siegel, Analysis of buoyancy effect of fully developed laminar heat transfer in a rotating tube, *J. Heat Transfer* **107**(2), 338 (1985).
19G. Y. S. Sim and W. J. Yang, Turbulent heat transfer in corotating annular disks, *Numer. Heat Transfer* **8**(3), 299 (1985).
20G. C. L. Soule and R. L. Merson, Heat transfer coefficients to Newtonian liquids in axially rotated cans, *J. Food Process Engng* **8**(1), 33 (1985).
21G. A. M. Soward, Bifurcation and stability of finite amplitude convection in a rotating layer, *Physica D: Non-linear Phenomena* **14D**(2), 227 (1985).
22G. S. Thangam and C. G. Speziale, Numerical study of thermal convection in rotating channel flow, *Int. J. numer. Meth. Fluids* **5**(2), 133 (1985).
23G. M. Ungarish and M. Israeli, Axisymmetric compressible flow in a rotating cylinder with axial convection, *J. Fluid Mech.* **154,** 121 (1985).
24G. H. Yamashita, R. Izumi, H. Maeda and Y. Sugiura, Study on a rotating condenser with a scraper (1st report, analysis of condensation on outer surface of horizontal cylinder), *Bull. J.S.M.E.* **28**(239), 868 (1985).

## COMBINED HEAT AND MASS TRANSFER

1H. R. Amono and S. Sugiyama, Investigation on turbulent heat transfer of an axisymmetric jet impinging on a flat plate, *Bull. J.S.M.E.* **28**(235), 74 (1985).
2H. R. Bhargava and M. Rani, Numerical solution of heat transfer in micropolar fluid flow in a channel with porous walls, *Int. J. Engng Sci.* **23**(4), 409 (1985).
3H. Ye. N. Bogomolov and V. I. Orlova, Analysis of the overall efficiency of cooling of a perforated wall of a stationary gas-turbine blade, *Heat Transfer—Sov. Res.* **16**(2), 111 (1984).
4H. C. Camci and T. Arts, Experimental heat transfer investigation around the film-cooled leading edge of a high-pressure gas turbine rotor blade (85-GT-114), *J. Engng Gas Turbine Pwr* **107**(4), 1016 (1985).
5H. C. Camci and T. Arts, Short duration measurements and numerical simulation of heat transfer along the suction side of a film-cooled gas turbine blade (85-GT-111), *J. Engng Gas Turbine Pwr* **107**(4), 991 (1985).
6H. B. T. F. Chung and J. S. Hsiao, Heat transfer with ablation in a finite slab subjected to time-variant heat flux, *A.I.A.A. Jl* **23**(1), 145 (1985).
7H. V. M. Epifanov, A. I. Leont'ev, A. M. Pavlyuchenko and A. V. Pashutov, Critical permeability parameter in supersonic gradient flow, *High Temp.* **23**(2), 279 (1985).
8H. A. D. Fitt, J. R. Ockendon and T. V. Jones, Aerodynamics of slot-film cooling: theory and experiment, *J. Fluid Mech.* **160,** 15 (1985).
9H. L. W. Florschuetz and H. H. Tseng, Effect of nonuniform geometries on flow distributions and heat transfer characteristics for arrays of impinging jets, *J. Engng Gas Turbine Pwr* **107**(1), 68 (1985).
10H. T. Fujii, T. Nagata and K.-Ei Shinzato, Experimental study of heat and mass transfer from humid air to a

horizontal tube in false tube banks, *Bull. J.S.M.E.* **28**(237), 436 (1985).
11H. D. P. Georgiou and J. F. Louis, Transpired turbulent boundary layer in various pressure gradients and the blow-off condition, *J. Engng Gas Turbine Pwr* **107**(3), 636 (1985).
12H. S. A. Gokuglu and D. E. Rosner, Thermophoretically enhanced mass transport rates to solid and transpiration-cooled walls across turbulent (law-of-the-wall) boundary layers, *Ind. Engng Chem. Fund.* **24**(2), 208 (1985).
13H. R. J. Goldstein, E. R. G. Eckert, H. D. Chiang and E. Elovic, Effect of surface roughness on film cooling performance (84-GT-41), *J. Engng Gas Turbine Pwr* **107**(1), 111 (1985).
14H. R. J. Goldstein and P. H. Chen, Film cooling on a gas turbine blade near the end wall (84-GT-42), *J. Engng Gas Turbine Pwr* **107**(1), 117 (1985).
15H. N. Hay, D. Lampard and C. L. Saluja, Effects of cooling films on the heat transfer coefficient on a flat plate with zero mainstream pressure gradient (84-GT-40), *J. Engng Gas Turbine Pwr* **107**(1), 105 (1985).
16H. N. Hay, D. Lampard and C. L. Saluja, Effects of the condition of the approach boundary layer and of mainstream pressure gradients on the heat transfer coefficient on film-cooled surfaces (84-GT-47), *J. Engng Gas Turbine Pwr* **107**(1), 99 (1985).
17H. B. R. Hollworth and L. R. Gero, Entrainment effects on impingement heat transfer: Part II—local heat transfer measurements, *J. Heat Transfer* **107**(4), 910 (1985).
18H. B. Jubran and A. Brown, Film cooling from two rows of holes inclined in the streamwise and spanwise directions (84-GT-286), *J. Engng Gas Turbine Pwr* **107**(1), 84 (1985).
19H. I. I. Kantorovich, L. I. Sevkovaskay, A. A. Vecher and A. S. Skoropanov, Theory of stability of gas-permeable cooling, *High Temp.* **23**(2), 268 (1985).
20H. K. R. Khair and A. Began, Mass transfer to natural convection boundary layer flow driven by heat transfer, *J. Heat Transfer* **107**(4), 979 (1985).
21H. S. Kikkawa and M. Nonogaki, The effect of vibration on film cooling over a gas turbine blade, *Heat Transfer—Japan. Res.* **13**(2), 1 (1984).
22H. S. B. Koshelev, V. N. Subbotin and V. V. Kharitonov, Components of heat transfer in the jet flow of water in a limited space, *High Temp.* **23**(3), 441–446 (1985).
23H. P. M. Ligrani and C. Camci, Adiabatic film cooling effectiveness from heat transfer measurements in compressible, variable-property flow, *J. Heat Transfer* **107**(2), 313 (1985).
24H. V. V. Lunev and I. N. Polyakov, Stability of steady solution of ablation equation, *Fluid Dynam.* **20**(2), 248 (1985).
25H. B. P. Mironov, V. N. Vasechkin and N. I. Yarygina, Heat transfer behind the injection section at different levels of freestream turbulence, *Heat Technol.* **3**(1), 1 (1985).
26H. K. Nomura and P. V. Farrell, Heat and mass transfer coeffficients for porous horizontal cylinder, *A.I.Ch.E. Jl* **31**(7), 1217 (1985).
27H. M. Salcudean, K. Y. M. Lai and R. I. L. Guthrie, Multidimensional heat, mass and flow phenomena in gas stirred reactors, *Can. J. chem. Engng* **63**(1), 51 (1985).
28H. V. D. Sovershennyy and S. V. Leonov, Cooling of a turbine blade by injection of air through porous zones, *Heat Transfer—Sov. Res.* **16**(3), 126 (1984).
29H. C. D. Surma Devi, M. Nagaraj, T. Ramesan and G. Nath, Unsteady compressible three-dimensional stagnation point boundary layers with large injection rates, *Z. angew. Math. Mech.* **65**(8), 385 (1985).
30H. H. S. Takhar and V. M. Soundalgekar, Flow and heat transfer of a micropolar fluid past a continuously moving porous plate, *Int. J. Engng Sci.* **23**(2), 201 (1985).
31H. E. S. Tillman, E. O. Hartel and H. F. Jen, The prediction of flow through leading edge holes in a film cooled airfoil with and without inserts (84-GT-4), *J. Engng Gas Turbine Pwr* **107**(1), 92 (1985).
32H. A. A. Vasil'yev, Efficiency of nonequilibrium two-phase vapor–liquid cooling films on adiabatic walls, *Heat Transfer—Sov. Res.* **16**(5), 119 (1985).

## CHANGE OF PHASE—BOILING

1J. M. A. Abdelghaffar and K. Cornwell, On the flow field generated by a growing sphere near a solid plane with application to nucleate boiling, *Int. J. Heat Mass Transfer* **28**, 1131 (1985).
2J. N. Abuaf, S. H. Black and F. W. Staub, Pool boiling performance of finned surfaces in R-113, *Int. J. Heat Fluid Flow* **6**(1), 23 (1985).
3J. J.-L. Achard, D. A. Drew and R. T. Lahey, Analysis of nonlinear density-wave oscillations in boiling channels, *J. Fluid Mech.* **155**, 213 (1985).
4J. N. H. Afgan, L. A. Jović, S. A. Kovalev and V. A. Lenykov, Boiling heat transfer from surfaces with porous layers, *Int. J. Heat Mass Transfer* **28**, 415 (1985).
5J. H. Akimoto, Analysis of TRAC-PF1 calculated core heat transfer for a CCTF test, *Nucl. Engng Des.* **88**, 215 (1985).
6J. K. A. Akiyev, Heat transfer in boiling of azeotropic mixture in inertial fields, *Heat Transfer—Sov. Res.* **16**(6), 89 (1984).
7J. A. I. Anikin, G. N. Danilova and N. I. Mirmov, Generalized correlation for coefficients of boiling heat transfer oil–refrigerant mixtures in tubes, *Heat Transfer—Sov. Res.* **16**(1), 42, (1984).
8J. A. Bar-Cohen and H. Schweitzer, Thermosyphon boiling in vertical channels, *J. Heat Transfer* **107**, 772 (1985).
9J. G. G. Bartolomey, Le Tin Chun and N'Guyen Chih Huo, The dependence of the point of onset of intensive vaporization in subcooled boiling on the operating parameters, *Heat Transfer—Sov. Res.* **16**(4), 60 (1984).
10J. S. Benedek, Scaling laws of homogeneous and two-fluid flow coupled with heat transmission from a heated rod, *Atomkernenergie/Kerntech.* **46**, 257 (1985).
11J. A. M. Bhat, J. S. Saini and R. Prakash, Heat transfer correlations for high heat flux region in nucleate pool boiling, *J. Inst. Engrs (India)*, Part ME, *Mech. Engng Div.* **66**(July), 20 (1985).
12J. S. Biyikli, Optimum use of longitudinal fins of rectangular profiles in boiling liquids, *J. Heat Transfer* **107**, 968 (1985).
13J. R. A. Broussard and J. W. Westwater, Diameter and velocity effects for cross-flow boilling, *A.I.A.A. Jl* **23**, 1615 (1985).
14J. T. D. Bui and V. K. Dhir, Transition boiling heat transfer on a vertical surface, *J. Heat Transfer* **107**, 756 (1985).
15J. T. D. Bui and V. K. Dhir, Film boiling heat transfer on an isothermal vertical surface, *J. Heat Transfer* **107**, 764 (1985).
16J. A. Calka and R. L. Judd, Some aspects of the interaction among nucleation sites during saturated nucleate boiling, *Int. J. Heat Mass Transfer* **28**, 2331 (1985).
17J. V. P. Carey, Surface tension effects on convective boiling heat transfer in compact exchangers with offset strip fins, *J. Heat Transfer* **107**, 970 (1985).

18J. G. P. Celata, M. Cumo, F. D'Annibale and G. E. Farello, A computation method for mass flowrate prediction in critical flows of initially subcooled liquid in long channels, *Heat Technol.* 3(3–4), 24 (1985).
19J. C. Cercignani, W. Fiszdon and A. Frezzotti, The paradox of the inverted temperature profiles between an evaporating and a condensing surface, *Phys. Fluids* **28**, 3237 (1985).
20J. M. Cerza and V. Sernas, A bubble growth model for nucleate boiling in thin, falling, superheated, laminar water films, *Int. J. Heat Mass Transfer* **28**, 1307 (1985).
21J. G. L. Chahine and H. L. Liu, Singular-perturbation theory of the growth of a bubble cluster in a superheated liquid, *J. Fluid Mech.* **156**, 257 (1985).
22J. L. S. Chang and J. C. Berg, Electroconvective enhancement of mass or heat exchange between a drop or bubble and surroundings in the presence of an interfacial tension gradient, *A.I.Ch.E. Jl* **31**, 149 (1985).
23J. M. Chattree and S. Sengupta, Heat transfer and evaporation from heated water bodies, *J. Heat Transfer* **107**, 779 (1985).
24J. T. C. Chawla and J. D. Bingle, Downward heat transfer in heat-generating boiling pools, *Int. J. Heat Mass Transfer* **28**, 81 (1985).
25J. S. C. Cheng, P. W. K. Lau and K. T. Poon, Measurements of true quench temperature of subcooled water under forced convective conditions, *Int. J. Heat Mass Transfer* **28**, 235 (1985).
26J. S. K. Roy Chowdhury and R. H. S. Winterton, Surface effects in pool boiling, *Int. J. Heat Mass Transfer* **28**, 1881 (1985).
27J. P. Chuchottaworn and K. Asano, Calculation of drag coefficients of an evaporating or a condensing droplet, *J. chem. Engng Japan* **18**, 91 (1985).
28J. G. N. Danilova and A. V. Tikhonov, Enhancement of heat transfer in the boiling of the R-113 refrigerant on various kinds of surfaces, *Heat Transfer—Sov. Res.* **16**(1), 59 (1984).
29J. V. H. Del Valle, M. and D. B. R. Kenning, subcooled flow boiling at high heat flux,' *Int. J. Heat Mass Transfer* **28**, 1907 (1985).
30J. K. P. Derewnicki, Experimental studies of heat transfer and vapour formation in fast transient boiling, *Int. J. Heat Mass Transfer* **28**, 2085 (1985).
31J. M. De Salve and B. Panella, Void fraction and quench time in bottom reflooding experiments, *Heat Technol.* 3(2), 64 (1985).
32J. D. S. Dhuga and R. H. S. Winterton, Measurement of surface contact in transition boiling, *Int. J. Heat Mass Transfer* **28**, 1869 (1985).
33J. F. Dobran, Heat transfer in an annular two-phase flow, *J. Heat Transfer* **107**, 472 (1985).
34J. B. M. Dorofeev, Acoustic phenomena in boiling, *High Temp.* **23**, 479 (1985).
35J. V. A. Dyundin, A. G. Solov'yev, A. V. Borishanskaya and Yu. A. Vol'nykh, Effect of the kind of surface roughness on the heat transfer coefficient in boiling of refrigerants, *Heat Transfer—Sov. Res.* **16**(1), 53 (1984).
36J. Z. Edelman, E. Elias and D. Naot, Inverted annular boiling in a stainless-steel tube with steady heat sources, *Int. J. Heat Mass Transfer* **28**, 1281 (1985).
37J. D. Evans, S. W. Webb and J. C. Chen, Axially varying vapor superheats in convective film boiling, *J. Heat Transfer* **107**, 663 (1985).
38J. H. Fik, Z. Kolenda, R. Ramirez-Zetina, J. Donizak and E. Kochanska, Influence of surface conditions on boiling heat transfer in New Jersey Zn–Pb–Cd distillation columns, *Trans. Inst. Min. Metall.* Section C **94**(June), 55 (1985).
39J. T. R. Fodemski, The influence of liquid viscosity and system pressure on stagnation point vapour thickness during forced-convection film boiling, *Int. J. Heat Mass Transfer* **28**, 69 (1985).
40J. V. V. Galaktionov and L. P. Trukhanova, Study of the process of heat and mass transfer in the region of the vapor–gas front in a gas-regulable heat pipe, *J. Engng Phys.* **48**, 296 (1985).
41J. A. Galati and S. Migliori, Bubble-breaking effect in a sodium boiling test, *Nucl. Sci. Engng* **90**, 209 (1985).
42J. Y. Hagiwara, T. Miwada and K. Suzuki, Heat transfer and wave structural in the developing region of two-component two-phase annular flow, *PhysicoChem. Hydrodynam.* **6**(1–2), 141 (1985).
43J. JeChin Han and L. S. Fletcher, Falling film evaporating and boiling in circumferential and axial grooves on horizontal tubes, *Ind. Engng Chem. Proc. Des. Dev.* **24**, 570 (1985).
44J. R. Hino and T. Ueda, Studies on heat transfer and flow characteristics in subcooled flow boiling—Part 1. Boiling characteristics, *Int. J. Multiphase Flow* **11**, 269 (1985).
45J. R. Hino and T. Ueda, Studies on heat transfer and flow characteristics in subcooled flow boiling—Part 2. Flow characteristics, *Int. J. Multiphase Flow* **11**, 283 (1985).
46J. T. O. Hui and J. R. Thome, A study of binary mixture boiling: boiling site density and subcooled heat transfer, *Int. J. Heat Mass Transfer* **28**, 919 (1985).
47J. Y.-H. Hung and S.-C. Yao, Pool boiling heat transfer in narrow horizontal annular crevices, *J. Heat Transfer* **107**, 656 (1985).
48J. E. A. Ibrahim and R. L. Judd, An experimental investigation of the effect of subcooling on bubble growth and waiting time in nucleate boiling, *J. Heat Transfer* **107**, 168 (1985).
49J. S. Inada, Y. Miyasaka and K. Nishida, Transient heat transfer for a water drop impinging on a heated surface (1st report, effects of drop subcooling on the liquid–solid contact state), *Bull. J.S.M.E.* **28**(245), 2675 (1985).
50J. Kh. E. Ioarand, I. A. Kamenev and Yu. I Kallas, Conjoint heat and mass transfer in a multicomponent vapor–liquid system, *J. appl. Chem. U.S.S.R.* **58**, 401 (1985).
51J. Y. K. Kao and J. Weisman, A moving-front transition boiling model, *A.I.Ch.E. Jl* **31**, 529 (1985).
52J. M. Kawaji, S. Y. Ng, S. Banerjee and G. Yadigaroglu, Reflooding with steady and oscillatory injection: Part I—Flow regimes, void fraction, and heat transfer, *J. Heat Transfer* **107**, 670 (1985).
53J. Y. Kikuchi, T. Hori and I. Michiyoshi, Minimum film boiling temperature for cooldown of insulated metals in saturated liquid, *Int. J. Heat Mass Transfer* **28**, 1105 (1985).
54J. Yu. A. Kirichenko, K. V. Rusanov and E. G. Tyurina, Effect of orientation of an annular channel on heat exchange in the boiling of nitrogen under conditions of free motion, *J. Engng Phys.* **48**, 121 (1985).
55J. H. Kisley and A. Nir, Droplet evaporation by combined mechanisms in an ICF reactor, *Int. J. Heat Mass Transfer* **28**, 1441 (1985).
56J. V. V. Klimenko, A. A. Kurilenko, V. I. Panevin, V. P. Firsov and A. G. Shelepin, Experimental study of film boiling of cryogenic fluids under free convection, *Heat Transfer—Sov. Res.* **16**(4), 76 (1984).
57J. N. I. Kobasko, N. M. Fialko and N. O. Meranova, Numerical determination of the duration of the nucleate-boiling phase in the course of steel-plate hardening, *Heat Transfer—Sov. Res.* **16**(2), 130 (1984).
58J. G. R. Kudritskiy, Experimental data and correlation for boiling heat transfer on microsurfaces, *Heat Transfer—Sov. Res.* **16**(5), 90 (1984).
59J. M. A. Kusumowardhoyo and T. Hardianto, Two phase heat transfer correlation for multi-component

mixtures in the saturated flow-boiling regime, *Int. J. Heat Fluid Flow* **6**(4), 265 (1985).

60J. S. S. Kutateladze and I. G. Malenkov, Hydrodynamic analogy between heat transfer and nucleate boiling crisis in boiling and bubbling. Experimental data, *Heat Transfer—Sov. Res.* **16**(4), 1 (1984).

61J. L. Y. W. Lee, J. C. Chen and R. A. Nelson, Liquid–solid contact measurements using a surface thermocouple temperature probe in atmospheric pool boiling water, *Int. J. Heat Mass Transfer* **28**, 1415 (1985).

62J. A. I. Leont'yev, Extension of limiting friction and heat transfer relationships to turbulent gas–liquid flow, *Heat Transfer—Sov. Res.* **16**(3), 1 (1984).

63J. J. H. Lienhard, On the two regimes of nucleate boiling, *J. Heat Transfer* **107**, 262 (1985).

64J. A. A. Malyshev, V. M. Azarskov, G. N. Danilova, B. B. Zemskov and V. K. Kirin, True volumetric vapor content of two-phase freon flows, *J. Engng Phys.* **48**, 128 (1985).

65J. V. L. Malyshev, L. A. Uvarova and A. S. Fel'dblym, Theoretical calculation of gas flows during isothermal vaporization of multicomponent liquids in narrow channels of different cross sections, *High Temp.* **23**, 274 (1985).

66J. I. Michiyoshi, N. Takenaka, T. Murata, T. Shiokawa and O. Takahashi, Effects of liquid level on boiling heat transfer in potassium layers on a horizontal plane heater, *J. Heat Transfer* **107**, 468 (1985).

67J. R. S. Miller, Photographic observations of bubble formation in flashing nozzle flow, *J. Heat Transfer* **107**, 750 (1985).

68J. K. Mishima and H. Nishihara, Effect of flow direction and magnitude on CHF for low pressure water in thin rectangular channels, *Nucl. Engng Des.* **86**, 165 (1985).

69J. K. Mishima, H. Nishihara and I. Michiyoshi, Boiling burnout and flow instabilities for water flowing in a round tube under atmospheric pressure, *Int. J. Heat Mass Transfer* **28**, 1115 (1985).

70J. O. Miyatake, T. Tomimura and Y. Ide, Enhancement of spray flash evaporation by means of the injection of bubble nuclei, *J. Sol. Energy Engng* **107**, 176 (1985).

71J. M. Monde, Critical heat flux in saturated forced convective boiling on a heated disk with an impinging jet, *Wärme- u. Stoffübertr.* **19**, 205 (1985).

72J. Y. H. Mori, Classification of configurations of two-phase vapor/liquid bubbles in an immiscible liquid in relation to direct-contact evaporation and condensation processes, *Int. J. Multiphase Flow* **11**, 571 (1985).

73J. A. Moriyama, K. Araki and T. Okouchi, Heat transfer from hot metal surface to an impinging water droplet in transitional boiling regime, *Trans. Iron Steel Inst. Japan* **25**(3), 198 (1985).

74J. D. G. Morris, C. B. Mullins and G. L. Yoder, Experimental study of rod bundle dispersed-flow film boiling with high-pressure water, *Nucl. Technol.* **69**, 82 (1985).

75J. I. A. Mudawwar, M. A. El-Masri, C. S. Wu and J. R. Ausman-Mudawwar, Boiling heat transfer and critical heat flux in high-speed rotating liquid films, *Int. J. Heat Mass Transfer* **28**, 795 (1985).

76J. Y. Murao, K. Fujiki and H. Akimoto, Experimental assessment of evaluation model for safety analysis on reflood phase of PWR-LOCA, *J. nucl. Sci. Technol.* **22**, 890 (1985).

77J. M. Murase and H. Suzuki, Evaluation of countercurrent gas/liquid flow in parallel channels with restricted ends, *Nucl. Technol.* **68**, 408 (1985).

78J. J. E. Myers, Short-lived sites in nucleate boiling, *A.I.Ch.E. Jl* **31**, 1441 (1985).

79J. H. Nagasaka, M. Katoh, T. Kagawa and H. Aoki, Thermal hydraulic behavior in upper plenum during refill-reflood phase of BWR LOCA, (I): CCFL and CCFL breakdown phenomena in upper plenum, *J. nucl. Sci. Technol.* **22**, 903 (1985).

80J. A. Nakayama and H. Koyama, On asymptotic results for film pool boiling on vertical surfaces, *Int. J. Multiphase Flow* **11**, 565 (1985).

81J. A. Nakayama and H. Koyama, Two-phase boundary layers in laminar film boiling, *Wärme- u. Stoffübertr.* **19**, 211 (1985).

82J. P. J. Nelson and B. M. Burnside, Boiling the immiscible water/*n*-nonane system from a tube bundle, *Int. J. Heat Mass Transfer* **28**, 1257 (1985).

83J. E. I. Nesis and K. A. Akiev, Heat exchange in the boiling of mixtures in strong gravitational fields, *J. Engng Phys.* **48**, 6 (1985).

84J. T. Nosoko and Y. H. Mori, Vaporization of drops of a denser, volatile liquid dropped onto a surface of another liquid, *J. Heat Transfer* **107**, 384 (1985).

85J. M. Ochiai, Experiment on transient heat transfer in closed narrow channel, *J. nucl. Sci. Technol.* **22**, 47 (1985).

86J. S. Olek and Y. Zvirin, Effect of temperature dependent properties on the rewetting velocity, *Int. J. Multiphase Flow* **11**, 577 (1985).

87J. Yu. M. Pavlov, V. I. Antipov and V. A. Leonov, The boiling crisis in natural circulation of helium in vertical channels, *Heat Transfer—Sov. Res.* **16**(4), 64 (1984).

88J. S. A. Potekhin, V. A. Shugayev and V. I. Babich, Heat transfer and film-boiling crisis with helium on a flat horizontal surface, *Heat Transfer—Sov. Res.* **16**(4), 70 (1984).

89J. N. Rajendra Prasad, J. S. Saini and R. Prakash, The effect of heater wall thickness on heat transfer in nucleate pool-boiling at high heat flux, *Int. J. Heat Mass Transfer* **28**, 1367 (1985).

90J. A. T. Prata and E. M. Sparrow, Diffusion-driven nonisothermal evaporation, *J. Heat Transfer* **107**, 239 (1985).

91J. A. T. Prata and E. M. Sparrow, Forced convection evaporation from a cavity containing a liquid whose surface is curved by capillarity: computations in interlocking rectangular and cylindrical domains, *Numer. Heat Transfer* **8**, 667 (1985).

92J. G. K. Raina and P. D. Grover, Direct contact heat transfer with change of phase: theoretical model incorporating sloshing effects, *A.I.Ch.E. Jl* **31**, 507 (1985).

93J. Yu. S. Ryazantsev, Thermocapillary motion of a reacting droplet in a chemically active medium, *Fluid Dynam.* **20**, 491 (1985).

94J. T. Sakai and F. Hirano, Effect of molecular weight distribution of mineral oils on their boiling heat transfer behavior, *Wear* **104**(3), 259 (1985).

95J. J. E. Sgheiza and J. E. Myers, Behavior of nucleation sites in pool boiling, *A.I.Ch.E. Jl* **31**, 1605 (1985).

96J. A. Sharan and J. H. Lienhard, On predicting burnout in the jet-disk configuration, *J. Heat Transfer* **107**, 398 (1985).

97J. A. Sharan, J. H. Lienhard and R. Kaul, Corresponding states correlations for pool and flow boiling burnout, *J. Heat Transfer* **107**, 392 (1985).

98J. L. A. Shneider and Yu. I. Landa, Examination of heat transfer in boiling of cryogenic agents of expansion microcryogenic systems, *Chem. Pet. Engng* **21**(1–2), 19 (1985).

99J. Ye. L. Smirnov, Critical heat flux in flooding in vertical channels, *Heat Transfer—Sov. Res.* **16**(3), 19 (1984).

100J. M. Sobajima and H. Adachi, Coolability study on two-bundle scale flow blockage in the reflood process, *Nucl. Engng Des.* **86**, 345 (1985).

101J. T. Soga, A kinetic theory analysis of evaporation and condensation of a diatomic gas, *Phys. Fluids* **28**, 1280 (1985).

102J. T. Soga, A kinetic theory analysis of evaporation from a droplet, *J. phys. Soc. Japan* **54**, 2494 (1985).
103J. T. Soga, Kinetic analysis of evaporation from a droplet in a rarefied vapor, *Trans. Japan Soc. aeronaut. Space Sci.* **27**(78), 228 (1985).
104J. A. S. P. Solomon, J.-S. Shuen, Q.-F. Zhang and G. M. Faeth, Measurements and predictions of the structure of evaporating sprays, *J. Heat Transfer* **107**, 679 (1985).
105J. Y. Sudo, K. Miyata, H. Ikawa, M. Kaminga and M. Ohkawara, Experimental study of differences in DNB heat flux between upflow and downflow in vertical rectangular channels, *J. nucl. Sci. Technol.* **22**, 604 (1985).
106J. T. N. Tandon, H. K. Varma and C. P. Gupta, A void fraction model for annular two-phase flow, *Int. J. Heat Mass Transfer* **28**, 191 (1985).
107J. A. M. Tatenov, Local heat transfer from a cylinder to a flow of a bubbly water–air mixture, *Heat Transfer—Sov. Res.* **16**(3), 49 (1984).
108J. P. K. Tewari, R. K. Varma, M. P. S. Ramani and S. P. Mahajan, Studies on nucleate boiling of sodium chloride solutions at atmospheric and sub-atmospheric pressures, *Desalination* **52**, 335 (1985).
109J. J. R. Thomas, Jr., F//N-method in kinetic theory: I. Half-space problems, *Transport Theory statist. Phys.* **14**, 485 (1985).
110J. N. P. Timchenko, S. A. Zhukov, K. G. Shkadinskiy and V. I. Fedorov, Effect of the shape of the boiling curve on the dynamics of self-generated waves, *Heat Transfer—Sov. Res.* **16**(1), 67 (1984).
111J. V. I. Tolubinskiy, Ye. D. Domashev and V. F. Godunov, Boiling crisis in annuli with artificially-induced roughness, *Heat Transfer—Sov. Res.* **16**(5), 96 (1984).
112J. C. R. Tong, M. J. Tan and S. G. Bankoff, Model for convective boiling in a narrow eccentric annular gap, *J. Engng Gas Turbine Pwr* **107**, 613 (1985).
113J. V. B. Utkin, Experimental study of boiling in horizontal annuli, *Heat Transfer—Sov. Res.* **16**(3), 35 (1984).
114J. S. J. D. Van Strahlen and W. M. Sluyter, Mass diffusion-controlled bubble behavior in boiling and electrolysis and effect of bubbles on ohmic resistance, *J. appl. Electrochem.* **15**, 527 (1985).
115J. A. N. Vasil'yev and N. I. Khramov, Experimental investigation of the thermodynamic boiling crisis, *Heat Transfer—Sov. Res.* **16**(3), 42 (1984).
116J. B.-X. Wang and D.-H. Shi, A semi-empirical theory for forced-flow turbulent film boiling of subcooled liquid along a horizontal plate, *Int. J. Heat Mass Transfer* **28**, 1499 (1985).
117J. P. C. Wayner, Jr., C. Y. Tung, M. Tirumala and J. H. Yang, Experimental study of evaporation in the contact line region of a thin film of hexane, *J. Heat Transfer* **107**, 182 (1985).
118J. V. V. Yagov and O. N. Kaban'kov, Experimental study of boiling heat transfer in pipes at below-atmospheric pressure, *Heat Transfer—Sov. Res.* **16**(4), 53 (1984).
119J. V. V. Yagov and V. A. Puzin, Critical heat fluxes in forced-convection boiling of refrigerant-12 under conditions of local heat sources, *Heat Transfer—Sov. Res.* **16**(4), 47 (1984).
120J. A. I. Zanin and E. N. Sinitsyn, Boiling of superheated n-pentane in an electric field, *J. Engng Phys.* **48**, 125 (1985).

## CHANGE OF PHASE—CONDENSATION

1JJ. Th. Adamek, Berechnung des bezuglich dem Warmeubergang durch filmkondensation optimalen wellenprofils mit hilfe der variationsrechnung, *Z. angew. Math. Phys.* **36**, 669 (1985).
2JJ. R. K. Ahluwalia and K. H. Im, Mass transfer to trace species from a superheated stream to a subcooled surface, *Int. J. Heat Mass Transfer* **28**, 2061 (1985).
3JJ. S. V. Alekseenko, V. Ye. Nakoryakov and B. G. Polusaev, Wave formation on a vertical liquid flim, *A.I.Ch.E. Jl* **31**, 1446 (1985).
4JJ. V. P. Carey, Note on heat transfer to turbulent liquid falling films at high Prandtl number, *A.I.Ch.E. Jl* **31**, 1575 (1985).
5JJ. T.-H. Chang and J. N. Chung, Effects of surfactants on the motion and transport mechanisms of a condensing droplet in a high Reynolds number flow, *A.I.Ch.E. Jl* **31**, 1149 (1985).
6JJ. M. N. Chepurnoi, V. N. Lomakin, V. E. Shnaider and V. M. Chepurnoi, Study of the process of frost formation in finned air coolers, *J. Engng Phys.* **48**, 34 (1985).
7JJ. M. di Marzo and M. H. Casarella, Film condensation over a horizontal cylinder for combined gravity and forced flow, *J. Heat Transfer* **107**, 687 (1985).
8JJ. D. Fullarton, E. U. Schluender and L. Yueksel, Condensation of isopropanol–water mixtures (in German), *Chem. Engng Proc.* **19**(2), 103 (1985).
9JJ. D. Galamba and V. K. Dhir, Transient simultaneous condensation and melting of a vertical surface, *J. Heat Transfer* **107**, 812 (1985).
10JJ. J. Huhn, Film flow with superposition of various effects, *Wärme- u. Stoffübertr.* **19**, 131 (1985).
11JJ. F. M. Joos and R. W. L. Snaddon, Electrostatically enhanced film condensation, *J. Fluid Mech.* **156**, 23 (1985).
12JJ. W. Kirchner and S. G. Bankoff, Condensation effects in reactor transient, *Nucl. Sci. Engng* **89**, 310 (1985).
13JJ. W. S. Kisaalita, K. V. Lo, L. M. Staley and M. A. Tung, Condensation heat and mass transfer from steam/air mixtures to a retort pouch laminate, *Can. agric. Engng* **27**, 137 (1985).
14JJ. S. Kotake, Effects of a small amount of noncondensable gas on film condensation of multicomponent mixtures, *Int. J. Heat Mass Transfer* **28**, 407 (1985).
15JJ. R. Krupiczka, Effect of surface tension on laminar film condensation on a horizontal cylinder, *Chem. Engng Proc.* **19**(4), 199 (1985).
16JJ. S. S. Kutateladze, I. I. Gogonin and V. I. Sosunov, The influence of condensate flow rate on heat transfer in film condensation of stationary vapor on horizontal tube banks, *Int. J. Heat Mass Transfer* **28**, 1011 (1985).
17JJ. S. S. Kutateladze and I. I. Gogonin, Investigation of heat transfer in film condensation of flowing vapor on horizontal tube banks, *Int. J. Heat Mass Transfer* **28**, 1831 (1985).
18JJ. S. S. Kutateladze and I. I. Gogonin, Heat transfer in condensation of flowing vapor on a single horizontal cylinder, *Int. J. Heat Mass Transfer* **28**, 1019 (1985).
19JJ. F. Legay-Desesquelles and B. Prunet-Foch, Dynamic behavior of a boundary layer with condensation along a flat plate: comparison with suction, *Int. J. Heat Mass Transfer* **28**, 2363 (1985).
20JJ. K. Mangnall and D. Webb, Vacuum condensation, *Chem. Engng Lond.* **420**, 37 (1985).
21JJ. A. Nakayama and H. Koyama, An integral treatment of laminar and turbulent film condensation on bodies of arbitrary geometrical configuration, *J. Heat Transfer* **107**, 417 (1985).
22JJ. M. M. Rahman, A. M. Fathi and H. M. Soliman, Flow pattern boundaries during condensation: new experimental data, *Can. J. chem. Engng* **63**, 547 (1985).
23JJ. D. P. Sekulic, Irreversible condensation conditions near the cryosurface, *Int. J. Heat Mass Transfer* **28**, 1205 (1985).
24JJ. R. Sethumadhavan and M. Raja Rao, Condensation of steam on single start and multistart spiral wire-

wound horizontal tubes, *Ind. Engng Chem. Proc. Des. Dev.* **24,** 783 (1985).
25JJ. T. Sundararajan and P. S. Ayyaswamy, Heat and mass transfer associated with condensation on a moving drop; solution for intermediate Reynolds numbers by a boundary layer formulation, *J. Heat Transfer* **107,** 409 (1985).
26JJ. T. N. Tandon, H. K. Varma and C. P. Gupta, Prediction of flow patterns during condensation of binary mixtures in a horizontal tube, *J. Heat Transfer* **107**(2), 424 (1985).
27JJ. Y. Utaka, A. Saito and T. Tani, Study on dropwise condensation curves, *Bull. J.S.M.E.* **28**(240), 1150 (1985).
28JJ. H. Yamaguchi, M. Satomura and K. Matsuki, Refrigerant flow condensation in annulus passage (in Japanese), *Shapu Giho* **31,** 49 (1985).
29JJ. M. Yanadori, K. Huikata, Y. Mori and M. Uchida, Fundamental study of laminar film condensation heat transfer on a downward horizontal surface, *Int. J. Heat Mass Transfer* **28,** 1937 (1985).

## CHANGE OF PHASE—FREEZING AND MELTING

1JM. V. Alexiades, D. G. Wilson and A. D. Solomon, Macroscopic global modeling of binary alloy solidification processes, *Q. appl. Math.* **43**(2), 143 (1985).
2JM. C. Bénard, D. Gobin and F. Martinez, Melting in rectangular enclosures: experiments and numerical simulations, *J. Heat Transfer* **107**(4), 794 (1985).
3JM. S. Bulik, Air blow devices in melt spinning machines for chemical fibers: Part I. Phenomena in the subdie zone dependent on spinning conditions, *Polimery* **30**(7), 257 (1985).
4JM. S. Carra, Problems of fluid dynamics in crystal growth, *Prog. Crystal Growth Character.* **11**(1), 1 (1985).
5JM. Ch. Charach and P. Zoglin, Solidification in a finite, initially overheated slab, *Int. J. Heat Mass Transfer* **28**(12), 2261 (1985).
6JM. C.-K. Chen, Y.-M. Chang and J. W. Cleaver, Variational embedding technique to inward solidification subject to convection and radiation, *J. Energy Res. Technol., Trans. Am. Soc. mech. Engrs* **107**(1), 135 (1985).
7JM. K. C. Cheng and P. Sabhapathy, Determination of local heat transfer coefficients at the solid–liquid interface by heat conduction analysis of the solidified region, *J. Heat Transfer* **107**(3), 703 (1985).
8JM. F. B. Cheung, Analysis of freeze coating on a nonisothermal moving plate by a perturbation method, *J. Heat Transfer* **107**(3), 549 (1985).
9JM. J. J. Derby, R. A. Brown, F. T. Geyling, A. S. Jordan and G. A. Nikolakopoulou, Finite element analysis of a thermal-capillary model for liquid encapsulated Czochralski growth, *J. electrochem. Soc.* **132**(2), 470 (1985).
10JM. J. Dowden, M. Davis and P. Kapadia, The flow of heat and the motion of the weld pool in penetration welding with a laser, *J. appl. Phys.* **57**(9), 4474 (1985).
11JM. C. Esposito, G. Daurelio and A. Cingolani, On cutting and penetration welding processes with high power lasers, *Opt. Lasers Engng* **6**(1), 1 (1985).
12JM. D. Frederick and R. Greif, A method for the solution of heat transfer problems with a change of phase, *J. Heat Transfer* **107**(3), 520 (1985).
13JM. C. Gau and R. Viskanta, Effect of natural convection on solidification from above and melting from below a pure metal, *Int. J. Heat Mass Transfer* **28**(3), 573 (1985).
14JM. C. Gau and R. Viskanta, Effect of crystal anisotropy on heat transfer during melting and solidification of a metal, *J. Heat Transfer* **107**(3), 706 (1985).
15JM. A. G. Gillen and B. Cantor, Photocalorimetric cooling rate measurements on a Ni–5wt%Al alloy rapidly solidified by melt spinning, *Acta Metall.* **33**(10), 1813 (1985).
16JM. L. Gradón and D. Orlicki, Separation of liquid mixtures in the freezing-out process—mathematical description and experimental verification, *Int. J. Heat Mass Transfer* **28**(11), 1983 (1985).
17JM. S. C. Gupta, Two-dimensional solidification in a cylindrical mold with imperfect mold contact, *Int. J. Engng Sci.* **23**(9), 901 (1985).
18JM. S. C. Gupta, Axisymmetric solidification in a long cylindrical mold, *Appl. scient. Res.* **42**(3), 229 (1985).
19JM. J. M. Hill and A. Kucera, An approximate solution for planar solidification with Newton cooling of the surface, *Z. angew. Math. Phys.* **36**(5), 637 (1985).
20JM. T. Hirata and M. Ishihara, Freeze-off conditions of a pipe containing a flow of water, *Int. J. Heat Mass Transfer* **28**(2), 331 (1985).
21JM. A. Holz, On the significance of conservation laws in two-dimensional melting, *Physica* **131A**(1), 212 (1985).
22JM. S. D. Howison, J. R. Ockendon and A. A. Lacey, Singularity development in moving-boundary problems, *Q. Jl Mech. appl. Math.* **38**(3), 343 (1985).
23JM. J. S. Huang and A. J. Barduhn, The effect of natural convection on ice crystal growth rates in salt solutions, *A.I.Ch.E. Jl* **31**(5), 747 (1985).
24JM. S. C. Huang, R. P. Laforce, A. M. Ritter and R. P. Goehner, Rapid solidification characteristics in melt spinning a Ni-base superalloy, *Metall. Trans. A (Phys. Metall. Mater. Sci.)* **16A**(10), 1773 (1985).
25JM. B. Kalhori and S. Ramadhyani, Studies on heat transfer from a vertical cylinder, with or without fins, embedded in a solid phase change medium, *J. Heat Transfer* **107**(1), 44 (1985).
26JM. H. Kehtarnavaz and Y. Bayazitoglu, Solidification of binary mixture in a finite planar medium: saline water, *J. Heat Transfer* **107**(4), 964 (1985).
27JM. G. S. H. Lock and T. M. V. Kaiser, Icing on submerged tubes: a study of occlusion, *Int. J. Heat Mass Transfer* **28**(9), 1689 (1985).
28JM. Kh. I. Makeev, V. A. Vaisberg and F. I. Selitskii, Growing cylindrical silicon crystals cooled by immersion in fluid, *Tsvetnye Metally* **2,** 54 (1985).
29JM. J. Mennig and M. N. Özişik, Coupled integral equation approach for solving melting or solidification, *Int. J. Heat Mass Transfer* **28**(8), 1481 (1985).
30JM. A. G. Merzhanov, V. A. Raduchev and E. N. Rumanov, Interaction between a nonuniformly heated dielectric and a microwave field, *J. appl. Mech. Tech. Phys.* **26**(1), 5 (1985).
31JM. M. K. Moallemi and R. Viskanta, Experiments on fluid flow induced by melting around a migrating heat source, *J. Fluid Mech.* **157,** 35 (1985).
32JM. M. K. Moallemi and R. Viskanta, Melting around a migrating heat source, *J. Heat Transfer* **107**(2), 451 (1985).
33JM. J. S. Nelson and E. M. Sparrow, Freezing in the presence of rotation, *J. Heat Transfer* **107**(4), 804 (1985).
34JM. F. A. Nichols, Kinetics of interfacial motion and bubble movement by vapor transport for two-component solid solution, *J. appl. Phys.* **58**(1), 287 (1985).
35JM. T. Nishimura, S. Ito, H. Tsuboi and Y. Kawamura, Analysis of two-dimensional freezing by the finite-element method, *Int. chem. Engng* **25**(1), 105 (1985).

36JM. J. R. Ockendon, A. B. Taylor, S. H. Emerman and D. L. Turcotte, Geodynamic thermal runaway with melting, *J. Fluid Mech.* **152**, 301 (1985).
37JM. M. Okada, Heat transfer during melting around a vertical cylinder (1st report, analysis and experiments of the melting without subcooling), *Bull. J.S.M.E.* **28**(243), 2007 (1985).
38JM. F. O. Oruma, M. N. Özişik and M. A. Boles, Effects of non-grayness on melting and solidification of a semi-infinite, semi-transparent medium, *J. Franklin Inst.* **319**(5), 459 (1985).
39JM. P. V. Padmanabhan and M. V. Krishnamurthy, Freezing around a finite heat sink immersed in an infinite phase change medium, *Int. J. Heat Fluid Flow* **6**(2), 104 (1985).
40JM. J. Prusa and L. S. Yao, Effects of density change and subcooling on the melting of a solid around a horizontal heated cylinder, *J. Fluid Mech.* **155**, 193 (1985).
41JM. G. S. Reddy and J. A. Sekhar, Microstructure refinement with forced convection in aluminium and superalloys, *J. Mater. Sci.* **20**(10), 3535 (1985).
42JM. M. A. Ruggiero and J. W. Rutter, Microstructural defects and their origins in CD-CUCD//3 eutectic, *Mater. Sci. Technol.* **1**(7), 550 (1985).
43JM. A. Saito, Y. Utaka, M. Akiyoshi and K. Katayama, On the contact heat transfer with melting (1st report, experimental study), *Bull. J.S.M.E.* **28**(240), 1142 (1985).
44JM. A. Saito, Y. Utaka, M. Akiyoshi and K. Katayama, On the contact heat transfer with melting (2nd report, analytical study), *Bull. J.S.M.E.* **28**(242), 1703 (1985).
45JM. A. Saito, Y. Utaka, S. Nagakubo and K. Katayama, A heat transfer study on latent heat thermal energy storage systems—discussions of the inner structure to improve the heat removal process, *Heat Transfer—Japan. Res.* **13**(1), 92 (1985).
46JM. H. Saito, I. Tokura, K. Kishinami and S. Uemura, A study on frost formation (dimensionless parameters correlating density and thickness of frost layer), *Heat Transfer—Japan. Res.* **13**(4), 76 (1984).
47JM. J. D. Sauzade and J. Guion, Mono-dimensional model analysis of solidification phenomena with subcooling using the enthalpy method, *Int. J. Heat Mass Transfer* **28**(10), 1859 (1985).
48JM. P. Schvan and R. E. Thomas, Time-dependent heat flow calculation of cw laser-induced melting of silicon, *J. appl. Phys.* **57**(10), 4738 (1985).
49JM. N. Seki, S. Fukusako, K. Matsuo and S. Uemura, An analysis of incipient frost formation, *Wärme- u. Stoffübertr.* **19**(1), 9 (1985).
50JM. D. Shaozhang and Y. Xiaolin, Mathematical model of heat-transfer in continuously cast billets and its numerical calculation method adaptable to microcomputer use, *Kang T'ieh/Iron Steel, Peking* **20**(7), 8 (1985).
51JM. M. Shimizu and H. Takeuchi, Solidification structure of Al-Pb alloy powder by gas atomization process, *J. Japan Soc. Powd. Metall.* **32**(8), 289 (1985).
52JM. T. Soh, T. Nakagawa and Y. Takebayashi, Solidification analysis of castings, *Res. Dev. Kobe Steel, Ltd* **35**(2), 75 (1985).
53JM. A. D. Solomon, V. Alexiades, D. G. Wilson and J. Drake, On the formulation of hyperbolic Stefan problems, *Q. appl. Math.* **43**(3), 295 (1985).
54JM. E. M. Sparrow and T. A. Myrum, Inclination-induced direct-contact melting in a circular tube, *J. Heat Transfer* **107**(3), 533 (1985).
55JM. K. Wollhöver, Ch. Körber, M. W. Scheiwe and U. Hartmann, Unidirectional freezing of binary aqueous solutions: an analysis of transient diffusion of heat and mass, *Int. J. Heat Mass Transfer* **28**(4), 761 (1985).
56JM. K. Wollhöver, M. W. Scheiwe, U. Hartmann and Ch. Körber, On morphological stability of planar phase boundaries during unidirectional transient solidification of binary aqueous solutions, *Int. J. Heat Mass Transfer* **28**(5), 897 (1985).
57JM. Guo-Ping Zhang, L. M. Jiji and S. Weinbaum, Quasi-three-dimensional steady state analytic solution for melting or freezing around a buried pipe in a semi-infinite medium, *J. Heat Transfer* **107**(1), 245 (1985).

## RADIATION IN PARTICIPATING MEDIA AND SURFACE RADIATION

1K. M. A. G. Abushagur and N. George, Polarization and wavelength effects on the scattering from dielectric cylinders, *Appl. Opt.* **24**(23), 4141 (1985).
2K. K. S. Adzerikho and S. B. Kostyukevich, Radiation of two-phase media bounded by reflecting and radiating surfaces, *J. Engng Phys.* **48**(1), 82 (1985).
3K. N. Araki, K. Kobayasi and M.-A. Ochi, Measuring thermal diffusivity of liquids by stepwise heating (second report, heat loss characteristics and measurements on molten salts), *Heat Transfer—Japan. Res.* **14**(1), 56 (1985).
4K. C. Arduini, Thermal analytical model of bidimensional and unidimensional structural elements in a space environment, *Acta astronaut.* **12**(7–8), 609 (1985).
5K. F. H. Azad, Differential approximation to radiative transfer in semitransparent media, *J. Heat Transfer* **107**(2), 478 (1985).
6K. E. Bahar and S. Chakrabarti, Scattering and depolarization by large conducting spheres with rough surfaces, *Appl. Opt.* **24**(12), 1820 (1985).
7K. S. Bakan, Thermal stability of radiating fluids: the scattering problem, *Phys. Fluids* **27**(12), 2969 (1984).
8K. C. E. Batten, Spectral optical constants of soots from polarized angular reflectance measurements, *Appl. Opt.* **24**(8), 1193 (1985).
9K. E. Battistelli and P. Bruscaglioni, A. Ismaelli and G. Zaccanti, Use of two scaling relations in the study of multiple-scattering effects on the transmittance of light beams through a turbid atmosphere, *J. opt. Soc. Am. A* **2**(6), 903 (1985).
10K. R. E. Bedford, C. K. Ma, Z. Chu, Y. Sun and S. Chen, Emissivities of diffuse cavities: 4: isothermal and nonisothermal cylindro-inner-cones, *Appl. Opt.* **24**(18), 2971 (1985).
11K. P. Berdahl, Radiant refrigeration by semiconductor diodes, *J. appl. Phys.* **58**(3), 1369 (1985).
12K. D. B. Betts, F. J. J. Clarke, L. J. Cox and J. A. Larkin, Infrared reflection properties of five types of black coating for radiometric detectors, *J. Phys. E: scient. Instrum.* **18**(8), 689 (1985).
13K. C. F. Bohren and G. Koh, Forward-scattering corrected extinction by nonspherical particles, *Appl. Opt.* **24**(7), 1023 (1985).
14K. R. S. Bretzlaff, Radiant-energy penetration effect in the thermal-diffusivity flash technique for layered and porous polymers, *J. appl. Phys.* **58**(8), 2816 (1985).
15K. M. A. Brosmer and C. L. Tien, Infrared radiation properties of methane at elevated temperatures, *J. quant. Spectrosc. radiat. Transfer* **33**(5), 521 (1985).
16K. M. A. Brosmer and C. L. Tien, Thermal radiation properties of acetylene, *J. Heat Transfer* **107**(4), 943 (1985).
17K. G. E. Caledonia, R. H. Krech and T. Wilkerson, Measurements of the CO first overtone bandstrength at elevated temperatures, *J. quant. Spectrosc. radiat. Transfer* **34**(2), 183 (1985).

18K. G. Camera-Roda, M. Bertelà and F. Santarelli, Mixed laminar convection in a participating irradiated fluid—1, *Numer. Heat Transfer* **8**(4), 429 (1985).

19K. M. W. P. Cann, R. W. Nicholls, P. L. Roney, A. Blanchard and F. D. Findlay, Spectral line shapes for carbon dioxide in the 4.3-$\mu$m band, *Appl. Opt.* **24**(9), 1374 (1985).

20K. R. Caps, J. Fricke and H. Reiss, Radiative heat transfer in anisotropically scattering fiber insulations, *High Temp.—High Press.* **17**(3), 303 (1985).

21K. Y. A. Cengel and M. N. Özişik, Radiation transfer in an anisotropically scattering plane-parallel medium with space-dependent albedo $\omega(x)$, *J. quant. Spectrosc. radiat. Transfer* **34**(3), 263 (1985).

22K. B. C. Choi and S. W. Churchill, A technique for obtaining approximate solutions for a class of integral equations arising in radiative heat transfer, *Int. J. Heat Fluid Flow* **6**(1), 42 (1985).

23K. R. W. Claus, G. M Neely and F. M. Humenik, Flame radiation and liner heat transfer in a tubular-can combustor, *J. Propul. Pwr* **1**(4), 270 (1985).

24K. A. Coppalle and P. Vervisch, Spectral emissivity of the 4.3-$\mu$m $CO_2$ band at high temperature, *J. quant. Spectrosc. radiat. Transfer* **33**(5), 465 (1985).

25K. C. Cousin, R. LeDoucen, C. Boulet and A. Henry, Temperature dependence of the absorption in the region beyond the 4.3-$\mu$m band head of $CO_2$.2: $N_2$ and $O_2$ broadening, *Appl. Opt.* **24**(22), 3899 (1985).

26K. A. L. Crosbie and G. W. Davidson, Dirac-delta function approximations to the scattering phase function, *J. quant. Spectrosc. radiat. Transfer* **33**(4), 391 (1985).

27K. A. L. Crosbie and R. L. Dougherty, Two-dimensional linearly anisotropic scattering in a finite-thick cylindrical medium exposed to a laser beam, *J. quant. Spectrosc. radiat. Transfer* **33**(5), 487 (1985).

28K. A. L. Crosbie and M. Pattabongse, Application of the singularity-subtraction technique to isotropic scattering in a planar layer, *J. quant. Spectrosc. radiat. Transfer* **34**(6), 473 (1985).

29K. A. L. Crosbie and R. G. Schrenker, Multiple scattering in a two-dimensional rectangular medium exposed to collimated radiation, *J. quant. Spectrosc. radiat. Transfer* **33**(2), 101 (1985).

30K. D. M. De Faveri, G. Fumarola, C. Zonato and G. Ferraiolo, Estimate flare radiation intensity, *Hydrocarbon Proc.* **64**(5), 89 (1985).

31K. G. Desrayaud and G. Lauriat, Natural convection of a radiating fluid in a vertical layer, *J. Heat Transfer* **107**(3), 710 (1985).

32K. M. Dragovan and S. H. Moseley, Resonant bolometer—results and an application, *Appl. Opt.* **24**(12), 1770 (1985).

33K. D. Duffy, The temperature distribution within a sphere placed in a directed uniform heat flux and allowed to radiatively cool, *J. Heat Transfer* **107**(1), 28 (1985).

34K. W. L. Dunn and C. E. Siewart, The searchlight problem in radiation transport: some analytical and computational results, *Z. angew. Math. Phys.* **36**(4), 581 (1985).

35K. J.-I. Eichberger, Calculation of geometric configuration factors in an enclosure whose boundary is given by an arbitrary polygon in the plane, *Wärme- u. Stoffübertr.* **19**(4), 269 (1985).

36K. A. F. Emery, H. R. Mortazavi and M. N. Nguyen, Radiation exchange in large space structures and frames, *A.I.A.A. Jl* **23**(6), 947 (1985).

37K. J. Fendley, An analysis of the measuring procedure for the integrating sphere spectrophotometer, *Sol. Energy* **35**(3), 281 (1985).

38K. N. N. Fomin, Unsteady radiation field in an optically thick atmosphere, *Izv. Akad. Nauk SSSR* **21**(1), 42 (1985).

39K. R. D. M. Garcia and C. E. Siewert, Benchwork results in radiative transfer, *Transport Theory statist. Phys.* **14**(4), 437 (1985).

40K. E. Garelis, T. E. Rudy and R. B. Hickman, A numerical solution to the steady-state equation of transfer in azimuthally symmetric geometries, *J. quant. Spectrosc. radiat. Transfer* **34**(5), 417 (1985).

41K. K. Gindele, M. Köhl and M. Mast, Spectral reflectance measurements using an integration sphere in the infrared, *Appl. Opt.* **24**(12), 1757 (1985).

42K. D. E. Glass, M. N. Özişik and B. Vick, Hyperbolic heat conduction with surface radiation, *Int. J. Heat Mass Transfer* **28**(10), 1823 (1985).

43K. D. S. Goodman, Linear systems methods in some problems of radiative transfer between parallel planes, *Appl. Opt.* **24**(19), 3240 (1985).

44K. J. E. Gordon, Simple method for approximating Mie scattering, *J. opt. Soc. Am. A* **2**(2), 156 (1985).

45K. J. I. Gordon and R. W. Johnson, Integrating nephelometer: theory and implications, *Appl. Opt.* **24**(16), 2721 (1985).

46K. S. Green, Calculation of pressure-broadened linewidths for CO in Ar, *J. quant. Spectrosc. radiat. Transfer* **33**(4), 299 (1985).

47K. W. L. Grosshandler and H. D. Nguyen, Application of the total transmittance nonhomogeneous radiation model to methane combustion, *J. Heat Transfer* **107**(2), 445 (1985).

48K. W. L. Grosshandler and J.-P. Vantelon, Predicting soot radiation in laminar diffusion flames, *Combust. Sci. Technol.* **44**(3–4), 125 (1985).

49K. W. S. Helliwell, Finite-difference solution to the radiative-transfer equation for in-water radiance, *J. opt. Soc. Am. A* **2**(8), 1325 (1985).

50K. W. G. Houf, F. P. Incropera and R. Viskanta, Thermal conditions in irradiated, slowly moving liquid layers, *J. Heat Transfer* **107**(1), 92 (1985).

51K. K. K. Hunt and N. J. McCormick, Numerical test of an inverse method for estimating single-scattering parameters from pulsed multiple-scattering experiments, *J. opt. Soc. Am. A* **2**(11), 1965 (1985).

52K. Y. Itaya and M. Hasatani, Effect of isotropic scattering on unsteady heat transfer in a fine-particle semitransparent liquid suspension layer heated by collimated radiation, *J. chem. Engng Japan* **18**(2), 119 (1985).

53K. Y. Itaya, N. Arai and M. Hasatani, Unsteady heat transfer characteristics in a semitransparent medium heated by diffuse and collimated radiation, *J. chem. Engng Japan* **18**(1), 87 (1985).

54K. J. Janata, Radiative heat transfer in isothermal-gas-filled enclosure, *Acta techn. CSAV* **30**(5), 539 (1985).

55K. K. Kamiuto and I. Kinoshita, Radiative properties of sodium mist, *J. nucl. Sci. Technol.* **22**(6), 442 (1985).

56K. C. T. Kelley and T. W. Mullikin, Why does the $F_N$-method work? *Transport Theory statist. Phys.* **14**(4), 513 (1985).

57K. T. K. Kim and T. F. Smith, Radiative and conductive transfer for a real gas in a cylindrical enclosure with gray walls, *Int. J. Heat Mass Transfer* **28**(12), 2269 (1985).

58K. Y. Kim and D. L. Jaggard, Inverse black body radiation: an exact closed-form solution, *IEEE Trans. Antennas Propagation* **AP-33**(7), 797 (1985).

59K. V. Ya. Klabukov, L. T. Grebenshchikov and E. A. Kosolapov, Experimental-theoretical study of influence of governing parameters on thermal radiation of high-temperature two-phase flow, *Sov. Aeronaut.* **28**(1), 36 (1985).

60K. W. Klose and M. Lent, Prediction of the thermal radiation in atherm media with an extendable *n*-flux-method, *Wärme- u. Stoffübertr.* **19**(1), 73 (1985).
61K. M. E. Larsen and J. R. Howell, The exchange factor method: an alternative basis for zonal analysis of radiating enclosures, *J. Heat Transfer* **107**(4), 936 (1985).
62K. P. Latimer, Experimental tests of a theoretical method for predicting light scattering by aggregates, *Appl. Opt.* **24**(19), 3231 (1985).
63K. R. LeDoucen, C. Cousin, C. Boulet and A. Henry, Temperature dependence of the absorption in the region beyond the 4.3 $\mu$m band head of $CO_2$ 1: pure $CO_2$ case, *Appl. Opt.* **24**(6), 897 (1985).
64K. S. A. Levchenko, G. I. Rudin, N. N. Stolovich and S. I. Shabunya, Nonresonance radiation absorption in a transparent fluid under the influence of a nanosecond laser pulse, *Heat Transfer—Sov. Res.* **16**(3), 117 (1984).
65K. F.-S. Lien, C.-K. Chen and J. W. Cleaver, Radiative effect on the conjugated forced convection-conduction analysis of heat transfer in a plate fin, *A.I.A.A. Jl* **23**(10), 1645 (1985).
66K. J. J. Loftus and R. D. Peacock, Wall and ceiling protection for heating appliances, *Fire Technol.* **21**(3), 213 (1985).
67K. T. Makino, I. Sakai, H. Kinoshita and T. Kumitomo, Thermal radiation properties of ceramic materials, *Heat Transfer—Japan. Res.* **13**(4), 33 (1984).
68K. K. Malachowski, Modification of the matrix-operator method for solving the equation of radiative transfer, *J. quant. Spectrosc. radiat. Transfer* **34**(2), 169 (1985).
69K. J. V. Martonchik and D. J. Diner, Three-dimensional radiative transfer using a Fourier-transform matrix-operator method, *J. quant. Spectrosc. radiat. Transfer* **34**(2), 133 (1985).
70K. H. Masuda and M. Higano, Transient calorimetric technique for measuring total hemispherical emissivities of metals with rigorous evaluation of heat loss through thermocouple leads, *J. opt. Soc. Am. A* **2**(11), 1877 (1985).
71K. F. U. Mathiak, Calculation of form-factors for plane areas with polygonal boundaries, *Wärme- u. Stoffübertr.* **19**(4), 273 (1985).
72K. L. K. Matthews, R. Viskanta and F. P. Incropera, Combined conduction and radiation heat transfer in porous materials heated by intense solar radiation, *J. Sol. Energy Engng* **107**(1), 29 (1985).
73K. A. T. Mattick and A. Hertzberg, Liquid droplet radiator performance studies, *Acta astronaut.* **12**(7–8), 591 (1985).
74K. M. E. McCabe and M. Van Migom, Application of transparent enclosure theory to solar energy absorption by cylindrical tubes in sunspaces, *J. Sol. Energy Engng* **107**(1), 5 (1985).
75K. N. J. McCormick, Methods for estimating the similarity parameter of clouds from internal measurements of the scattered radiation field, *J. quant. Spectrosc. radiat. Transfer* **33**(1), 63 (1985).
76K. M. P. Mengüc and R. Viskanta, On the radiative properties of polydispersions: a simplified approach, *Combust. Sci. Technol.* **44**(3–4), 143 (1985).
77K. M. P. Mengüc and R. Viskanta, Radiative transfer in three-dimensional rectangular enclosures containing inhomogeneous, anisotropically scattering media, *J. quant. Spectrosc. radiat. Transfer* **33**(6), 533 (1985).
78K. R. S. Mikhalchenko, V. F. Getmanets, N. P. Pershin and Yu. V. Batozskii, Theoretical and experimental investigation of radiative–convective heat transfer in multilayer insulation, *Cryogenics* **25**(5), 275 (1985).
79K. K. C. Mills and W. A. Wakeham, Effect of radiation on thermal transport measurements, *High Temp.—High Press.* **17**(3), 343 (1985).
80K. N. A. Nilsson, T. S. Eriksson and C. G. Granqvist, Infrared-transparent convection shields for radiative cooling: initial results on currugated polyethylene foils, *Solar Energy Mater.* **12**(5), 327 (1985).
81K. M. Nishimura, M. Kuraishi, Y. Bando and H. Jojima, Influence of the spectral distribution of incident radiation on the effect of internal heating in infrared drying of coated films, *Heat Transfer—Japan. Res.* **13**(2), 30 (1984).
82K. J. C. Oelund and N. J. McCormick, Sensitivity of multiple-scattering inverse transport methods to measurement errors, *J. opt. Soc. Am. A* **2**(11), 1972 (1985).
83K. T. Oguri, A. Takeda, K. Torii and S. Inaba, Radiation heat transfer of combustion flames in a diesel engine, *Bull. J.S.M.E.* **28**(238), 638 (1985).
84K. Y. Ohwada, Numerical calculation of bandlimited effective emissivity, *Appl. Opt.* **24**(2), 280 (1985).
85K. T. Okamoto, S. Kawata and S. Minami, Optical method for resolution enhancement in photodiode array Fourier transform spectroscopy, *Appl. Opt.* **24**(23), 4221 (1985).
86K. F. O. Oruma, M. N. Özişik and M. A. Boles, Effects of anistropic scattering on melting and solidification of a semi-infinite, semi-transparent medium, *Int. J. Heat Mass Transfer* **28**(2), 441 (1985).
87K. R. C. Peterson and N. M. Laurendeau, Emittance of yttrium–beryllium oxide thermocouple coating, *Combust. Flame* **60**(3), 279 (1985).
88K. V. K. Pustovalov and G. S. Romanov, The theory of heating and evaporation of a spherical particle exposed to optical radiation, *Int. J. Heat Mass Transfer* **28**(1), 277 (1985).
89K. B. V. Putyatin, Exact solution of the heat propagation equations in a radiative medium, *J. appl. Math. Mech.* **48**(3), 369 (1984).
90K. D. F. G. Rault, Radiation energy receiver for solar propulsion systems, *J. Spacecraft Rockets* **22**(6), 642 (1985).
91K. J. Reinkenhof, Transient heat transfer in cooled cavities with apertures permeable to radiation, *Wärme- u. Stoffübertr.* **19**(1), 85 (1985).
92K. H. Reiss and B. Ziegenbein, An experimental method to determine temperature-dependent extinction coefficients and solid thermal conductivities of glass fibre insulations in calorimetric measurements, *Int. J. Heat Mass Transfer* **28**(2), 459 (1985).
93K. M. N. Rolin and F. B. Yurevich, Evaluating certain ambiguities in results of calculations of radiative-convective heat exchange in hypersonic flow about a body, *High Temp.* **23**(2), 282 (1985).
94K. J. A. Roux and A. M. Smith, Biangular reflectance for an absorbing and isotropically scattering medium, *A.I.A.A. Jl* **23**(4), 624 (1985).
95K. S. P. Rusin, Application of optico-geometric functions to the computation of radiative heat transfer in cavity systems, *Izv. Sibirskogo Otdeleniya Akad. Nauk SSSR* **10**, 3 (1985).
96K. B. Rutily and J. Bergeat, The Neumann solution of the multiple scattering problem in a plane-parallel medium—I. The infinite medium, *J. quant. Spectrosc. radiat. Transfer* **33**(4), 373 (1985).
97K. E. A. Saad, A. A. Hendi and S. A. El Wakil, Radiation transfer by a finite-emitting inhomogeneous medium, *J. quant. Spectrosc. radiat. Transfer* **34**(1), 65 (1985).
98K. Y. Sakurai and D. K. Edwards, Transient temperature distributions in a radiantly heated hollow cylinder, *J. Spacecraft Rockets* **22**(6), 665 (1985).

99K. P. Scheuerpflug, R. Caps, D. Buettner and J. Fricke, Apparent thermal conductivity of evacuated, $SiO_2$-aerogel tiles under variation of radiative boundary conditions, *Int. J. Heat Mass Transfer* **28**(12), 2299 (1985).
100K. S. Seedorf, H. J. Eichler and H. Koch, Detector for the VUV to the IR using sodium salicylate as a combined fluorescent and reflective coating, *Appl. Opt.* **24**(9), 1335 (1985).
101K. N. Selçuk, Exact solutions for radiative heat transfer in box-shaped furnaces, *J. Heat Transfer* **107**(3), 648 (1985).
102K. A. B. Shapiro, Computer implementation, accuracy and timing of radiation view factor algorithms, *J. Heat Transfer* **107**(3), 730 (1985).
103K. C. E. Siewert, On the singular components of the solution to the searchlight problem in radiative transfer, *J. quant. Spectrosc. radiat. Transfer* **33**(6), 551 (1985).
104K. C. E. Siewert and J. R. Thomas, Jr., Radiative transfer calculations in spheres and cylinders, *J. quant. Spectrosc. radiat. Transfer* **34**(1), 59 (1985).
105K. T. F. Smith and S. S. Severin, Development of the finite analytic with radiation method, *J. Heat Transfer* **107**(3), 735 (1985).
106K. T. F. Smith, Z. F. Shen and A. M. Alturki, Radiative and convective transfer in a cylindrical enclosure for a real gas, *J. Heat Transfer* **107**(2), 482 (1985).
107K. A. Soufiani, J. M. Hartmann and J. Taine, Validity of band-model calculations for $CO_2$ and $H_2O$ applied to radiative properties and conductive–radiative transfer, *J. quant. Spectrosc. radiat. Transfer* **33**(3), 243 (1985).
108K. E. M. Sparrow and M. A. Ansari, Convective–radiative heat transfer from a horizontal finned tube with sidewall or sidewall/floor interactions, *Int. J. Heat Mass Transfer* **28**(3), 641 (1985).
109K. G. Spiga and M. Spiga, Effects of boundary reflection on radiative heat transfer in participating media, *Int. J. Heat Fluid Flow* **6**(4), 235 (1985).
110K. G. Spiga and M. Spiga, Radiant heat transfer in participating media bounded by reflecting surfaces, *Ann. nucl. Energy* **12**(6), 307 (1985).
111K. S. V. Stepanov and M. A. Berkovskii, Radiation characteristics of a plane layer of a strongly scattering, weakly absorbing medium with an arbitrary character of reflection at the boundaries, *High Temp.* **23**(2), 288 (1985).
112K. W. Q. Tao and E. M. Sparrow, Ambiguities related to the calculation of radiant heat exchange between a pair of surfaces, *Int. J. Heat Mass Transfer* **28**(9), 1786 (1985).
113K. H. L. Tardy, Flux concentrators in integrating sphere experiments: potential for increased detector signal, *Appl. Opt.* **24**(22), 3914 (1985).
114K. Y. Terauchi, H. Nadano and M. Kohno, On the temperature rise caused by moving heat sources (2nd report, calculation of temperature considering heat radiation from surface), *Bull. J.S.M.E.* **28**(245), 2789 (1985).
115K. M. E. Thomas and R. J. Nordstrom, Line shape model for describing infrared absorption by water vapor, *Appl. Opt.* **24**(21), 3526 (1985).
116K. S. T. Thynell and M. N. Özişik, Integrals involving an exponential integral function and exponentials arising in the solution of radiation transfer, *J. quant. Spectrosc. radiat. Transfer* **33**(3), 259 (1985).
117K. S. T. Thynell and M. N. Özişik, Radiation transfer in an isotropically scattering homogeneous solid sphere, *J. quant. Spectrosc. radiat. Transfer* **33**(4), 319 (1985).
118K. S. T. Thynell and M. N. Özişik, Radiation transfer in an isotropically scattering solid sphere with space dependent albedo, $\omega(r)$, *J. Heat Transfer* **107**(3), 732 (1985).
119K. R. A. Toth, Line positions and strengths of $CO_2$ in the 1200–1430 $cm^{-1}$ region, *Appl. Opt.* **24**(2), 261 (1985).
120K. V. A. Tovstonog, Analysis of heat exchange in light-diffusing materials heated by radiation, *Phys. Chem. Mater. Treat.* **19**(3), 189 (1985).
121K. A. V. Trofimenko, Radiation heat transfer in a system of semitransparent screens, *J. Engng Phys.* **48**(2), 220 (1985).
122K. D. S. Tsai and W. Strieder, Radiation across a spherical cavity having both specular and diffuse reflectance components, *Chem. Engng Sci.* **40**(1), 170 (1985).
123K. M. M. Tunç and A. Karakaş, Three-dimensional formulation of the radiant heat flux variation on a cylinder engulfed in flames, *J. Heat Transfer* **107**(4), 949 (1985).
124K. M. Tunç and J. E. S. Venart, Incident radiation from an engulfing pool fire to a horizontal cylinder—part I, *Fire Safety J.* **8**(2), 81 (1985).
125K. S. Twomey, Green's function formulae for the internal intensity in radiative transfer computations by matrix-vector methods, *J. quant. Spectrosc. radiat. Transfer* **33**(6), 575 (1985).
126K. H. Uchiyama, M. Nakajima and S. Yuta, Measurement of flame temperature distribution by IR emission computed tomography, *Appl. Opt.* **24**(23), 4111 (1985).
127K. S. A. El Wakil, M. H. Haggag, H. M. Machali and E. A. Saad, Radiation transfer in dispersive media, *J. Phys. D: appl. Phys.* **18**(8), 1469 (1985).
128K. B. W. Webb and R. Viskanta, Analysis of heat transfer and solar radiation absorption in an irradiated thin, falling molten salt film, *J. Sol. Energy Engng* **107**(2), 113 (1985).
129K. W. H. Wells and J. J. Sidorowich, Computational techniqes for radiative transfer by spherical harmonics, *J. quant. Spectrosc. radiat. Transfer* **33**(4), 347 (1985).
130K. W. W. Yuen and W. Dunaway, Calculation of the geometric-mean transmittance in a multi-dimensional absorbing and anisotropically-scattering medium, *Int. J. Heat Mass Transfer* **28**(8), 1507 (1985).
131K. W. W. Yuen and C. F. Ho, Analysis of two-dimensional radiative heat transfer in a gray medium with internal heat generation, *Int. J. Heat Mass Transfer* **28**(1), 17 (1985).

## NUMERICAL METHODS

1N. S. Acharya and S. V. Patankar, Use of an adaptive grid procedure for parabolic flow problems, *Int. J. Heat Mass Transfer* **28**(6), 1057 (1985).
2N. G. Athanasiadis, Direct and indirect boundary element methods for solving the heat conduction problem, *Comput. Meth. appl. Mech. Engng* **49**(1), 37 (1985).
3N. G. Athanasiadis, Numerical investigations of direct and indirect integral equations for solving the heat conduction problem, *Comput. Meth. appl. Mech. Engng* **49**(2), 203 (1985).
4N. M. C. Bhattacharya, Explicit conditionally stable finite difference equation for heat conduction problems, *Int. J. numer. Meth. Engng* **21**(2), 239 (1985).
5N. T. K. Bhattacharyya and A. B. Datta, Residual method of finite differencing for the elliptic transport problem and its application to cavity flow, *Int. J. numer. Meth. Fluids* **5**(1), 71 (1985).

6N. B. A. Bhutta, C. H. Lewis and F. A. Kautz II, Comparative analysis of numerical schemes for hypersonic re-entry flows, *J. Spacecraft Rockets* **22**(5), 541 (1985).

7N. G. Burgess and E. Mahajerin, On the numerical solution of Laplace's equation using personal computers, *Int. J. mech. Engng Educ.* **13**(1), 45 (1985).

8N. H. R. Busby and D. M. Trujillo, Numerical solution to a two-dimensional inverse heat conduction problem, *Int. J. numer. Meth. Engng* **21**(2), 349 (1985).

9N. G. F. Carey and R. Krishan, Continuation techniques for a penalty approximation of the Navier–Stokes equations, *Comput. Meth. appl. Mech. Engng* **49**(3), 265 (1985).

10N. A. Charette, R. T. Bui and G. Simard, Effect of stringent boundary conditions on the solution of a transient heat conduction problem, *Math. Comput. Simulation* **27**(1), 47 (1985).

11N. J. A. Dantzig and S. C. Lu, Modeling of heat flow in sand castings: Part I. The boundary curvature method, *Metall. Trans.* **16B**(2), 195 (1985).

12N. J. A. Dantzig and J. W. Wiese, Modeling of heat flow in sand castings: Part II. Applications of the boundary curvature method, *Metall. Trans.* **16B**(2), 203 (1985).

13N. D. E. Dietrich and J. J. Wormeck, An optimized implicit scheme for compressible reactive gas flow, *Numer. Heat Transfer* **8**(3), 335 (1985).

14N. V. I. Dmitriev and E. N. Solov'eva, Numerical solution method for the multiple-free-boundary Stefan problem with a variable critical temperature, *Moscow Univ. Comput. Math. Cybernet.* **1**, 30 (1985).

15N. J. Donea, T. Belytschko and P. Smolinski, A generalized Galerkin method for steady convection–diffusion problems with application to quadratic shape function elements, *Comput. Meth. appl. Mech. Engng* **48**(1), 25 (1985).

16N. A. Sh. Dorfman, Errors arising in convective-heat-transfer problems when using boundary conditions of the third kind, *High Temp.* **23**(3), 430 (1985).

17N. A. Sh. Dorfman, A new type of boundary condition in convective heat transfer problems, *Int. J. Heat Mass Transfer* **28**(6), 1197 (1985).

18N. D. J. Evans and A. R. Abdullah, New explicit method for the diffusion–convection equation, *Comput. Math. Applic.* **11**(1–3), 145 (1985).

19N. B. Farouk and T. Fusegi, Coupled solution of the vorticity-velocity formulation of the incompressible Navier–Stokes equations, *Int. J. numer. Meth. Fluids* **5**(12), 1017 (1985).

20N. M. Gellert, Discrete numerical solution of the generalized Boussinesq problem, *Int. J. numer. Meth. Engng* **21**(12), 2131 (1985).

21N. D. E. Glass, M. N. Ozişik, D. S. McRea and B. Vick, On the numerical solution of hyperbolic heat conduction, *Numer. Heat Transfer* **8**(4), 497 (1985).

22N. J. B. Greenberg, New self-adaptive grid method, *A.I.A.A. Jl* **23**(2), 317 (1985).

23N. R. S. Gupta and A. Kumar, Treatment of multi-dimensional moving boundary problems by coordinate transformation, *Int. J. Heat Mass Transfer* **28**(7), 1355 (1985).

24N. F. Haghighat, T. E. Unny and M. Chandrashekar, Stochastic modeling of transient heat flow through walls, *J. Sol. Energy Engng* **107**(3), 202 (1985).

25N. J. C. Heinrich, Finite element approximation to buoyancy-driven flows with cyclic boundary conditions, *Comput. Meth. appl. Mech. Engng* **48**(1), 91 (1985).

26N. T. Honma, Y. Tanaka and I. Kaji, Regular boundary element solutions to steady-state convective diffusion equations, *Engng Analysis* **2**(2), 95 (1985).

27N. J. S. Hsiao, An efficient algorithm for finite-difference analyses of heat transfer with melting and solidification, *Numer. Heat Transfer* **8**(6), 653 (1985).

28N. T. J. R. Hughes and T. E. Tezduyar, Analysis of some fully-discrete algorithms for the one-dimensional heat equation, *Int. J. numer. Meth. Engng* **21**(1), 163 (1985).

29N. U. K. Kaul and D. S. Chaussee, Comparative study of the parabolized Navier–Stokes code using various grid-generation techniques, *Comput. Fluids* **13**(4), 421 (1985).

30N. B. R. Latimer and A. Pollard, Comparison of pressure-velocity coupling solution algorithms, *Numer. Heat Transfer* **8**(6), 635 (1985).

31N. G. Lauriat and I. Altimir, New formulation of the SADI method for the prediction of natural convection flows in cavities, *Comput. Fluids* **13**(2), 141 (1985).

32N. M. P. Leonchuk, Z. V. Sivak and Yu. E. Shevtsov, Implicit method of solving mass-transfer equations in the variables velocity–vorticity, *Sov. Atomic Energy* **58**(3), 192 (1985).

33N. E. Livne and A. Glasner, A finite difference scheme for the heat conduction equation, *J. comput. Phys.* **58**(1), 59 (1985).

34N. H. P. Miller, Comparison of the flux-corrected transport method with other low-dispersive schemes for the two-dimensional linear advection equation, *RCA Rev.* **46**(2), 214 (1985).

35N. A. Mizukami, An implementation of the streamline-upwind/Petrov–Galerkin method for linear triangular elements, *Comput. Meth. appl. Mech. Engng* **49**(3), 357 (1985).

36N. A. Mizukami and T. J. R. Hughes, A Petrov–Galerkin finite element method for convection-dominated flows and accurate upwinding technique for satisfying the maximum principle, *Comput. Meth. appl. Mech. Engng* **50**(2), 181 (1985).

37N. R. A. Pasmanter, Exact and approximate solutions of the convection–diffusion equation, *Q. Jl Mech. appl. Math.* **38**(1), 1 (1985).

38N. M. K. Patel, N. C. Markatos and M. Cross, Critical evaluation of seven discretization schemes for convection–diffusion equations, *Int. J. numer. Meth. Fluids* **5**(3), 225 (1985).

39N. Q. T. Pham, A fast, unconditionally stable finite-difference scheme for heat conduction with phase change, *Int. J. Heat Mass Transfer* **28**(11), 2079 (1985).

40N. R. E. Phillips and F. W. Schmidt, Multigrid techniques for the solution of the passive scalar advection–diffusion equation, *Numer. Heat Transfer* **8**(1), 25 (1985).

41N. R. E. Phillips and F. W. Schmidt, A multilevel–multigrid technique for recirculating flows, *Numer. Heat Transfer* **8**(5), 573 (1985).

42N. C. Prakash and S. V. Patankar, Control volume-based finite-element method for solving the Navier–Stokes equations using equal-order velocity–pressure interpolation, *Numer. Heat Transfer* **8**(3), 259 (1985).

43N. S. Ramadhyani and S. V. Patankar, Solution of the convection–diffusion equation by a finite-element method using quadrilateral elements, *Numer. Heat Transfer* **8**(5), 595 (1985).

44N. K. R. Rapagopal and A. M. Sadegh, A boundary integral equation method for the study of some laminar forced convection problems, *Numer. Heat Transfer* **8**(4), 485 (1985).

45N. M. J. Raw and G. E. Schneider, New implicit solution procedure for multidimensional finite-difference modeling of the Stefan problem, *Numer. Heat Transfer* **8**(5), 559 (1985).

46N. M. J. Raw, G. E. Schneider and V. Hassani, Nine-noded quadratic control-volume-based finite element

for heat conduction, *J. Spacecraft Rockets* **22**(5), 523 (1985).
47N. J. G. Rice and R. J. Schnipke, A monotone streamline upwind finite method for convection-dominated flows, *Comput. Meth. appl. Mech. Engng* **48**(3), 313 (1985).
48N. P. J. Roache, Additional performance aspects of marching methods for elliptic equations, *Numer. Heat Transfer* **8**(5), 519 (1985).
49N. E. Runca, P. Melli and F. Sardel, An analysis of a finite-difference and a Galerkin technique applied to the simulation of advection and diffusion of air pollutants from a line source, *J. comput. Phys.* **59**(1), 152 (1985).
50N. T. M. Shih, Literature survey on numerical heat transfer (1982–1983), *Numer. Heat Transfer* **8**(1), 1 (1985).
51N. A. K. Singhal, Critical look at the progress in numerical heat transfer and some suggestions for improvement, *Numer. Heat Transfer* **8**(5), 505 (1985).
52N. P. J. Sullivan and H. Yip, A solution-scheme for the convective–diffusion equation, *Z. angew. Math. Phys.* **36**(4), 596 (1985).
53N. J. Thibault, Comparison of nine three-dimensional numerical methods for the solution of the heat diffusion equation, *Numer. Heat Transfer* **8**(3), 281 (1985).
54N. S. Uchikawa and R. Takeda, Use of a boundary-fitted coordinate transformation for unsteady heat conduction problems, in multi-connected regions with arbitrarily shaped boundaries, *J. Heat Transfer* **107**(2), 494 (1985).
55N. P. K. Wang, A potential and stream function analysis of two-dimensional steady-state convective diffusion equations involving Laplace fields, *Int. J. Heat Mass Transfer* **28**(6), 1089 (1985).
56N. T. Yoshimura and K. Ikuta, Inverse heat-conduction problem by finite-element formulation, *Int. J. Syst. Sci.* **16**(11), 1365 (1985).
57N. N. Zamani, Some remarks on the use of the boundary element method in transient heat conduction problems, *Math. Comput. Simulation* **27**(1), 61 (1985).
58N. M. Zedan and G. E. Schneider, A coupled strongly implicit procedure for velocity and pressure computation in fluid flow problems, *Numer. Heat Transfer* **8**(5), 537 (1985).

## TRANSPORT PROPERTIES

1P. R. T. Abramov, P. M. Kolesnikor, L. Krejci and I. Vogel, An inverse method of determining linear variations of thermophysical properties and heat fluxes, *Heat Transfer—Sov. Res.* **16**(3), 96 (1984).
2P. F. A. Ansari, V. Charan and H. K. Varma, Measurement of thermophysical properties and analysis of heat transfer during freezing of slab-shaped food commodities, *Int. J. Refrig.* **8**(2), 85 (1985).
3P. F. Bakhtar and K. Zidi, On the self diffusion of water vapour, *Proc. Inst. mech. Engrs, Part C, mech. Engng Sci.* **199**(2), 159 (1985).
4P. M. E. Baltatu, J. F. Ely, H. J. M. Hanley, M. S. Graboski, R. A. Perkins and E. D. Sloan, Thermal conductivity of coal-derived liquids and petroleum fractions, *Ind. Engng Chem. Proc. Des. Dev.* **24**(2), 325 (1985).
5P. R. L. Barker and M. L. Young, Thermal insulation properties of fabrics in high-intensity heat exposures, *Tappi J.* **68**(12), 62 (1985).
6P. D. Buettner, J. Fricke and H. Reiss, Thermal conductivity of evacuated load-bearing powder and fiber insulations under variable external load, *High Temp.—High Press.* **17**(3), 333 (1985).
7P. R. K. Y. Chan and D. A. Jackson, An automated falling-cylinder high pressure laser-Doppler viscometer, *J. Phys. E: scient. Instrum.* **18**, 510 (1985).
8P. K. S. Chang, R. T. Farrell and J. W. Snellen, Thermal properties of metallized plastics and polyethylene sheeting: a direct calorimetric assessment, *Ergonomics* **28**(11), 1557 (1985).
9P. J. G. Collins, S. J. Collocott and G. K. White, Thermal properties of stabilized zirconi at low temperatures, *Aust. J. Phys.* **38**(4), 617 (1985).
10P. B. Farnworth and P. A. Dolhan, Heat and water transport through cotton and polypropylene underwear, *Text Res. J.* **55**(10), 627 (1985).
11P. J. K. Fink and L. Leibowitz, Analysis of measurements of the thermal conductivity of liquid urania, *High Temp.—High Press.* **17**(1), 17 (1985).
12P. G. C. Glatzmaier and W. F. Ramirez, Simultaneous measurement of the thermal conductivity and thermal diffusivity of unconsolidated materials by the transient hot wire method, *Rev. scient. Instrum.* **56**(7), 1394 (1985).
13P. A. M. Golovin and V. E. Chizhov, The effective thermal conductivity of a suspension, *J. appl. Math. Mech.* **48**(2), 191 (1984).
14P. Z. Guozhen and X. Laoli, Measurements of viscosity and density by a vibrational sphere, *Rev. scient. Instrum.* **56**(8), 1639 (1985).
15P. I. Hatta, Y. Sasuga, R. Kato and A. Maesono, Thermal diffusivity measurement of thin films by means of an AC calorimetric method, *Rev. scient. Instrum.* **56**(8), 1643 (1985).
16P. H. Hatta and M. Taya, Effective thermal conductivity of a misoriented short fiber composite, *J. appl. Phys.* **58**(7), 2478 (1985).
17P. J. B. Henderson and S. C. Hagen, Radiant heat flux apparatus for measuring the thermal response of polymeric materials to high temperatures, *Polymer Composites* **6**(2), 110 (April 1985).
18P. J. H. B. Hoogland, H. R. Van Den Berg and N. J. Trappeniers, Measurements of the viscosity of sulfur hexafluoride up to 100 bar by a capillary-flow viscometer, *Physica* **134A**(1), 169 (1985).
19P. C. C. Huang, J. M. Viner and J. C. Novack, New experimental technique for simultaneously measuring thermal conductivity and heat capacity, *Rev. scient. Instrum.* **56**(7), 1390 (1985).
20P. J. Kestin, N. Imaishi, S. H. Nott, J. C. Nieuwoudt and J. V. Sengers, Viscosity of light and heavy water and their mixtures, *Physica* **134A**(1), 38 (1985).
21P. P. J. Kortbeek, M. J. P. Muringer, N. J. Trappeniers and S. N. Biswas, Apparatus for sound velocity measurements in gases up to 10 kbar: experimental data for argon, *Rev. scient. Instrum.* **56**(6), 1269 (1985).
22P. M. H. Kuok, H. K. Sy and K. L. Tan, Determination of thermal conductivity and its variation with density for polyurethane foam, *Reg. J. Energy Heat Mass Transfer* **7**(1), 17 (1985).
23P. P. C. Lanchester and K. A. Mohammed, Apparatus for heat capacity measurements of amorphous metal, *J. Phys. E: scient. Instrum.* **18**, 581 (1985).
24P. R. Lemlich, Semitheoretical equation to relate conductivity to volumetric foam density, *Ind. Engng Chem. Proc. Des. Dev.* **34**(3), 686 (1985).
25P. T.-H. Lin, J. S. Watson and P. W. Fischer, Thermal conductivity of iron–titanium powders, *J. Chem. Engng Data* **30**(4), 369 (1985).
26P. W. C. McCall, Thermal properties of sandwich panels, *Concrete Int.: Des. Construct.* **7**(1), 35 (1985).
27P. D. A. McIntyre, *In situ* measurements of *U*-values, *Bldg. Services Engng Res. Technol.* **6**(1), 1 (1985).
28P. Y. A. Mikhno and V. Z. Geller, Thermal conductivity of multicomponent saturated refrigerants, *Heat Transfer—Sov. Res.* **16**(1), 12 (1984).

29P. V. V. Mirkovich and T. A. Wheat, Thermal transport properties of CaO-stabilized zirconia with varying amounts of stabilization, *High Temp.—High Press.* **17**(1), 67(1), 67 (1985).

30P. D. K. Modi and S. M. Benner, Moisture gain of spray-applied insulations and its effect on effective thermal conductivity—Pt. I, *J. thermal Insulation* **8**, 259 (1985).

31P. T. Nemoto, S. Sasaki and Y. Hakuraku, Thermal conductivity of alumina and silicon carbide ceramics at low temperatures, *Cryogenics* **25**(9), 531 (1985).

32P. B. Nysten, L. Praus and J.-P. Issi, Thermal conductivity of pitch-derived fibres, *Physica D: appl. Phys.* **18**(7), 1311 (1985).

33P. D. J. O'Neil, Rheology and mass/heat transfer aspects of anaerobic reactor design, *Biomass* **8**(3), 205 (1985).

34P. H. Oya and N. Wada, Specific heat of ultrafine particles of Ag prepared by gas evaporation technique, *J. phys. Soc. Japan* **54**(9), 3228 (1985).

35P. K. N. Potter, R. M. Cruse and R. Horton, Tillage effects of soil thermal properties, *Soil Sci. Soc. Am. J.* **49**(4), 968 (July–August 1985).

36P. M. Rehman, V. G. K. Murti and M. R. Gupta, A novel precision type liquid conductivity measuring system, *J. Phys. E: scient. Instrum.* **18**, 902 (1985).

37P. M. R. Riazi and A. Faghri, Prediction of the thermal conductivity of gases at high pressures, *A.I.Ch.E. Jl* **31**, 164 (1985).

38P. M. R. Riazi and A. Faghri, Thermal conductivity of liquid and vapor hydrocarbon systems: pentanes and heavier at low pressures, *Ind. Engng Chem. Process Des. Dev.* **24**(2), 398 (1985).

39P. I. Rowlands, Organic coolant: key to simpler and cheaper thermal reactors? *Nucl. Engng Int.* **30**(376), 52 (1985).

40P. S. Sato, H. Furuya, Y. Nishino and M. Sugisaki, Thermal conductivity of simulated radioactive waste glass, *Nucl. Technol.* **70**(2), 235 (1985).

41P. P. Scheurpflug, R. Caps, D. Büttner and J. Fricke, Apparent thermal conductivity of evacuated $SiO_2$-aerogel tiles under variation of radiative boundary conditions, *Int. J. Heat Mass Transfer* **28**(12), 2299 (1985).

42P. G. H. Shaw and D. A. "Buzz" Caldwell, Device for measuring sound speeds in reactive liquids at high pressure and temperature, *Rev. scient. Instrum.* **56**(6), 1402 (1985).

43P. T. Ya. Shimchuk, Thermal diffusivity of partially crystalline polymers, *Heat Transfer—Sov. Res.* **16**(1), 136 (1984).

44P. H. Soumerai, Latent heat of vaporization of a widely diverse class of fluids, *J. Heat Transfer* **107**(2), 449 (1985).

45P. K. Srinivasan and M. V. Krishna Murthy, Corresponding states treatment of saturated liquid viscosity of some halogenated hydrocarbon refrigerants, *Int. J. Refrig.* **8**(1), 13 (1985).

46P. J. A. Stark and R. E. Taylor, Determination of thermal transport properties in ammonium perchlorate, *J. Propul. Pwr* **1**(5), 409 (1985).

47P. V. Z. Svoiskii, Heat-conduction coefficient of gas mixtures at high densities, *J. Engng Phys.* **48**(3), 305 (1985).

48P. S. W. Tam, L. Leibowitz, Y. Y. Liu, R. Blomquist and C. E. Johnson, Saturation phenomena and percolative transitions in the high temperature thermal conductivity of -LiA10//2, *J. Nucl. Mater.* 133–134 August 1985 Fusion Reaction Material, *Proc. 1st Int. Conference*, ICFRM-1, Tokyo (1984).

49P. A. S. Teja, P. A. Thurner and B. Pasumarti, Calculation of transport properties of mixtures for synfuels process design, *Ind. Engng Chem. Proc. Des. Dev.* **24**(2), 144 (1985).

50P. S. Torquato and G. Stell, Bounds of the effective thermal conductivity of a dispersion of fully penetrable spheres, *Int. J. Engng Sci.* **23**(3), 375 (1985).

51P. R. D. Trengove, K. R. Harris, H. L. Robjohns and P. J. Dunlop, Diffusion and thermal diffusion in some dilute binary gaseous systems between 195 and 400 K: tests of several asymmetric potentials using the infinite order Sudeden approximation, *Physica* **131A**(3), 506 (1985).

52P. T. S. Vinson and S. L. Jahn, Latent heat of frozen saline coarse-grained soil, *J. Geotech. Engng* **11**(5), 607 (1985).

53P. M. S. Wire, Z. Fisk and G. W. Webb, High-temperature specific heat by a pulse-heating method, *Rev. scient. Instrum.* **56**(6), 1223 (1985).

54P. R. H. Zee, J. F. Watters and R. D. Davidson, Technique to determine solute diffusion coefficient and partial pressure simultaneously, *Rev. scient. Instrum.* **56**(8), 1635 (1985).


## HEAT TRANSFER APPLICATIONS—HEAT PIPES AND HEAT EXCHANGERS


1Q. K. A. Antonopoulos, Heat transfer in tube banks under conditions of turbulent inclined flow, *Int. J. Heat Mass Transfer* **28**(9), 1645 (1985).

2Q. K. A. Antonopoulos, Heat transfer in tube assemblies under conditions of laminar axial, transverse and inclined flow, *Int. J. Heat Fluid Flow* **6**(3), 193 (1985).

3Q. L. A. Ashmantas, B. V. Dzyubenko, G. A. Dreitser and M. D. Segal, Unsteady-state heat transfer and mixing of a heat carrier in a heat exchanger with flow twisting, *Int. J. Heat Mass Transfer* **28**(4), 867 (1985).

4Q. E. Azad, F. Bahar and F. Moztarzadeh, Design of water-to-air gravity-assisted heat pipe heat exchanger, *J. Heat Recovery Syst.* **5**(2), 89 (1985).

5Q. E. Azad and F. Moztarzadeh, Design of air-to-water co-axial heat pipe heat exchanger, *J. Heat Recovery Syst.* **5**(3), 217 (1985).

6Q. B. S. Baclic, The application of the Galerkin method to the solution of the symmetric and balanced counterflow regenerator problem, *J. Heat Transfer* **107**(1), 214 (1985).

7Q. P. J. Banks, Prediction of heat and mass regenerator performance using nonlinear analogy method: Part 1—Basis, *J. Heat Transfer* **107**(1), 222 (1985).

8Q. P. J. Banks, Prediction of heat and mass regenerator performance using nonlinear analogy method: Part 2—Comparison of methods, *J. Heat Transfer* **107**(1), 230 (1985).

9Q. V. L. Barantsevich, S. I. Opryshko and V. Ya. Sasin, Methods for improving the maximum heat transfer capacity of axially grooved heat pipes, *Heat Transfer—Sov. Res.* **16**(4), 92 (1985).

10Q. A. Bar-Cohen and M. Jelinek, Optimum arrays of longitudinal, rectangular fins in convective heat transfer, *Heat Transfer Engng* **6**(3), 68 (1985).

11Q. M. K. Bassiouny and H. Martin, Temperature distribution in parallel channels of plate heat exchangers, *Chem.-Ing.-Tech.* **57**(4), 330 (1985).

12Q. M. K. Bassiouny and H. Martin, Temperature distribution in a four channel plate heat exchanger, *Heat Transfer Engng* **6**(2), 58 (1985).

13Q. I. I. Belyakov, M. A. Kvetnyi and D. A. Loginov, Effect of a ballast zone on the hydraulic stability of a direct-flow steam generator, *Sov. atom. Energy* **58**(3), 177 (1985).

14Q. S. Biykili, Optimum use of longitudinal fins of rectangular profiles in boiling liquids, *J. Heat Transfer* **107**(4), 968 (1985).

15Q. M. S. Bohn, Air molten salt direct-contact heat exchange, *J. Sol. Energy Engng* **107**(3), 208 (1985).

16Q. M. Bohnet, Fouling of heat transfer surfaces, *Chem.-Ing.-Tech.* **57**(1), 24 (1985).
17Q. M. K. Bologa, V. V. Pushkov and A. B. Berkov, Electric field induced heat transfer enhancement in a gas–solid suspension heat exchanger, *Int. J. Heat Mass Transfer* **28**(7), 1245 (1985).
18Q. M. Bottoni, B. Dorr, C. Homann and D. Struwe, BACCHUS-3D/SP, a computer program to describe transient three-dimensional single phase flow in LMFBR rod bundles, *Nucl. Technol.* **71**(1), 43 (1985).
19Q. L. Boumehdi, P. Guigon and J. F. Large, Heat recovery from solids in a raining bed exchanger, *J. Heat Recovery Syst.* **5**(5), 407 (1985).
20Q. O. M. Bragina, V. L. Leichuk, A. G. Sorokin and A. V. Turkin, A method for predicting pressure drop in a shell-and-tube heat exchanger with roughened tubes and a smooth shell surface, *Heat Transfer Engng* **6**(1), 26 (1985).
21Q. J. Buxmann and T. Hoffmann, Trockenkühlturm (Änderung des Wasserdurchsatzes bei geschlossenen Kühlkreisläufen mit Trockenkühlturm), *Brennstoff Wärme Kraft* **37**(6), 259 (1985).
22Q. P. I. Bystrov, V. S. Mikhailov, N. N. Garbuz and V. F. Goncharov, Hydraulic characteristics of heat exchangers on a base of porous structures, *High Temp.* **23**(2), 323 (1985).
23Q. V. P. Carey, Surface tension effects on convective boiling heat transfer in compact heat exchangers with offset strip fins, *J. Heat Transfer* **107**(4), 970 (1985).
24Q. W. S. Chang and G. T. Colwell, Mathematical modeling of the transient operating characteristics of a low-temperature heat pipe, *Numer. Heat Transfer* **8**(2), 169 (1985).
25Q. K. Chen, On the oscillatory instability of closed-loop thermosyphons, *J. Heat Transfer* **107**(4), 826 (1985).
26Q. F. M. Chernomurov, N. G. Parfent'yev and V. N. Krivenko, Industrial test of operation of a heat pipe in a metallurgical furnace, *Heat Transfer—Sov. Res.* **16**(2), 122 (1984).
27Q. D. Chisholm, Two-phase flow in heat exchangers and pipelines, *Heat Transfer Engng* **6**(2), 48 (1985).
28Q. S. W. Churchill and P. Tepper, Characteristics of a single-fluid, double- or triple-pass heat exchanger and combustor for low-heating-value gas, *Ind. Engng Chem. Proc. Des. Dev.* **24**(3), 542 (1985).
29Q. F. Dobran, Steady-state characteristics and stability thresholds of a closed two-phase thermosyphon, *Int. J. Heat Mass Transfer* **28**(5), 949 (1985).
30Q. M. P. Dudukovic and P. A. Ramachandran, Evaluation of thermal efficiency for heat regenerators in periodic operation by approximate methods, *Chem. Engng Sci.* **40**(9), 1629 (1985).
31Q. M. P. Dudukovic and P. A. Ramachandran, Quick design and evaluation of heat regenerators, *Chem. Engng* **92**(12), 63 (1985).
32Q. P. W. Eckels and T. J. Rabas, Heat transfer and pressure drop of typical air cooler finned tubes, *J. Heat Transfer* **107**(1), 198 (1985).
33Q. P. W. Eckels and T. J. Rabas, Heat transfer and pressure drop performance of finned tube bundles, *J. Heat Transfer* **107**(1), 205 (1985).
34Q. W. W. Focke, J. Zachariades and I. Olivier, The effect of the corrugation inclination angle on the thermohydraulic performance of plate heat exchangers, *Int. J. Heat Mass Transfer* **28**(8), 1469 (1985).
35Q. P. J. Fryer and N. K. H. Slater, Direct simulation procedure for chemical reaction fouling in heat exchangers, *Chem. Engng Jl* **31**(2), 97 (1985).
36Q. T. Fujii, T. Nagata and K. Shinzato, Experimental study of heat and mass transfer from humid air to a horizontal tube in false tube banks, *Bull. J.S.M.E.* **28**(237), 436 (1985).
37Q. K. Fukuda, T. Fukuda, S. Hasegawa, R. Echigo and K. Sanokawa, Improvement of high temperature heat exchanger efficiency by inserted porous material, (I): shell and tube type heat exchanger, *Nippon Genshiryoku Gakkaishi* **27**(2), 159 (1985).
38Q. K. Fukuda, T. Fukuda, T. Yamamoto, S. Hasegawa, R. Echigo and K. Sanokawa, Improvement of high temperature heat exchanger efficiency by inserted porous material, (II): preheating, single tube type shell and tube heat exchanger, *Nippon Genshiryoku Gakkaishi* **27**(3), 243 (1985).
39Q. J. Fürst and J. E. Roth, Wärmeaustauscher, *Brennstoff Wärme Kraft* **37**(4), 178 (1985).
40Q. M. A. Gotovsky, E. D. Fedorovich, E. V. Firsova, A. J. Blagoveshchensky, N. V. Mizonov, V. N. Piskunov and V. F. Vinokurov, Thermal effectiveness of heat exchangers: effect of manufacturing inaccuracies and deformation of tube bundles, *Heat Transfer Engng* **6**(1), 52 (1985).
41Q. U. Gross and E. Hahne, Heat transfer in a two-phase thermosyphon operating with a fluid in the near critical state, *Int. J. Heat Mass Transfer* **28**(3), 589 (1985).
42Q. J. E. Hart, A model of flow in a closed-loop thermosyphon including the Soret effect, *J. Heat Transfer* **107**(4), 840 (1985).
43Q. J. E. Hart, A note on the loop thermosyphon with mixed boundary conditions, *Int. J. Heat Mass Transfer* **28**(5), 939 (1985).
44Q. J. E. Hart, Observations of complex oscillations in a closed thermosyphon, *J. Heat Transfer* **107**(4), 833 (1985).
45Q. H. T. Haukas, Design of a plate-type evaporator for heat pumps, *Aust. Refrig. Air Condit. Heat.* **39**(4), 22 (1985).
46Q. R. Hoffmann, W. Krug and M. Arras, Evaluation of experimental investigations into the heat transfer process in plate-type heat exchangers, *Luft Kaeltetech* **3**(21), 160 (1985).
47Q. I. Hossain and J. Zaman, Thermal characteristics of heat exchanger type chemical reactors, *J. Chem. Engng Japan* **18**(3), 193 (1985).
48Q. A. N. Hrymak, G. J. McRae and A. W. Westerberg, Combined analysis and optimization of extended heat transfer surfaces, *J. Heat Transfer* **107**(3), 527 (1985).
49Q. B. J. Huang and J. T. Tsuei, A method of analysis for heat pipe heat exchangers, *Int. J. Heat Mass Transfer* **28**(3), 553 (1985).
50Q. G. H. Junkhan, A. E. Bergles, V. Nirmalan and T. Ravigururajan, Investigation of turbulators for fire tube boilers, *J. Heat Transfer* **107**(2), 354 (1985).
51Q. N. Kaji, Y. H. Mori and Y. Tochitani, Heat transfer enhancement due to electrically induced resonant oscillation of drops, *J. Heat Transfer* **107**(3), 788 (1985).
52Q. E. K. Kalinin, G. A. Dreitser and E. V. Dubrovsky, Compact tube and plate-finned heat exchangers, *Heat Transfer Engng* **6**(1), 44 (1985).
53Q. Y. Kobayashi, Heat pipe thermodynamic cycle and its applications, *J. Sol. Energy Engng* **107**(2), 153 (1985).
54Q. G. L. Koester III and E. O. Classon, Impedance pipe heating, *Heat Transfer Engng* **6**(3), 53 (1985).
55Q. V. M. Korotayev and N. A. Kolesnikova, Solution of equations of the method of finite fluid characteristics with a single governing similitude criterion and its application to heat exchanger design, *Heat Transfer—Sov. Res.* **16**(2), 105 (1984).
56Q. A. D. Kraus and A. D. Snider, Choking and optimization of extended surface arrays, *J. Heat Transfer* **107**(4), 746 (1985).

57Q. Yu. N. Kuznetsov and V. E. Lipatov, Study of high-performance convective surfaces for viscous fluids, *Heat Transfer Engng* **6**(1), 31 (1985).

58Q. R. S. Larson, On the design of recirculated-liquid gas cooler/humidifier, *Ind. Engng Chem. Proc. Des. Dev.* **24**(4), 1023 (1985).

59Q. R. Lavie, Optimal interaction of heat and mass exchanger for the improvement of separation efficiency, *Chem. Engng Sci.* **40**(11), 2019 (1985).

60Q. C. W. Leung, S. D. Probert and M. J. Shilston, Heat exchanger: optimal separation for vertical rectangular fins protruding from a vertical rectangular base, *Appl. Energy* **19**(2), 77 (1985).

61Q. C. W. Leung, S. D. Probert and M. J. Shilston, Heat exchanger design: optimal uniform separation between rectangular fins protruding from a vertical rectangular base, *Appl. Energy* **19**(4), 287 (1985).

62Q. C. W. Leung, S. D. Probert and M. J. Shilston, Heat exchanger design: thermal performances of rectangular fins protruding from vertical or horizontal rectangular bases, *Appl. Energy* **20**(2), 123 (1985).

63Q. C.-H. Li and R. K. Shah, The maximum slope of single-blow transient testing for compact heat exchanger surfaces, *J. Heat Transfer* **107**(1), 264 (1985).

64Q. Y. A. Liu, F. A. Pehler and D. R. Cahela, Studies in chemical process design and synthesis, Pt. VII: systematic synthesis of multipass heat exchanger networks, *A.I.Ch.E. Jl* **31**(5), 487 (1985).

65Q. H. Maeda, R. Izumi, H. Yamashita and S. Kaga, Study on a rotating condenser with a scraper (3rd report, experiment of condensation on outer surface of vertical and horizontal cylinders), *Bull. J.S.M.E.* **28**(235), 94 (1985).

66Q. A. A. Mikhalevich, Computer calculation and parameter optimization of heat transfer equipment, *Heat Transfer Engng* **6**(1), 39 (1985).

67Q. L. F. Melo and J. D. Pinheiro, Estimating friction factors in a fouled annulus, *Can. J. chem. Engng* **63**(4), 693 (1985).

68Q. M. N. Netrakanti and C. L. D. Huang, Optimization of annular fins with variable thermal parameters by invariant imbedding, *J. Heat Transfer* **107**(4), 966 (1985).

69Q. C. J. L. Otero, J. L. Otero de la Gandara, Multiple-stage heat regenerator—2: experimental determination of thermal stage efficiency, *Rev. Metal., Madrid* **21**(1), 3 (1985).

70Q. J. A. Perez and E. M. Sparrow, Determination of shell-side heat transfer coefficients by the naphthalene sublimation technique, *Heat Transfer Engng* **6**(2), 19 (1985).

71Q. A. I. Petrov and S. I. Efimov, Effect of flow-through capacity of a Stirling engine regenerator on its thermal and hydraulic characteristics, *Mashinostroenie* **3**, 69 (1985).

72Q. M. J. Pettigrew, L. N. Carlucci, P. L. Ko and G. L. Holloway, Computer techniques to analyze shell-and-tube heat exchangers, *Heat Transfer Engng* **6**(3), 40 (1985).

73Q. G. P. Purohit, Costs of double-pipe and multitube heat exchangers: Pt. 1, *Chem. Engng* **92**(5), 93 (1985).

74Q. R. Ponnappan, J. E. Beam and T. Mahefkey, Improved double-wall artery high-capacity heat pipe, *J. Spacecraft Rockets* **22**(6), 592 (1985).

75Q. K. N. Proskuryakov and V. A. Uruchev, Thermohydraulic method of generation of high-intensity ultra-sound for removal of scale and deposits from heat-exchanger tubes, *Heat Transfer—Sov. Res.* **16**(4), 139 (1985).

76Q. G. R. Putman and W. M. Rohsenow, Viscosity induced non-uniform flow in laminar flow heat exchangers, *Int. J. Heat Mass Transfer* **28**(5), 1031 (1985).

77Q. E. Ramos, M. Sen and C. Treviño, A steady-state analysis for variable area one- and two-phase thermosyphon loops, *Int. J. Heat Mass Transfer* **28**(9), 1711 (1985).

78Q. B. M. Rassamakin and E. V. Gal'perin, Laws of formation of a plug of liquid heat-transfer agent in the vapor channel of a thermal diode heat pipe, *J. Engng Phys.* **48**(2), 134 (1985).

79Q. D. A. Reay, Heat pipes, *Phys. Technol.* **16**(2), 69 (1985).

80Q. F. E. Romie, Transient response of the parallel-flow heat exchanger, *J. Heat Transfer* **107**(3), 727 (1985).

81Q. A. Ronen and Y. Zvirin, The behavior of a toroidal thermosyphon at high Graetz (and Grashof) numbers, *J. Heat Transfer* **107**(1), 254 (1985).

82Q. T. M. Rudy and R. L. Webb, An analytical model to predict condensate retention on horizontal integral-fin tubes, *J. Heat Transfer* **107**(2), 361 (1985).

83Q. R. Sarunac, The experimental determination of thermal characteristics of oil-air type heat exchanger, *Strojarstvo* **27**(4), 221 (1985).

84Q. M. Sen, E. Ramos and C. Treviño, On the steady-state velocity of the inclined toroidal thermosyphon, *J. Heat Transfer* **107**(4), 974 (1985).

85Q. M. Sen, E. Ramos and C. Treviño, The toroidal thermosyphon with known heat flux, *Int. J. Heat Mass Transfer* **28**(1), 219 (1985).

86Q. G. L. Serebryanyi, Influence of contacts on the thermal resistance of a bundle of rectangular fins, *J. Engng Phys.* **48**(2), 236 (1985).

87Q. I. Shishido, T. Matsuda, T. Iida and S. Ohtani, Measurement of the working fluid distribution within a heat pipe wick, *Heat Transfer—Japan. Res.* **13**(2), 65 (1984).

88Q. J. Siderowicz, Heat-transfer coils, *Plant Engng* **39**(12), 84 (1985).

89Q. B. Smith, Up-date on shellside two phase heat transfer, *Chem. Engr* **414**, 16 (1985).

90Q. E. M. Sparrow and S. S. Kang, Longitudinally-finned cross-flow tube banks and their heat transfer and pressure drop characteristics, *Int. J. Heat Mass Transfer* **28**(2), 339 (1985).

91Q. E. M. Sparrow and J. A. Perez, Internal, shellside heat transfer and pressure drop characteristics for a shell and tube heat exchanger, *J. Heat Transfer* **107**(2), 345 (1985).

92Q. E. M. Sparrow and S. B. Vemuri, Natural convection/radiation heat transfer from highly populated pin fin arrays, *J. Heat Transfer* **107**(1), 190 (1985).

93Q. J. Starczewski, Better refrigerant exchanger design, *Hydrocarbon Process.* **64**(4), 93 (1985).

94Q. J. K. Steimke, Natural convection heat transfer for a concentric tube thermosyphon, *J. Heat Transfer* **107**(3), 583 (1985).

95Q. K. Suzuki, E. Hirai, T. Miyake and T. Sato, Numerical and experimental studies on a two-dimensional model of an offset-strip-fin type compact heat exchanger used at low Reynolds number, *Int. J. Heat Mass Transfer* **28**(4), 823 (1985).

96Q. G. Swift, A. Migliori and J. Wheatley, Construction of and measurements with an extremely compact cross-flow heat exchanger, *Heat Transfer Engng* **6**(2), 39 (1985).

97Q. H. Takazawa and T. Kajikawa, Condensing heat transfer enhancement on vertical spiral double fin tubes with drainage gutters, *J. Sol. Energy Engng* **107**(3), 222 (1985).

98Q. T. Takizuka and H. Kaburaki, Research on crossflow in VHTR core, (I) two-block crossflow experiments, *Nippon Genshiryoku Gakkaishi* **27**(4), 347 (1985).

99Q. M. Turaga and R. W. Guy, Refrigerant side heat transfer and pressure drop estimates for direct expan-

sion coils: a review of works in North American use, *Int. J. Refrig.* **8**(3), 134 (1985).
100Q. A. H. Tuthill, Sedimentation in condensers and heat exchangers: causes and effects, *Pwr Engng* **89**(6), 46 (1985).
101Q. H. Uehara, T. Nakaoka and S. Nakashima, Heat transfer coefficients for a vertical fluted-plate condenser with R113 and 114, *Int. J. Refrig.* **8**(1), 22 (1985).
102Q. H. C. Ünal, Determination of the temperature distribution in an extended surface with a non-uniform heat transfer coefficient, *Int. J. Heat Mass Transfer* **28**(12), 2279 (1985).
103Q. H. C. Ünal, Two simple correlations for the inception of density-wave oscillations in long sodium-heated stream generator tubes, *Int. J. Heat Mass Transfer* **28**(7), 1385 (1985).
104Q. S. B. Uttarwar and M. R. Rao, Augmentation of laminar flow heat transfer in tubes by means of wire coil inserts, *J. Heat Transfer* **107**(4), 930 (1985).
105Q. L. L. Vasiliev, Low-temperature heat pipes, *J. Heat Recovery Syst.* **5**(3), 203 (1985).
106Q. D. L. Vinograd, I. B. Zhvanetskii, V. M. Platonov and V. V. Zolotorev, Modeling of a heat exchanger for the synthesis of chemical engineering systems, *Theoret. Found. chem. Engng* **9**(1), 38 (1985).
107Q. R. L. Wagner and S. Sjogren, Optimizing heat exchanger design for crude oil stabilization, *Chem. Engng Prog.* **81**(2), 46 (1985).
108Q. R. L. Webb, T. M. Rudy and M. A. Kedzierski, Prediction of the condensation coefficient on horizontal integral-fin tubes, *J. Heat Transfer* **107**(2), 369 (1985).
109Q. R. L. Webb and A. Villacres, Performance simulation of evaporation heat exchanger (cooling towers, fluid coolers, and condensers), *Heat Transfer Engng* **6**(2), 31 (1985).
110Q. Z. Wozniak, Dynamics of transient states of the counter-flow heat regenerator, *Numer. Heat Transfer* **8**(6), 751 (1985).
111Q. K. K. Yau, J. R. Cooper and J. W. Rose, Effect of fin spacing on the performance of horizontal integral-fin condenser tubes, *J. Heat Transfer* **107**(2), 377 (1985).
112Q. K. Yoshikawa, H. Kajiyama, T. Okamure, S. Kabashima, H. Yamasaki, S. Shioda, M. Yamada, T. Yokota, M. Ishimura, K. Nakayama, K. Nakamoto and T. Sasaki, Experimental studies on thermal performance of a pebble bed high-temperature heat exchanger, *J. Heat Transfer* **107**(3), 722 (1985).
113Q. N. I. Zhidov, V. N. Kozlov and B. A. Makarov, Calculation of temperature fields of a cross-flow heat exchanger, accounting for hydraulic and temperature nonuniformities at the inlet, *Teploenergetika* **4**, 68 (1985).
114Q. A. V. Zhukov, A. P. Sorokin and N. M. Matyukhin, Heat removal in fast reactor cores, *Sov. atom. Energy* **58**(4), 250 (1985).
115Q. A. A. Zukauskas and R. Ulinskas, Efficiency parameters for heat transfer in tube banks, *Heat Transfer Engng* **6**(1), 19 (1985).
116Q. A. A. Zukauskas, R. Ulinskas and P. Daunoras, The influence of surface roughness on the heat transfer and drag of tube banks in crossflow, *Heat Technol.* **3**(2), 1 (1985).
117Q. Y. Zvirin, The instability associated with the onset of motion in a thermosyphon, *Int. J. Heat Mass Transfer* **28**(11), 2105 (1985).
118Q. Y. Zvirin, Throughflow effects on the transient and stability characteristics of a thermosyphon, *Wärme- u. Stoffübertr.* **19**(2), 113 (1985).

## HEAT TRANSFER APPLICATIONS—GENERAL

1S. G. G. Achterbosch, P. P. G. de Jong, C. E. Krist-Spit, S. F. van der Meulen and J. Verberne, Development of a convenient thermal dynamic building model, *Energy Bldg* **8**(3), 183 (1985).
2S. M. R. Barone and D. A. Caulk, Nonuniform cavity surface temperature in injection molding, *Polymer Process Engng* **3**(1–2), 149 (1985).
3S. E. Barta, R. Beyar and S. Sideman, Temperature distribution within the left ventricular wall of the heart, *Int. J. Heat Mass Transfer* **28**(3), 663 (1985).
4S. G. Beccali, G. Panno and A. Giaccone, Analysis of greenhouse ground heating by underground pipes, *Energie Alternative Habitat Territorio Energia* **7**(35), 194 (1985).
5S. A. E. Beck and P. V. Shen, Temperature distribution in flowing liquid wells, *Geophys.* **50**(7), 1113 (1985).
6S. K. H. Betts, R. R. Parsons and M. J. Brett, Heat mirrors for greenhouses, *Appl. Opt.* **24**(16), 2651 (1985).
7S. B. E. Boyack, Survey of natural-circulation cooling in U.S. pressurized water reactors, *Nucl. Sci. Engng* **91**(3), 248 (1985).
7aS. B. E. Boyack, Survey of natural-circulation cooling in U.S. pressurized water reactors, *Nucl. Sci. Engng* **91**(3), 248 (1985).
8S. D. R. Boyd, C. P. Wong and Y. S. Cha, Thermal-hydraulic assessment of high heat flux removal techniques for fusion applications, *Nucl. Engng Des.* **88**(1), 103 (1985).
9S. L. A. Brovkin, O. I. Gorinov, V. M. Olabin, V. V. Primaychek and L. P. Olevskaya, Experimental investigation of heat transfer in the heating of cylindrical blanks in a glass-melt bath agitated by jets of combustion products, *Heat Transfer—Sov. Res.* **16**(5), 103 (1985).
10S. A. Cardella, Heat removal from the plasma of fusion reactors, *Heat Technol.* **3**(3–4), 58 (1985).
11S. G. F. Carrier, F. E. Fendell and P. S. Feldman, Firestorms, *J. Heat Transfer* **107**(1), 19 (1985).
12S. P. Cernik, Wind direction effects on energy consumption in buildings, *Energy Bldg* **8**(2), 157 (1985).
13S. S. Chandra, R. Kumar, S. Kaushik and S. Kaul, Thermal performance of a non-air-conditioned building with PCM thermal storage wall, *Energy Conv.* **25**(1), (1985).
14S. G. T. Chrusciel and L. A. Pool, Knudsen layer characteristics for a highly cooled blunt body in hypersonic rarefied flow, *A.I.A.A. Jl* **23**(6), 836 (1985).
15S. A. C. Cleland, Experimental verification of a mathematical model for simulation of industrial refrigeration plants, *Int. J. Refrig.* **8**(5), 275 (1985).
16S. E. W. Comings, Contributions of T. K. Sherwood and associates to the field of drying. II, *Drying Technol.* **2**(4), 117 (1983–84).
17S. E. W. Comings, Contributions of T. K. Sherwood and associates to the field of drying. III, *Drying Technol.* **2**(2), 265 (1983–84).
18S. R. J. Crawford and J. A. Scott, Experimental study of heat transfer during rotational moulding of plastics, *Plastics Rubber Process. Applic.* **5**(3), 239 (1985).
19S. W. K. Cui, W. J. M. Douglas and A. S. Mujumdar, Impingement steam drying of paper, *Drying Technol.* **3**(2), 307 (1985).
20S. G. A. Dorrer, A model of the spreading of a forest fire, *Heat Transfer—Sov. Res.* **16**(6), 39 (1984).
21S. B. Dorri, A. F. Emery and P. C. Malte, Drying rate of wood particles with longitudinal mass transfer, *J. Heat Transfer* **107**(1), 12 (1985).
22S. J. C. Dunn and H. C. Hardee, Surface heat flow measurements at the Phimau hot spot, *Geophys.* **50**(7), 1108 (1985).

23S. P. W. Eckels, J. Buttyan, J. H. Parker, Jr. and A. Patterson, Superconducting generator cooling system simulation, *Cryogenics* **25**(8), 471 (1985).
24S. G. Eigenberger and W. Ruppel, Problems of mathematical modelling for industrial fixed-bed reactors, *Chem.-Ing.-Tech.* **57**(3), 181 (1985).
25S. Y. Enomomoto, S. Furuhama and K. Minakami, Heat loss to combustion chamber wall of 4-stroke gasoline engine (1st report, heat loss to piston and cylinder), *Bull. J.S.M.E.* **28**(238), 647 (1985).
26S. V. Erckmann, G. Janzen, W. Kasparek, G. Mueller, P. G. Schueller, K. Schwoerer, M. Thumm and R. Wilheim, Electron cyclotron resonance heating experiments in the Wendelstein VII-A stellarator, *Fusion Technol.* 7(2), (1985).
27S. A. Francis and R. E. Craine, On a model for frictioning stage in friction welding of thin tubes, *Int. J. Heat Mass Transfer* **28**(9), 1747 (1985).
28S. R. Ghetzler, J. C. Chato and J. M. Crowley, Turbulent convective heat transfer in forced cooled underground electric transmission systems, *J. Heat Transfer* **107**(2), 327 (1985).
29S. E. S. Gogolev and A. N. Krasavin, Investigation of heat transfer during an undulating motion of water at the icy surface, *Izv. Sibirsk. Otdel. Akad. Nauk SSSR, Seriya Tekkjicheskikh Nauk* **10**(14), (1985).
30S. G. M. Greene and S. I. Outcalt, Simulation model of river ice cover thermodynamics, *Cold Reg. Sci. Technol.* **10**(3), 251 (1985).
31S. M. A. Hares, J. Ben-Asher, A. D. Matthias and A. W. Warrick, Simple method to evaluate daily positive soil heat flux, *Soil. Sci. Soc. J.* **49**(1), 45 (1985).
32S. I. Holmer, Heat exchange and thermal insulation compared in woolen and nylon garments during wear trials, *Textile Res. J.* **55**(9), 511 (1985).
33S. W. W. Jones, Multicompartment model for the spread of fire, smoke and toxic gases, *Fire Safety J.* **9**(1), 55 (1985).
34S. S. A. Jurovics, C.-H. Ho and F. Y. Sorrell, New energy-efficient materials for the building envelope, *Bldg Envir.* **20**(2), 55 (1985).
35S. R. L. Kiang, Scaling criteria for nuclear reactor thermal hydraulics, *Nucl. Sci. Engng* **89**(3), 207 (1985).
36S. Ya. S. Kiselev and A. A. Toporishcev, Kinetics of thermal oxidation of wood, *Heat Transfer—Sov. Res.* **16**(6), 53 (1984).
37S. M. Kobari, Y. Shimizum and M. Endo, Contact drying of fibrous sheet material, *Ind. Engng Chem. Proc. Des. Dev.* **24**(1), 188 (1985).
38S. G. L. Koester III and E. O. Classon, Impedence pipe heating, *Heat Transfer Engng* **6**(3), 53 (1985).
39S. E. V. Konev, Analysis of the spreading of natural and intentionally set forest fires, *Heat Transfer—Sov. Res.* **16**(6), 1 (1984).
40S. P. Kurpiers, A. Steiff and P.-M. Weinspach, Heat transfer and scale-up in stirred single- and multiphase reactors with immersed heating elements, *German Chem. Engng* **8**(5), 267 (1985).
41S. P. Kurpiers, A. Steiff and P.-M. Weinspach, Heat transfer and scale-up of agitated single- and multiphase reactors with immersed heating elements, *Chem.-Ing.-Tech.* **57**(6), 632 (1985).
42S. P. Kurpiers, A. Steiff and P.-M. Weinspach, Heat transfer between reactor wall and fluid in a stirred single- and multiphase reactor on use of one- and two-stage disc stirrers, *Chem.-Ing.-Tech.* **57**(6), 700 (1985).
43S. L.-C. Lundin, Simulated physical effects of shallow soil heat extraction, *Cold Reg. Sci. Technol.* **11**(1), 45 (1985).
44S. R. E. Maebius, Effects of heat transfer in melt spinning, *J. appl. Polymer Sci.* **30**(4), 1639 (1985).
45S. C. L. Macosko and J. L. Lee, Heat transfer and property development in liquid silicone rubber molding, *Rubber Chem. Technol.* **58**(2), 436 (1985).
46S. J.-C. Mareschal, J. P. Cunningham and R. P. Lowell, Downward continuation of heat flow data; method and examples from the western United States, *Geophys.* **50**(5), 846 (1985).
47S. M. M. Menon, C. C. Tsai, J. H. Whealton and D. E. Schechter, Heat loading on the components of multi-megawatt ion sources, *J. appl. Phys.* **58**(9), 3356 (1985).
48S. M. D. Mikhailov, Luikov's contribution to drying, *Drying Technol.* **2**(4), 517 (1983–84).
49S. D. B. Moog and B. Rubinsky, An analytical model of thermal and vapor diffusion in freezing of wet coal, *J. Heat Transfer* **107**(1), 5 (1985).
50S. M. J. T. Norton, S. J. Kadolph, R. F. Jordan and A. Kenneth, Design, construction and use of Minnesota woman, a thermally instrumented mannequin, *Textile Res. J.* **55**(1), 5 (1985).
51S. R. W. Olsen, L. J. Hayes, E. H. Wissler, H. Nikaidoh and R. C. Eberhart, Influence of hypothermia and circulatory arrest on cerebral temperature distributions, *J. biochem. Engng* **107**(4), 354 (1985).
52S. S. J. Palaszewski, L. M. Jiji and S. Weinbaum, Performance of power plant spray cooling modules and systems, *Heat Transfer Engng* **6**(3), 60 (1985).
53S. G. Pantelis, Saturated-unsaturated flow in unconfined acquifers. *Z. angew, Math. Phys.* **36**(5), 648 (1985).
54S. H. Pfeifer, F. N. Fett, H. Schaefer and K.-H. Heinen, Heating-up model for steel casting ladles, *Stahl Eisen* **105**(14–15), 759 (1985).
55S. O. A. Plumb, G. A. Spolek and B. A. Olmstead, Heat and mass transfer in wood during drying, *Int. J. Heat Mass Transfer* **28**(9), 1669 (1985).
56S. S. S. Sandhu and H. R. Hashemi, A model for simultaneous heating and devolatilation of a single coal particle in a hot gas stream in the presence of a thermal radiative field, *A.I.Ch.E. Jl* **31**(10), 1714 (1985).
57S. M. T. Schobeiri, The influence of trailing-edge ejection on the mixing losses behind a cooled blade, *Forsch. Ing.* **51**(1), 25 (1985).
58S. D. Schieber, Heating effects through unipolar induction, *J. Franklin Inst.* **320**(1), 15 (1985).
59S. R. Schönfeld, Temperaturverteilung in Brennstabbündeln, *Brennstoff Wärme Kraft* **37**(7–8), 291 (1985).
60S. J. A. Stark, Thermal control system of the Purdue University space shuttle payload, *J. Spacecraft Rockets* **22**(3), 382 (1985).
61S. E. Taberlet and Y. Fautrelle, Turbulent stirring in an experimental induction furnace, *J. Fluid Mech.* **159**(409), (1985).
62S. M. Tajima, T. Mai and K. Katayama, Study of heat transfer phenomena in quenching of steel (effect of latent heat of phase transformation), *Bull. J.S.M.E.* **28**(242), 1710 (1985).
63S. R. Viskanta and D. M. Kin, Heat transfer from a partially uncovered reactor core, *Nucl. Engng Des.* **85**(1), 71 (1985).
64S. M. Walton, Seasonal thermal energy storage (STES), *Underground Space* **9**(1), 5 (1985).
65S. K.-H. Wehde and J. Stichlmair, Heat transfer in the concentration of *contained* sulphuric acid, *Chem.-Ing.-Tech.* **57**(2), 172 (1985).
66S. C. K. Wei, H. T. Davis, E. A. Davis and J. Gordon, Heat and mass transfer in water-laden sandstone: microwave heating, *A.I.Ch.E. Jl* **31**(5), 842 (1985).
67S. Z. Yan, F. Zhen, L. J. Ni and J. Liu, Heat transfer and thermal loading of air-cooled diesel engines, *Neiranji Xuebao* (*Trans. Chin. Soc. intern. Combust. Engrs*) **3**(1), 77 (1985).

68S. H.-Z. You, Investigation of the fire-plume impingement on a horizontal ceiling. 2 — Impingement and ceiling-jet regions, *Fire Math.* **9**(1), 46 (1985).

## SOLAR ENERGY

1T. M. Abdul-Hadi, Thermal analysis of a thermosyphon V-trough solar concentrator, *Heat Technol.* **3**(2), 132 (1985).
2T. R. Almanza and J. Lara, Simulation of solar ponds with an experimental transmittance function, *J. Sol. Energy Engng* **107**(4), 357 (1985).
3T. A. K. Athienitis, M. Chandrashekar and H. F. Sullivan, Modeling and analysis of thermal networks through subnetworks for multizone passive solar buildings, *Appl. Math. Modell.* **9**(2), 109 (1985).
4T. D. E. Beasley, J. A. Clark and M. J. Holstege, Observations on the decay of a thermocline in a rock bed with no net fluid flow, *J. Sol. Energy Engng* **107**(1), 50 (1985).
5T. C. Bénard, Y. Body and A. Zanoli, Experimental comparison of latent and sensible heat thermal walls, *Sol. Energy* **34**(6), 475 (1985).
6T. N. C. Bhowmik and S. C. Mullick, Calculation of turbular absorber heat loss factor, *Sol. Energy* **35**(3), 219 (1985).
7T. V. E. Cachorro, A. M. de Frutos and J. L. Casanova, Comparison between various models of solar spectral irradiance and experimental data, *Appl. Opt.* **24**(19), 3249 (1985).
8T. S. C. Chang and J. A. Roux, Thermodynamic analysis of a solar zeolite refrigeration system, *J. Sol. Energy Engng* **107**(3), 189 (1985).
9T. D. E. Chelghoum and A. Bejan, Second-law analysis of solar collectors with energy storage capability, *J. Sol. Energy Engng* **107**(3), 244 (1985).
10T. M. Collares-Pereira, Description and testing of a non-evacuated 1.5 × CPC collector thermal performance comparison with other-collector types, *J. Sol. Energy Engng* **107**(4), 277 (1985).
11T. S. Crha and G. E. Schneider, Effect of contact spacing on efficiency of flat-plate solar collectors, *J. Spacecraft Rockets* **22**(6), 585 (1985).
12T. D. Feuermann, J. M. Gordon and Y. Zarmi, On massive envelopes in passively-heated solar buildings: an analytic sensitivity study, *Sol. Energy* **35**(3), 271 (1985).
13T. J. L. A. Francey and J. Papaioannou, Wind-related heat losses of a flat-plate collector, *Sol. Energy* **35**(1), 15 (1985).
14T. G. Galassini, A. Arconada and G. Labrosse, A contribution to the study of convective regimes in a horizontal solar converter with modulation of the temperature of the absorbing surface, *Int. Chem. Engng* **25**(3), 447 (1985).
15T. H. P. Garg, V. K. Sharma and A. K. Bhargava, Theory of multiple-pass solar air heaters, *Energy* **10**(5), 589 (1985).
16T. J. M. Gordon and Y. Zarmi, Single-pass open-loop solar thermal energy systems: on maximum energy delivery by variable flow rate, *J. Sol. Energy Engng* **107**(4), 273 (1985).
17T. E. Hahne, Parameter effects on design and performance of flat plate solar collectors, *Sol. Energy* **34**(6), 497 (1985).
18T. J. A. Harris and T. G. Lenz, Thermal performance of solar concentrator/cavity receiver systems, *Sol. Energy* **34**(2), 135 (1985).
19T. K. G. T. Hollands and K. Iynkaran, Proposal for a compound-honeycomb collector, *Sol. Energy* **34**(4/5), 309 (1985).
20T. G. B. Hotchkiss, L. C. Burmeister and K. A. Bishop, Solar collector parameter identification from unsteady data by a discrete-gradient algorithm, *J. Sol. Energy Engng* **107**(1), 70 (1985).
21T. B. J. Huang and C. T. Hsieh, A simulation method for solar thermosyphon collector, *Sol. Energy* **35**(1), 31 (1985).
22T. J. R. Hull, Solar pond ground heat loss to a moving water table, *Sol. Energy* **35**(3), 211 (1985).
23T. Y. Jaluria and C. K. Cha, Heat rejection to the surface layer of a solar pond, *J. Heat Transfer* **107**(1), 99 (1985).
24T. W. Kamminga, The approximate temperatures with a flat-plate solar collector under transient conditions, *Int. J. Heat Mass Transfer* **28**(2), 433 (1985).
25T. T. G. Karyiannis and J. D. Tarasuk, Influence of temperature characteristics of the upper surface on heat transfer in a solar collector, *Trans. Can. Soc. mech. Engrs* **9**(1), 32 (1985).
26T. K. E. Kasza and M. M. Chen, Improvement of the performance of solar energy or waste heat utilization systems by using phase-change slurry as an enhanced heat-transfer storage fluid, *J. Sol. Energy Engng* **107**(3), 229 (1985).
27T. B. A. Kimball, Cooling performance and efficiency of night sky radiators, *Sol. Energy* **34**(1), 19 (1985).
28T. R. J. Kind and D. Kitaljevich, Wind-induced heat losses from solar collector arrays on flat-roofed buildings, *J. Sol. Energy Engng* **107**(4), 335 (1985).
29T. P. D. Lund and M. B. Östman, A numerical model for seasonal storage of solar heat in the ground by vertical pipes, *Sol. Energy* **34**(4/5), 351 (1985).
30T. G. L. Morrison and J. E. Braun, System modeling and operation characteristics of thermosyphon solar water heaters, *Sol. Energy* **34**(4/5), 389 (1985).
31T. G. Olalde, G. Flamant, D. Schwander and C. Combescure, Advanced high temperature semi-transparent solar absorbers, *Sol. Energy Mater.* **12**(6), 461 (1985).
32T. D. Proctor and S. R. James, Analysis of the Sanyo evacuated tube solar collector test results from the IEA Task III Programme, *Sol. Energy* **35**(5), 387 (1985).
33T. R. L. Reid, B. A. McGraw and A. F. G. Bedinger, Passive solar performance of tech house V, *J. Sol. Energy Engng* **107**(1), 35 (1985).
34T. K. H. Taylor and A. D. Weir, Simulation of a solar timber drier, *Sol. Energy* **34**(3), 249 (1985).
35T. R. Uhlemann and N. K. Bansal, Side-by-side comparison of a pressurized and a nonpressurized solar water heating thermosyphon system, *Sol. Energy* **34**(4/5), 317 (1985).
36T. B. Vaxman and M. Sokolov, Experiments with an integral compact solar water heater, *Sol. Energy* **34**(6), 447 (1985).
37T. N. E. Wijeysundera, Effect of variable Nusselt number and nonuniform wall irradiation on collector performance, *J. Sol. Energy Engng* **107**(2), 148 (1985).
38T. H. F. Zhang and Z. Lavan, Thermal performance of a serpentine absorber plate, *Sol. Energy* **34**(2), 175 (1985).
39T. Y. Zhiqiang, G. L. Harding, S. Craig, R. E. Collins and B. Window, Comparative study of fluid-in-metal manifolds for heat extraction from single ended evacuated glass tubular collectors, *Sol. Energy* **35**(1), 81 (1985).
40T. A. Zollner, S. A. Klein and W. A. Beckman, A performance prediction methodology for integral collection-storage solar domestic hot water systems, *J. Sol. Energy Engng* **107**(4), 265 (1985).

## PLASMA HEAT TRANSFER AND MHD

1U. V. Ye. Abaltusov and A. N. Golovanov, Experimental study of heat and mass exchange between a plasma

jet and a permeable wall cooled by injection of a two-phase flow, *Heat Transfer—Sov. Res.* **16**(5), 141 (1985).
2U. M. Abbaoui, B. Cheminat et P. Andason, Influence de la nature du metal sur la conductivité d'un plasma argon–metal, *J. Phys. D: appl. Phys.* **18**(10), L159 (1985).
3U. J. Amouroux, A. Gicquel, S. Cavvadias, D. Morvan and F. Arefi, Progress in the applications of plasma surface modifications and correlations with the chemical properties of the plasma phase, *Pure appl. Chem.* **57**(9), 1207 (1985).
4U. J. Bacri, A.-M. Gomes and M. Eymard, Ambipolar diffusion in a nitrogen thermal plasma, *J. Phys. D: appl. Phys.* **18**(12), 2339 (1985).
5U. P. Bayle, M. Bayle and G. Forn, Neutral heating in glow to spark transition in air and nitrogen, *J. Phys. D: appl. Phys.* **18**(12), 2395 (1985).
6U. L. Benzerga, C. Lhiaubet and R. M. Meyer, Improvement of a proposed model for heat conduction in an electrode submitted to an electric discharge: application to the indirect determination of the anodic and cathodic voltage drops, *J. appl. Phys.* **58**(1), 604 (1985).
7U. T. K. Bose, D. Kannappan and R. V. Seeniraj, On reactive heat conduction for multiple ionized two-temperature argon plasma, *Wärme- u. Stoffübertr.* **19**(1), 3 (1985).
8U. R. Chapman, T. Morin, M. Finzel and M. C. Hawley, Measurement of energy distribution in flowing hydrogen microwave plasmas, *J. Spacecraft Rockets* **22**(6), 626 (1985).
9U. B. Chemicat et P. Andanson, La conduction dans la colonne d'un arc electrique contamine par des vapeurs de curivre, *J. Phys. D: appl. Phys.* **18**(11), 2183 (1985).
10U. Xi Chen, Y. P. Chyou, Y. C. Lee and E. Pfender, Heat transfer to a particle under plasma conditions with vapor contamination from the particle, *Plasma Chem. Plasma Process.* **5**(2), 119 (1985).
11U. Xi Chen and E. Pfender, Effect of pressure on heat transfer to a particle exposed to a thermal plasma (84-GT-287), *J. Engng Gas Turbine Pwr* **107**(1), 147 (1985).
12U. L. E. Cram, Statistical evaluation of radiative power losses from thermal plasmas due to spectral lines, *J. Phys. D: appl. Phys.* **18**(3), 401 (1985).
13U. U. Daybelge, Theory of the self-induced electric field at a cathodic arc spot, *Phys. Fluids* **28**(2), 312 (1985).
14U. H. Drost, H.-D. Klotz, G. Schulz and H.-J. Spangenberg, The influence of hydrogen on the kinetics of plasmapyrolytic methane conversion, *Plasma Chem. Plasma Process.* **5**(1), 55 (1985).
15U. K. Etemadi and E. Pfender, Impact of anode evaporation on the anode region of a high-intensity argon arc, *Plasma Chem. Plasma Process.* **5**(2), 175 (1985).
16U. D. A. Erwin and J. A. Kunc, Electron temperature and ionization degree dependence of electron transport coefficients in monatomic gases, *Phys. Fluids* **28**(11), 3349 (1985).
17U. B. C. Eu, Temperature dependence of thermal conductivity of a dilute plasma in a magnetic field, *Physica* **133A**(1, 2), 120 (1985).
18U. A. Ya Faenov, S. Ya Khakhalin, A. A. Kolomensky, S. A. Pikuz, A. I. Samokhin and I. Yu. Skobelev, Superdense high-temperature exploded-wire plasma observation in a high-current vacuum diode, *J. Phys. D: appl. Phys.* **18**(7), 1347 (1985).
19U. P. Fauchais, A. Vardelle, M. Vardelle, J. F. Coudert and B. Pateyron, Plasma spraying and extractive metallurgy: Comparisons between mathematical modeling and measurements and between applications and development, *Pure appl. Chem.* **57**(9), 1171 (1985).
20U. S.-I. Himeno, M. Seki and H. Mochizuki, Computer method for new elliptical Abel inversion applied to holographic plasma diagnostics, *J. phys. Soc. Japan* **54**(5), 1737 (1985).
21U. S. Ishiguro, T. Kamimura and T. Sato, Double layer formation caused by contact between different temperature plasmas, *Phys. Fluids* **28**(7), 2100 (1985).
22U. D. Karabourniotis and C. Karras, Line broadening in optically thick gas discharges: influence on plasma temperature determination, *J. appl. Phys.* **57**(11), 4861 (1985).
23U. M. Kobayashi, T. Honda and A. Kanzawa, Numerical analysis of thermal plasma flow in a pipe, *Int. Chem. Engng* **25**(2), 308 (1985).
24U. M. Kobayashi, T. Honda and A. Kanzawa, Numerical analysis of a thermal plasma flow in a tube, *Heat Transfer—Japan. Res.* **13**(1), 64 (1984).
25U. M. Kobayashi, T. Honda and A. Kanzawa, The effect of gas injection on a thermal argon plasma flow in a water-cooled tube, *Plasma Chem. Plasma Process.* **5**(1), 39 (1985).
26U. I. S. Kovalenko, V. I. Kucharenko and V. A. Sechenov, Three-chamber heated shock tube for investigating a high-enthalpy dense plasma, *J. appl. Mech. Tech. Phys.* **26**(2), 278 (1985).
27U. P. Kovitya, Physical properties of high-pressure plasmas of hydrogen and copper in the temperature range 5000–60,000 K, *IEEE Trans. Plasma Sci.* **13**(6), 587 (1985).
28U. P. Kovitya and J. J. Lowke, Two-dimensional analysis of free burning arcs in argon, *J. Phys. D: appl. Phys.* **18**(1), 53 (1985).
29U. T. Kubono, Calculation of effective work-function and average cooling energy of electrons emitted from an arc cathode root, *J. Phys. D: appl. Phys.* **18**(6), 1131 (1985).
30U. J. A. Kunc, Conductivity of weakly and highly ionized gases in quasistatic electric fields, *Phys. Fluids* **27**(12), 2859 (1984).
31U. H. Lee, A method for computing the radial temperature profiles in high-pressure, high-current arcs, *J. Phys. D: appl. Phys.* **18**(3), 425 (1985).
32U. H. E. Lee and L. E. Cram, On the theory of radiation-dominated wall-stabilized arcs, *J. Phys. D: appl. Phys.* **18**(8), 1561 (1985).
33U. Y. C. Lee, Y. P. Chyou and E. Pfender, Particle dynamics and particle heat and mass transfer in thermal plasmas — II. Particle heat and mass transfer in thermal plasmas, *Plasma Chem. Plasma Process.* **5**(4), 391 (1985).
34U. R. R. Mitchell, D. T. Tuma and J. F. Osterle, Transient two-dimensional calculations of properties of forced convection-stabilized electric arcs, *IEEE Trans. Plasma Sci.* **13**(4), 207 (1985).
35U. L. Monchick and E. A. Mason, A reconsideration of thermal diffusion in ionized gases: quantal and dynamic shielding effects, *Phys. Fluids* **28**(11), 3341 (1985).
36U. A. L. Mosse, V. V. Pechkovsky, E. D. Dzyuba and L. I. Krasovskaya, Production of condensed phosphate by plasma chemical treatment of phosphate raw material, *Plasma Chem. Plasma Process* **5**(3), 275 (1985).
37U. J. Mostaghimi, P. Proulx and M. I. Boulos, An analysis of the computer modeling of the flow and temperature fields in an inductively coupled plasma, *Numer. Heat Transfer* **8**(2), 187 (1985).
38U. Y. Ohguchi, Estimation of thermal conductivity of hydrogen gas through arc studies, *J. phys. Soc. Japan* **53**(12), 4183 (1985).
39U. K. Onda, K. Takano and K. Kato, Spectral emission from MHD combustion gas mixed with pulverized coal, *J. quant. Spectrosc. radiat. Transfer* **33**(3), 281 (1985).
40U. D. I. Sharakhovskiy and N. A. Kostin, Vortex flows in electric-arc gas heaters, *Heat Transfer—Sov. Res.* **16**(5), 126 (1985).

41U. H. Shindo and T. Tamaru, An improved relaxation method for measuring gas temperature in arc plasmas, *J. quant. Spectrosc. radiat. Transfer* **33**(4), 331 (1985).
42U. H. Shirai, K. Tabei and S. Kato, Temperature measurements of non-equilibrium high-temperature plasmas by means of $N_2^+$ first negative bands, *Bull. J.S.M.E.* **28**(242), 1718 (1985).
43U. S. V. Joshi, Jin Y. Park, P. R. Taylor and L. S. Richardson, The integral mean diffusivity for particle–gas mass transfer calculations under thermal plasma conditions, *Plasma Chem. Plasma Process.* **5**(2), 143 (1985).
44U. E. Pfender, Heat and momentum transfer to particles in thermal plasma flows, *Pure appl. Chem.* **57**(9), 1179 (1985).
45U. E. Pfender and Y. C. Lee, Particle dynamics and particle heat transfer in thermal plasmas — I. The motion of a single particle without thermal effects, *Plasma Chem. Plasma Process.* **5**(3), 211 (1985).
46U. P. Proulx, J. Mostaghimi and M. I. Boulos, Plasma–particle interaction effects in induction plasma modeling under dense loading conditions, *Int. J. Heat Mass Transfer* **28**(7), 1327 (1985).
47U. H. P. Stormberg and R. Schafer, Determination of temperature profiles from optically thick lines, *J. quant. Spectrosc. radiat. Transfer* **33**(1), 27 (1985).
48U. S. Vacquie, A. Gleizes and H. Kafrouni, Measurements of electron density in a $SF_6$ arc plasma, *J. Phys. D: appl. Phys.* **18**(11), 2193 (1985).
49U. S. Venkataramana and D. Bathaiah, MHD combined free and forced convection flow of an incompressible conducting viscoelastic fluid through two parallel porous plates, *Reg. J. Energy Heat Mass Transfer* **7**(1), 47 (1985).
50U. T. Vijayan and V. K. Rohatgi, Characteristics of exploding-wire plasmas, *IEEE Trans. Plasma Sci.* **13**(4), 197 (1985).
51U. F. Weling, A model for the plasma-activated chemical vapor deposition process, *J. appl. Phys.* **57**(9), 4441 (1985).
52U. H. Wilhelmi, W. Wimmer and E. Pfender, Modeling of the transport phenomena in the anode region of high current arcs, *Numer. Heat Transfer* **8**(6), 731 (1985).
53U. G. Wilks and R. Hunt, Low Prandtl number MHD convection about a semi-infinite horizontal plate, *Numer. Heat Transfer* **8**(2), 203 (1985).
54U. Ye. M. Yermolayeva, D. Hebecker, V. K. Zabrodin and A. L. Mosse, Investigation of heat transfer between a hydrogen-plasma jet and the wall of a cylindrical channel, *Heat Transfer—Sov. Res.* **16**(4), 130 (1985).
55U. R. M. Young and E. Pfender, Generation and behavior of fine particles in thermal plasmas—a review, *Plasma Chem. Plasma Process.* **5**(1), 1 (1985).