

Heat Transfer 1986

Proceedings of
The Eighth International
Heat Transfer Conference

Volume 5

Heat Transfer 1986

Proceedings of
The Eighth International
Heat Transfer Conference
San Francisco, California USA

Volume

5

General
Papers

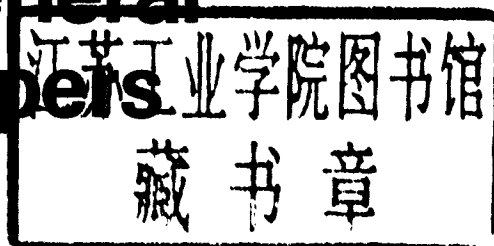
Edited by
C. L. Tien, V. P. Carey,
and J. K. Ferrell

in cooperation with the members of the
International Scientific Committee

M. Combarous, M. Curno, J. K. Ferrell,
E. Hahne, G. Hetsroni, G. F. Hewitt, C. J.
Hoogendoorn, M. V. Krishnamurthy,
M. Majcen, J. H. Masliyah, T. Mizushima,
H. C. Simpson, M. A. Styrikovich, C. L. Tien

and members of the
U.S. Scientific Committee

V. P. Carey, J. C. Chen, J. K. Ferrell, L. S.
Fletcher, J. R. Howell, L. A. Kennedy, D. E.
Metzger, R. K. Shah, K. H. Sun, C. L. Tien



The logo of these Proceedings is an interferogram of natural convection flow around two horizontal cylinders held one above the other. It was taken by R. B. Goldstein in the Heat Transfer Laboratory of the University of Minnesota.

The Eighth International Heat Transfer Conference was held in San Francisco, California USA, August 17-22, 1986. The conference was organized under the authority of the Assembly for International Heat Transfer Conferences, in cooperation with the International Scientific Committee, the U.S. Scientific Committee, The American Society of Mechanical Engineers, and The American Institute of Chemical Engineering.

In order to make these volumes available as economically and as rapidly as possible, the authors' typescripts have been reproduced in their original form.

HEAT TRANSFER 1986

Copyright © 1986 by Hemisphere Publishing Corporation. All rights reserved. Printed in the United States of America. Except as permitted under the United States Copyright Act of 1976, no part of this publication may be reproduced or distributed in any form or by any means, or stored in a data base or retrieval system, without the prior written permission of the publisher.

1 2 3 4 5 6 7 8 9 0 B R B R 8 9 8 7 6

Library of Congress Cataloging in Publication Data

International Heat Transfer Conference (8th : 1986 : San Francisco, Calif.)
Heat transfer, 1986.

Bibliography: p.

Includes index.

Contents: v. 1. Plenary and keynote papers—

v. 2-6. General papers.

1. Heat—Transmission—Congresses. I. Tien, Chang L. II. Carey, V. P. (Van P.) III. Ferrell, J. K. (James K.) IV. Title.

QC319.8.I57 1986 .B21.402'2 86-12043

ISBN 0-89116-559-2 (set) Hemisphere Publishing Corp.

ISBN 0-89116-593-2 (vol. 5) Hemisphere Publishing Corp.

DISTRIBUTION OUTSIDE NORTH AMERICA:

ISBN 3-540-16896-6 Springer-Verlag Berlin

Preface

These six volumes contain the invited and general papers presented at the Eighth International Heat Transfer Conference. The papers consist of 2 plenary lectures, 28 keynote lectures and 450 general presentations.

As indicated in the first plenary lecture by Dr. E. R. G. Eckert, the series of International Heat Transfer Conferences started in London (1951) as an International Discussion on Heat Transfer. The general conference format was established in the Second Conference in Boulder, Colorado (1961). The regular four-year cycle of the Conferences began at the Third Conference in Chicago (1966). The Conference immediately became the major event of the international heat transfer community, with ever increasing participation of heat transfer engineers and scholars from all over the world as manifested in the subsequent Conferences in Versailles (1970), Tokyo (1974), Toronto (1978), and Munich (1982).

The Eighth International Heat Transfer Con-

ference has again received most enthusiastic responses from the international community, reflecting a continuing state of growth and vitality. In many countries, the number of good-quality papers offered for presentation far exceeded the allocation, thus making the selection a most difficult task. For this, we owe special thanks to the members of the International Scientific Committee and their national editors and reviewers. We are also grateful to the other members of the U.S. Scientific Committee who have labored long and hard on the Conference Scientific Program. The strong support of the Conference Executive Committee under Chairman R. J. Goldstein for the Scientific Program and its publication is essential and very much appreciated.

Chang-Lin Tien
Van P. Carey
James K. Ferrell

Nomenclature

Symbol	Quantity	SI Unit
A (or S)	area, cross section	m ²
a	thermal diffusivity	m ² /S
a _t	turbulent (eddy) thermal diffusivity	m ² /s
C	heat capacity	J/K
C _B	molecular concentration of component B	mol/m ³
C _D (or ζ)	drag coefficient	—
c	specific heat capacity	J/(K kg)
c _p	specific heat capacity at constant pressure	J/(K kg)
c _v	specific	
D	diffusion coefficient	m ² /s
d (or D)	diameter	m
d _e	equivalent (hydraulic) diameter	m
E	energy	J
E _e	irradiance	W/m ²
F	force	N
f	friction factor	—
G	weight	N
g	local gravitational acceleration, (standard acceleration, g _n = 9.80665 m/s ²)	m/s ²
H (or I)	enthalpy	J
h (or i)	specific enthalpy	J/kg
h	height	m
h (or α)	heat transfer coefficient	W/(m ² K)
Δh_v	specific latent heat of vaporization	J/kg
Δh_s	specific latent heat of solidification	J/kg
K	equilibrium constant	—
k (or U)	overall heat transfer coefficient	W/(K m ²)

Symbol	Quantity	SI Unit
k (or λ)	thermal conductivity	W/(m K)
L	length	m
m	mass	kg
m	mass flow rate	kg/s
M	molar mass	kg/mol
n	amount of substance	mol
P	power	W
P	pressure	N/m ²
Q	quantity of heat	J
Q (or ϕ)	heat flow rate	W
q (or ϕ_h)	heat flux density	W/m ²
R	universal gas constant, $R = 8.3144 \text{ J/(mol K)}$	J/(mol K)
R _i	individual (specific) gas constant	J/(kg K)
r	radius	m
S	entropy	J/K
S (or A)	cross section	m ²
s	specific entropy	J/(kg K)
T	thermodynamic temperature	K
t	time	s
U (or k)	overall heat transfer coefficient	W/m ² K
V	volume	m ³
V _m	molar volume	m ³ /mol
v	specific volume	m ³ /kg
W	work	J
x	quality	—

Greek Letters

α (or h)	heat transfer coefficient	W/m ² K
α_r	absorptance for radiation	—
α, β, γ	plane angles	rad
β	mass transfer coefficient	m/s
γ (or β_v)	cubic (volumetric) expansion coefficient	K ⁻¹
δ (or d)	thickness	m
ϵ	emissivity	—
ϵ (or ψ)	void fraction	—

Symbol	Quantity	SI Unit
<i>Greek Letters (Continued)</i>		
ζ (or C_D)	drag coefficient	—
η (or μ)	dynamic viscosity	kg/(sm)
v	Celsius temperature	°C
λ (or k)	thermal conductivity	W/(m K)
λ_t	turbulent thermal conductivity	W/(m K)
μ (or η)	dynamic viscosity	kg/(s m)
μ	chemical potential	J/kg
ν	kinematic viscosity	m ² /s
ν_t	turbulent kinetic viscosity (eddy diffusivity for momentum)	m ² /s
ρ	mass density	kg/m ³
ρ_r	reflectance	—
ρ_B	mass concentration of substance B	kg/m ³
ρ_l	density of liquid	kg/m ³
ρ_v	density of vapor	kg/m ³
σ	Stefan-Boltzmann constant	W/(k ⁴ m ²)
σ	surface tension	W/m
τ_t	transmittance	—
τ_s	shear stress	N/m ²
ϕ (or Q)	heat flow rate	W
ϕ_n (or q)	heat flux density	W/m ²
ϕ_m	mass flux density	kg/(s m ²)
ψ	relative humidity	—
ψ (or ϵ)	void fraction	—
Ω	solid angle	sr
<i>Coordinates</i>		
x, y, z	cartesian coordinates	
r, ϕ, z	cylindrical coordinates	
r, ϕ, ψ	spherical coordinates	

Symbol and Definition

Name

Dimensionless parameters

$$Ar = \frac{g_n L^3 \Delta \rho}{\nu^2 \rho}$$

Archimedes number

Symbol and Definition	Name
<i>Dimensionless parameters (Continued)</i>	
$Bi = \frac{\alpha \cdot L}{\lambda_{\text{solid}}}$	Biot number
$Fo = \frac{a \cdot L}{L^2}$	Fourier number
$Fr = \frac{u}{\sqrt{gl}}$	Froude number
$Gr = \frac{gL^3 \gamma \Delta T}{\nu^2}$	Grashof number
$Ja = \frac{c_p \rho_l \Delta T}{\rho_l \Delta h_v}$	Jakob number
$Le = \frac{a}{D}$	Lewis number
$Nu = \frac{\alpha L}{\lambda}$	Nusselt number
$Pe = \frac{uL}{a} = Re \cdot Pr$	Peclet number
$Pe^* = \frac{uL}{D} = Re \cdot Sc$	Peclet number for mass transfer
$Pr = \frac{\nu}{a} = \frac{c_p \eta}{\lambda}$	Prandtl number
$Re = \frac{uL}{\nu}$	Reynolds number
$Sc = \frac{\nu}{D}$	Schmidt number
$Sh = \frac{\beta L}{D}$	Sherwood number
$St = \frac{\alpha}{\rho u c_p} = \frac{Nu}{Re Pr}$	Stanton number
$St^* = \frac{\beta}{u} = \frac{Sh}{Re Sc}$	Stanton number for mass transfer
$We = \frac{u^2 \rho L}{\sigma_v}$	Weber number

Conference Officers

Assembly for International Heat Transfer Conferences

President—U. Grigull, F.R.G.

Vice President—R. J. Goldstein, U.S.A.

Secretary—T. W. Simon, U.S.A.

Conference General Chairman, R. J. Goldstein

Executive Committee

R. J. GOLDSTEIN, *Chairman*

T. W. SIMON, *Secretary*

Members

J. K. FERRELL

S. J. GREEN

C. L. TIEN

Organizing Committee

S. J. GREEN, *Chairman*

G. J. BENKLY

R. J. MOFFAT

D. R. MULLEN

V. E. SCHROCK

E. R. MILLER

J. R. ZIOLKO

Exhibits Subcommittee

R. K. SHAH

K. J. BELL

Short Course Subcommittee

A. D. KRAUS

A. E. BERGLES

Delegates

M. Combarnous, France

M. Cumo, Italy

J. K. Ferrell, U.S.A.

R. J. Goldstein, U.S.A.

J. Gosse, France

U. Grigull, F.R.G.

E. Hahne, F.R.G.

G. F. Hewitt, U.K.

C. J. Hoogendoorn, The Netherlands

Y. Katto, Japan

S. S. Kutateladze, U.S.S.R.

M. Majcen, Yugoslavia

J. H. Masliyah, Canada

T. Mizushima, Japan

D. Moalem-Maron, Israel

D. Poljak, Yugoslavia

A. Ramachandran, India

S. Sideman, Israel

M. Silvestri, Italy

H. C. Simpson, U.K.

S. P. Sukhatme, India

D. A. de Vries, The Netherlands

M. Yovanovich, Canada

A. Zukauskas, U.S.S.R.

International Scientific Committee

C. L. Tien, Chairman, U.S.A.
M. Combarous, France
M. Cumo, Italy
J. K. Ferrell, U.S.A.
E. Hahne, F.R.G.
G. Hetsroni, Israel
G. F. Hewitt, U.K.

C. J. Hoogendoorn, The Netherlands
M. V. Krishnamurthy, India
M. Majcen, Yugoslavia
J. H. Masliyah, Canada
T. Mizushima, Japan
H. C. Simpson, U.K.
M. A. Styrikovich, U.S.S.R.

A large number of national associate editors and reviewers, whose names are not listed here, have supported the members of the International Scientific Committee in the process of reviewing the papers. Their assistance was invaluable for ensuring the quality of the proceedings, and is hereby gratefully acknowledged.

U. S. Scientific Committee

C. L. Tien, Chairman
University of California-Berkeley
J. K. Ferrell, Co-Chairman
North Carolina State University
V. P. Carey, University of California-Berkeley
J. C. Chen, Lehigh University

L. S. Fletcher, Texas A&M University
J. R. Howell, University of Texas-Austin
L. A. Kennedy, Ohio State University
D. E. Metzger, Arizona State University
R. K. Shah, General Motors Co.
K. H. Sun, Electric Power Research Institute

Contents of Volumes 1-6

Preface	xxxiii
Nomenclature	xxxv
Conference Officers	xxxix

PLENARY PAPERS

The early history of international heat transfer conferences	3
E. R. G. Eckert	
Fahrenheit, a pioneer of exact thermometry	9
Ulrich Grigull	

VOLUME 1

KEYNOTE PAPERS

Measurement of thermophysical properties	21
J. E. S. Venart	
Application of laser velocimetry and Rayleigh scattering to engine flows	29
J. H. Whitelaw	
Recent developments in thermal contact, gap and joint conductance theories and experiments	35
M. M. Yovanovich	
Heat transfer augmentation in single-phase flow	47
A. Žukauskas	
Thermal drag and thermal roundabout flow in convective problems	59
Zeng-Yuan Guo	
Turbulent flow and heat transfer with buoyancy effect	69
Fumimaru Ogino	
Experimental investigation of turbulent momentum and heat transfer in the proximity of the wall	79
Ye. M. Khabakhpasheva	
Transfer processes in impinging-streams	91
Abraham Tamir	
Finite difference methods for natural and mixed convection in enclosures	101
Graham deVahl Davis	
Natural convection in enclosures	111
C. J. Hoogendoorn	

Buoyancy effects in double-diffusive and mixed convection flows F. P. Incropera	121
Numerical modeling of natural convection-radiation interactions in enclosures K. T. Yang	131
Radiative heat transfer in scattering media: Real property contributions Richard O. Buckius	141
Heat and mass transfer in flames G. M. Faeth	151
Recent progress in enhancing film condensation heat transfer on horizontal tubes P. J. Marto	161
Critical heat flux in boiling Y. Katto	171
Phase-change heat transfer in porous media K. E. Torrance	181
Heat and mass transfer between a fluidized bed and immersed surfaces and suspended particles A. P. Baskakov and N. F. Philippovsky	189
Bubble dynamics and heat transfer in fluidized beds V. M. K. Sastri and A. K. Kolar	199
Recent advances in two-phase flow instrumentation J. M. Delhay	215
Some thermohydraulic problems associated with the safety of water cooled nuclear reactors Hugh C. Simpson	227
Design of process heat exchangers by computers—A short history J. W. Palen	239
Analytical techniques for basic thermal design of complex heat exchanger configurations Alberto Pignotti	249
High temperature heat exchangers Y. Mori	259
Compact heat exchangers with phase change J. W. Westwater	269
Thermal energy storage: Some views on some problems E. Hahne	279
Heat transfer in electronic systems Richard C. Chu	293
Recent advances in cryopreservation of biological organs and in cryosurgery Boris Rubinsky	307

VOLUME 2

NUMERICAL TECHNIQUES AND MODELING

Thermal models reduction: Why and how? J. B. Saulnier, P. Merour, and A. Alexandre	319
--	-----

Computer analysis of heat transfer problems to check the validity of engineering formulae C. J. M. Lasance	325
Analysis of convective heat transfer in a horizontal cylinder with computer-extended perturbation series D. Long Nguyen and T. Hung Nguyen	331
Isoparametric transition finite elements with temperature gradients for axisymmetric heat conduction Karan S. Surana and Perwez Kalim	337
Finite element simulation of non-isothermal, low Reynolds number, non-Newtonian flows J. Vlachopoulos	349
High frequency cyclic thermal analysis through finite element M. Prasad and S. K. Mazumdar	355
An effective two-dimensional finite element heat transfer analysis with ablation J. S. Hsiao and B. T. F. Chung	361
Numerical and exact mathematical analyses of two-dimensional rectangular composite fins H. Barrow, J. Mistry, and D. Clayton	367
Conjugate heat transfer from a hollow cylinder C. K. Aidun and S. P. Lin	373
Analysis of compact heat exchangers using finite element method S. G. Ravi Kumaur, K. N. Seetharamu, and P. A. Aswatha Narayana	379
Sensitivity analysis applied to Monte Carlo simulation of heat exchangers A. K. M. Uddin and K. J. Bell	385
Use of a Monte-Carlo technique for the determination of radiation exchange areas in 'long furnace' models R. J. Tucker and J. Ward	391
A general coordinates system method for computing transport phenomena Wei Shyy	397
CONDIF: A modified central-difference scheme with unconditional stability and very low numerical diffusion Akshai K. Runchal	403
Numerical prediction of laminar flow and heat transfer in a square cavity covered by a moving wall M. Morzynski and C. O. Popiel	409
Prediction of heat transfer in laminar flow over a rearward-facing step using the partially-parabolized Navier-Stokes equations I.-T. Chiu and R. H. Pletcher	415
Heat transfer and fluid flow analysis for an array of interrupted plates, positioned obliquely to the flow direction Yutaka Asako and M. Faghri	421
Unsteady heat transfer from a cylinder in crossflow; a direct numerical simulation G. E. Karniadakis, B. B. Mikic, and A. T. Patera	429
Numerical studies of mixed convection flows in the annulus between vertical concentric cylinders with rotating inner cylinder Kenneth S. Ball and Bakhtier Farouk	435
Numerical prediction of natural convection from a horizontal disk B. J. Tsai and J. A. Liburdy	441

A numerical model for convection in complex two-dimensional geometries and its application to buoyancy flow in a power cable	447
R. C. Broughton and A. J. Oliver	
A numerical simulation of the boiling crises phenomenon	453
Dominique Gentile and Jaroslaw Pakleza	
Numerical simulation of casting processes	459
M. Salcudean, Z. Abdullah	
MEASUREMENT TECHNIQUES	
Analysis of a local heat flux probe	467
Donald E. Beasley and Richard S. Figliola	
A critical analysis of the calorimetric method for determining the heat flux in soils	473
D. A. de Vries	
The accurate measurement of heat flux using a film heat flux sensor with application to axisymmetric bodies	477
D. C. Shallcross and D. G. Wood	
Theoretical and experimental analysis of two surface thermocouples	483
B. Cassagne, J. P. Bardou, and J. V. Beck	
Simultaneous determination of heat transfer coefficient and adiabatic wall effectiveness on a film cooled surface using the swollen polymer technique	489
N. Háy, D. Lampard, R. Maali, and I. Burns	
An analysis of the uniform naphthalene layer mass transfer analogue method applied to laminar flow over a flat plate	495
J. P. Brakell and T. A. Cowell	
The dither-technique for steady-state transition boiling measurements	501
A. Auracher and W. Marquardt	
A study of transport phenomena in the interline region of an evaporation thin liquid film using a scanning ellipsometer	507
J. G. Truong and P. C. Wayner, Jr.	
Evaluation of natural and forced-convection heat transfer coefficients in and over an enclosure by Mach-Zehnder interferometry	513
N. N. Saidi and J. D. Tarasuk	
A tomographical method using holographic interferometry for the registration of three-dimensional unsteady temperature profiles in laminar and turbulent flow	519
W. Ostendorf, F. Mayinger, and D. Mewes	
Thermal stability in binary droplet vaporization a flat plate by real-time holographic interferometry	525
Nengli Zhang, Yoren Xu, and Wen-Jei Yang	
Measurement of natural convection by speckle photography	531
U. Wernekinck and W. Merzkirch	
Experimental study of thermally stratified unsteady flow by NMR-CT	537
Sang Joon Lee and Myung Kyoong Chung	
Thermal conductivity of aqueous LiCl measured by transient hot wire method	543
M. Takeuchi, S. Katoh, J. Kamoshida, and Y. Kurosaki	
Temperature correction for the output response of a constant-temperature hot-film anemometer in nonisothermal flows with strong property-temperature dependence	549
S. A. Sherif and R. H. Fletcher	

Acoustic temperature and velocity measurement in combustion gases S. F. Green	555
Pyrometry using photothermal effect O. Berthet and J. J. Greffet	561
Models and experiments for radiation estimation of absorbing, emitting and anisotropically scattering media J. F. Sacadura, G. Uny, and A. Venet	565
Radiative properties of aerosols and solids in the infrared industrial applications P. Herve, S. Mattei, P. Adam, P. Masclet, and M. Boisson	571
Measurement of transient behaviors in thermal radiation characteristics of materials by high-speed spectroscopy T. Makino, S. Matsuda, N. Hirata, and T. Kunitomo	577
Influence of oxide films and surface damage on the emittance of 18/8 stainless steel S. A. M. Haquani, P. A. German, B. N. Furber, and L. A. Popple	583
 CONDUCTION AND INSULATION	
On the solutions of boundary and initial-boundary value problems with supplementary data—The overdetermined problems Zygmunt S. Kolenda	591
New applications of conformal mapping to the unsteady heat conduction problem P. Braun-Angott	597
Experimental validation of a new space marching finite difference algorithm for the inverse heat conduction problem M. Raynaud and J. Bransier	603
Solution of inverse heat-conduction problems with unknown initial conditions C. K. Hsieh and Jeou-feng Lin	609
Hyperbolic heat conduction in composite regions J. I. Frankel, Brian Vick, and N. N. Ozisik	615
Transient response of a composite hollow cylinder heated by a moving line source with hyperbolic heat conduction equation H. S. Chu, J. M. Chen, and J. H. Tzou	621
On the theoretical prediction of the effective thermal conductivity of bricks Fabio Gori	627
Thermal diffusivity measurements of insulators by a step function heat flux method J. S. Goodling and D. G. Swann	633
Heat transfer between rough surfaces in contact over a highly elliptical contour area: Comparison of experimental and numerical results T. C. Currie and J. T. Rogers	639
Effect of plastically formed surface waves on the thermal resistance of an expanded pressure tube in contact with a surrounding concentric calandria tube M. H. Schankula, J. W. DeVaal, and V. D. Kroeger	645
On heat flow across cylindrical joints C. V. Madhusudana	651
Small scale thermal contact resistance of aluminum against silicon Jeffrey C. Eid and Vincent W. Antonetti	659

Identification or control of the boundary input of a linear thermal system with no intrusive measurements, in the presence of internal heat source disturbances	665
Christine Bénard, Béatrice Guerrier, and Marie-Minerve Rosset	
The effect of conduction down the wall on the growth of a temperature interface	671
W. D. Baines and I. W. Totman	
Numerical simulation of a double-glazed window unit with a particular attention on the gas filling the window cavity	677
Jules Thibault	
Concrete slabs as summer solar collectors	683
Dr. Robert H. Turner	
Analysis of circular tapering radiator plates	691
K. Badari Narayana, S. Uma Kumari, and H. Narayana Murthy	
Shuttle heat transfer in the insulated diesel	697
John Dewey Jones	
Analysis of transient heat transfer measurements on porous thermal insulations	703
T. W. Tong, D. L. McElroy, and D. W. Yarbrough	
Study of heat transfer in evacuated insulations at various gas loadings	709
M. Luu, B. A. Allmon, K. E. Kneidel, and J. G. Stevens	
Thermal insulation system for buildings including ventilated air ducts	715
Ph. Gervais, A. Gery, and M. Laurent	
The effect of radiation barriers on conduction and radiation heat transfer in fibrous insulations	721
J. W. Rish, III and J. A. Roux	
 RADIATION AND COMBUSTION	
Radiative entropy production	729
V. S. Arpaci and A. Selamet	
Total emissivity and absorptivity models for carbon dioxide, water vapor and their mixtures	735
F. R. Steward and Y. S. Kocaefe	
Radiative properties of aluminized propellant flames	741
M. Quinn Brewster	
Absorptivities of diffuse cylindrical cavities	747
J. Galindo and E. Bilgen	
Accurate evaluation of radiative direct-exchange areas for rectangular geometries	751
R. G. Siddall	
Radiant transfer in gas filled enclosures by radiant energy absorption distribution method	757
Hiroshi Taniguchi, Wen-Jei Yang, Kazuhiko Kudo, Hiroshi Hayasaka, Masahito Oguma, Akio Kusama, Ichiro Nakamachi, and Noboru Okigami	
A solution of mean beam lengths of radiating gases in rectangular parallelepiped enclosures	763
E. Scholand and P. Schenkel	
Mean beam length for a scattering medium	769
J. D. Cartigny	
Enhancement of radiative heat transfer based on non-gray feature of radiative gas	773
M. Hirano, T. Miyauchi, and Y. Mori	

Laminar natural convection heat transfer to non-Newtonian fluids with thermal radiation effects Michael J. Galuska, Kenneth H. Kim, and Yeunsik Choi	779
Radiation and forced convection interaction in thermally-developing laminar flow through a circular pipe Y. Yener and T. M. Fong	785
Coupled convective and radiative transfer in strongly nonisothermal CO₂ and H₂O laminar flows A. Soufiani and J. Taine	791
Conjugated heat transfer of a radiatively participating gas in a channel M. Kassemi and B. T. F. Chung	797
Heat transfer for flow of an absorbing, emitting, and isotropically scattering medium through a tube with reflecting walls Theodore F. Smith, Ki-Hong Byun, and Martha J. Ford	803
Combined radiative and conductive transient heat transfer between a wall and a fluidized bed G. Flamant	809
An assessment of spectral radiative heat transfer predictions for a pulverized coal-fired furnace M. P. Mengüç and R. Viskanta	815
Radiative heat transfer calculation for pulverized coal combustion application of Lorenz-Mie theory D. Grouset and D. Rebuffat	821
Analytical and experimental studies on radiative propagation in porous media with internal heat generation R. Echigo, Y. Yoshizawa, K. Hanamura, and T. Tomimura	827
The effect of thermal radiation on the propagation of laminar flames W. W. Yuen and S. H. Zhu	833
Flame propagation in a closed tube K. N. Tennankore and J. F. Lafortune	843
Steady propagation of an opposed-wind diffusion flame on a charring solid Arvind Atreya	849
Laser ignition of bulk 1018 carbon steel in pure oxygen K. Nguyen and M. C. Branch	857
A study of the combustion and agglomeration of coal slurry fuel Lawrence A. Kennedy and L. K. Hwang	863

VOLUME 3

INTERNAL FORCED CONVECTION

A generalized closed-form solution to laminar thermal entrance problems R. Lakshminarayanan and A. Haji-Sheikh	871
Simultaneously developing flow and heat transfer in the entrance region of elliptical ducts C. W. Rapley, R. Stainsby, and A. I. C. Webb	877
Solutions to the combined entrance region in a circular tube J. X. Ling and A. Dybbs	883
Momentum and heat transfer in the entrance region of a circular pipe with oblique inlet of air M. Jícha and V. Enenkl	889