

ISSN 1044-5110
ATSPE2

ATOMIZATION AND SPRAYS

Journal of the International Institutes for Liquid Atomization and Spray Systems

Volume 1

1991

ATOMIZATION AND SPRAYS

Journal of the International Institutes for Liquid Atomization and Spray Systems

Editor

NORMAN CHIGIER

Department of Mechanical Engineering
Carnegie-Mellon University
Pittsburgh, PA 15213-3890
(412) 268-2498

Editorial Assistant

Eunice Hench

EDITORIAL BOARD

Will Bachalo, Sunnyvale, CA
W. Balachandran, Surrey, U.K.
Josette Bellan, Pasadena, CA
W. Buschulte, Hardthausen am Kocher, Germany
E. Johansen Crosby, Madison, WI
Lee G. Dodge, San Antonio, TX
Norman Dombrowsky, Leeds, U.K.
M. M. Elkoth, Cairo, Egypt
G. Faeth, Ann Arbor, MI
Omer L. Gulder, Ottawa, Ontario
Hiroyuki Hiroyasu, Saijo-Machi Ohaza Sitami, Japan

Jan B. Kennedy, East Hartford, CT
H. H. Kuo, Warren, MI
Arthur H. Lefebvre, West Lafayette, IN
J. E. Peters, Urbana, IL
Rolf Reitz, Warren, MI
G. S. Samuelsen, Irvine, CA
D. W. Senser, W. Lafayette, IN
W. A. Sirignano, Irvine, CA
Yoram Tambour, Haifa, Israel
A. J. Yule, Manchester, U.K.
S. Zanelli, Pisa, Italy

Editorial Office: Norman Chigier, Department of Mechanical Engineering, Carnegie-Mellon University, Pittsburgh, PA 15213, telephone (412) 268-2498.

Publishing, Advertising, and Production Offices: Publishing and Advertising: Taylor & Francis/Hemisphere, 79 Madison Avenue, Suite 1106, New York, NY 10016-7892, (212) 725-1999; or Taylor & Francis Ltd., Rankine Road, Basingstoke, Hampshire RG24 0PR, England. Production: Hemisphere Publishing Corporation, 1101 Vermont Avenue, N.W., Suite 200, Washington, DC 20005-3521, Telephone (202) 289-2174, Joyce Duncan, Production Editor.

Atomization and Sprays (ISSN 1044-5110) is published four times per year by Taylor & Francis Ltd., 4 John Street, London WC1N 2ET U.K. for Hemisphere Publishing Corporation. Annual 1991 institutional subscription £75, US \$135. Personal subscription rate US \$35; available to home address only and must be paid for by personal check or credit card.

Second-class postage pending at Jamaica, New York 11431. **U.S. Postmaster:** Send address changes to Atomization and Sprays, Publications Expediting, Inc., 200 Meacham Avenue, Elmont, NY 11003.

Dollar rates apply to subscribers in all countries except the UK and the Republic of Ireland, where the sterling price applies. All subscriptions are payable in advance and all rates include postage. Subscriptions are entered on an annual basis, i.e., January to December. Payment may be made by sterling check, dollar check, international money order, National Giro, or credit card (AMEX, VISA, Mastercard/Access).

Orders originating in the following territories should be sent directly to: **Australia**—R. Hill & Son, Ltd., Suite 2, 119 Gardenvale Road, Gardenvale, Victoria, Australia 3185. **India**—Universal Subscription Agency Pvt. Ltd., 101-102 Community Centre, Malviya Nagar Extn., Post Bag No. 8, Saket, New Delhi. **Japan**—Kinokuniya Company, Ltd., Journal Department, P.O. Box 55, Chitose, Tokyo 156, Japan. **New Zealand**—R. Hill & Son, Ltd., Private Bag, Newmarket, Auckland 1. **USA, Canada, and Mexico**—Taylor & Francis, Inc./Hemisphere Publishing Corporation, 1900 Frost Road, Suite 101, Bristol, PA 19007, USA. **UK and all other territories**—Taylor & Francis Ltd., Rankine Road, Basingstoke, Hampshire RG24 0PR, England.

Copyright © 1991 by Hemisphere Publishing Corporation. All rights reserved. Printed in the United States of America. Authorization to photocopy items for internal or personal use, or the internal or personal use of specific clients, is granted by Hemisphere Publishing Corporation for libraries and other users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$3.00 per copy, plus .00 per page is paid directly to CCC, 27 Congress St., Salem, MA 01970, USA.

The publisher assumes no responsibility for any statements of fact or opinion expressed in the published papers or in the advertisements. **Atomization and Sprays** is owned by Hemisphere Publishing Corporation.

CONTENTS OF VOLUME 1

NUMBER 1

- i Editorial
- 1 Influence of Liquid Viscosity on Pressure-swirl Atomizer Performance **S. K. Chen, A. H. Lefebvre, and J. Rollbuhler**
- 23 Parametric Experiments on Liquid Jet Atomization Spray Angle **Francisco Ruiz and Norman Chigier**
- 47 Interaction between Two Thin Liquid Jets with Disintegration by Gas Flow **H. Hashimoto, T. Suzuki, and T. Matsuya**
- 63 Experimental Investigation of Fuel Spray Vapor Phase Characterization **J. A. Drallmeier and J. E. Peters**
- 89 2-D Laser Sheet Visualization of a Pulsed Hollow Cone Spray: Stagnant and Simulated Two-stroke Engine Environments **D. G. Talley, Y. C. Lin, and M. Morris**
- 113 Effect of Shock Waves on Liquid Atomization of a Two-dimensional Airblast Atomizer **K. D. Kihm and N. Chigier**

NUMBER 2

- 137 Geometrical Effects on Discharge Coefficients for Plain-Orifice Atomizers **T. R. Ohrn, D. W. Senser, and A. H. Lefebvre**
- 155 Liquid Sheet Disintegration by Impinging Air Streams **J. E. Beck, A. H. Lefebvre, and T. R. Koblisch**
- 171 Production of Uniformly Sized Dual Concentric Droplets from Coaxial Smooth Jet under Applied AC Electric Field **Takashi Sakai, Masayoshi Sadakata, Masayuki Sato, and Kiyoshi Kimura**
- 187 Mechanism of Spray Formation from Liquid Sheets **B. Creighton and S. P. Lin**
- 199 Application of Image Processing in Spray Diagnostics: High-Velocity Jets **L. Azzarelli, M. Chimenti, O. Salvetti, and L. Tognotti**

- 215 Analysis of Pressure Swirl and Pure Airblast Atomization **Chien-Pei Mao, S. G. Chuech, and A. J. Przekwas**
- 237 Book Review

NUMBER 3

- 239 Effervescent Atomization of High-Viscosity Fluids: Part I. Newtonian Liquids **Harry N. Buckner and Paul E. Sojka**
- 253 Geometric Effects on Spray Cone Angle for Plain-Orifice Atomizers **T. R. Ohrn, D. W. Senser, and A. H. Lefebvre**
- 269 Operation, Calibration, and Accuracy of the Forward Scattering Spectrometer Probe in an Icing Environment **Edward A. Hovenac**
- 303 Impinging Diesel Spray Dynamics **J. R. Zurlo and N. Chigier**
- 319 Spray Behavior in Nonswirling and Swirling Annular Air Flows **Xianguo Li and Richard S. Tankin**
- 337 Analysis of Pre-Ignition Mechanisms in a Diesel Combustion Engine with the Aid of Image Processing **A. Cavaliere, S. Pintus, L. Tognotti, and S. Zanelli**

NUMBER 4

- 349 Wave Characteristics of Liquid Jets from Airblast Coaxial Atomizers **H. Eroglu and N. Chigier**
- 367 A Model of the Evaporation of Binary-Fuel Clusters of Drops **K. Harstad and J. Bellan**
- 389 Gray Level Factors Used in Image Processing of Two-Dimensional Drop Images **Sang Yong Lee, Byung Suh Park, and In Goo Kim**
- 401 Atomization and Evaporation of Diesel Sprays in High-Pressure and High-Temperature Environments **A. Cavaliere, R. Ragucci, A. D'Alessio, and C. Noviello**
- 421 Primary Breakup in Liquid-Gas Mixing Layers **P.-K. Wu, G. A. Ruff, and G. M. Faeth**
- 441 Measurement and Modeling of Diesel Sprays **A. J. Yule and A. P. Watkins**

Following page 466:

Title Page to Volume 1
Contents of Volume 1
Author Index to Volume 1
Subject Index to Volume 1

AUTHOR INDEX TO VOLUME 1

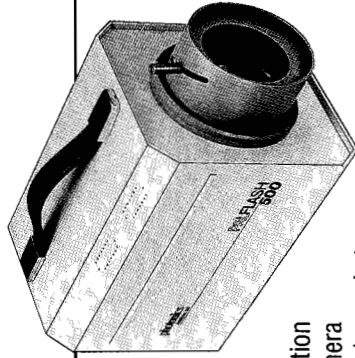
- Azzarelli, L., 199
- Beck, J. E., 155
Bellan, J., 367
Buckner, H. N., 239
- Cavaliere, A., 337, 401
Chen, S. K., 1
Chigier, N., 23, 113, 303, 349
Chimenti, M., 199
Chuech, S. G., 215
Creighton, B., 199
- D'Alessio, A., 401
Drallmeier, J. A., 63
- Eroglu, H., 349
- Faeth, G. M., 421
- Harstad, K., 367
Hashimoto, H., 47
Hovenac, E. A., 269
- Kihm, K. D., 113
Kim, I. G., 389
Kimura, K., 171
Koblish, T. R., 155
- Lee, S. Y., 389
Lefebvre, A. H., 1, 137, 155, 253
Li, X., 319
Lin, L. C., 89
Lin, S. P., 199
- Mao, C.-P., 215
Matsuya, T., 47
Morris, M., 89
- Noviello, C., 401
- Ohrn, T. R., 137, 253
- Park, B. S., 389
Peter, J. E., 63
Pintus, S., 337
Przekwas, A. J., 215
- Ragucci, R., 401
Rollbuhler, J., 1
Ruff, G. A., 421
Ruiz, F., 23
- Sadakata, M., 171
Sakai, T., 171
Salvetti, O., 199
Sato, M., 171
Senser, D. W., 137, 253
Sojka, P. E., 239
Suzuki, T., 47
- Talley, D. G., 89
Tankin, R. S., 319
Tognotti, L., 199, 337
- Watkins, A. P., 441
Wu, P.-K., 421
- Yule, A. J., 441
- Zanelli, S., 337
Zurlo, J. R., 303

SUBJECT INDEX TO VOLUME 1

- Airblast coaxial atomizers, wave characteristics, 349
- Annular air flows, swirling, 319
- Binary-fuel cluster of drops, evaporation of, 367
- Diesel combustion engine and pre-ignition mechanisms, 337
- Diesel spray dynamics, 303
- Diesel sprays, in high pressures and high temperatures, 401
- Diesel sprays, measurement and modeling, 441
- Forward scattering spectrometer probe, 269
- Fuel spray vapor spray characterization, 63
- High-viscosity fluids, effervescent atomization of, 239
- Image processing in spray diagnostics, high-velocity jets, 199
- Liquid atomization and shock waves, 113
- Liquid jet atomization spray angle, parametric experiments, 23
- Liquid jets and disintegration by gas flow, 47
- Liquid sheet disintegration, by impinging air streams, 155
- Liquid-gas mixing layers, breakup in, 421
- Plain-orifice atomizers, discharge coefficients, 137
- Plain-orifice atomizers and spray cone angles, 253
- Pressure swirl and airblast atomization, analysis of, 215
- Pressure-swirl atomizer performance, liquid viscosity and, 1
- Pulsed hollow cone spray, 2-d laser sheet visualization, 89
- Spray formation from liquid sheets, 187
- Two-dimensional drop images, image processing of, 389
- Uniformly sized, dual concentric droplets, production of, 171

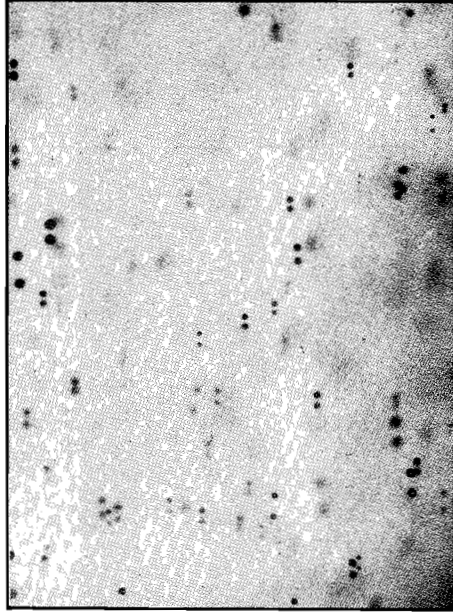
SPRAY MOTION ANALYSIS

using the **PALFLASH** SHORT EXPOSURE
PULSED FLASH UNIT



Features:

- very short exposure
- 500 nsec freezes motion
- uses regular still camera
- fast repetition rate to 1 μ sec between flashes – adjustable
- multiple flashes – maximum four
- sharp shadows due to point source and collimating optics
- high stability with Argon Gas purging
- high energy makes most films usable, including colour film



Aerosol droplets photographed using a two-flash PALFLASH with exposure time of 300 nsec. moving at 2.7 m/sec. Average size of particles 100 μ m.

For more information contact:

photonics
Analysis Ltd

410 Conestogo Road
Waterloo, Ontario, Canada N2L 4E2
Tel: (519) 885-2159 Fax: (519) 885-4712

Distributed in the USA by: The Cooke Corporation
900 Hertel Ave., Box 209
Buffalo, NY 14216-0209 Tel: (716) 833-8274

Books in...

ENGINEERING FROM HEMISPHERE

New Volume!

THERMODYNAMIC PROPERTIES OF INDIVIDUAL SUBSTANCES Fourth Edition, Volume 2

L. V. Gurvich and I. V. Veyts, both of the Institute for High Temperatures, Academy of Sciences of the USSR, and C. B. Alcock, University of Notre Dame, Indiana

Thermodynamic Properties of Individual Substances Series

This exceptional compilation of data contains the most current calculations available in a single volume. This resource is unmatched in its comprehensive and up-to-date presentation of elemental properties. It deals with the properties of

5 elements (carbon, silicon, germanium, tin, and lead) and their compounds with oxygen, hydrogen, halogens, sulfur, and nitrogen. Included are 304 tables with thermodynamic properties of these substances. Totally new data for germanium, inherent to the computer industry, is presented.

1990 • 952pp • Hardcover 0-89116-533-9 • \$249.00

Latest Research!

PROPERTIES OF WATER AND STEAM Proceedings of the 11th International Conference

Edited by M. Pichal and O. Sifner, both of the Institute of Thermomechanics, Czechoslovak Academy of Sciences

This book contains the proceedings of the 11th International Conference of the Properties of Steam, conducted in 1989 at Czechoslovakia. The session provided an international forum for the dissemination of information on recent progress in experiment, theory and formulation of the properties of steam and aqueous

systems in the power industry during the past five years. The papers reflect present knowledge of the thermophysical properties of pure ordinary and heavy water, the properties of aqueous solutions, the power cycle chemistry, and corrosion in power plants.

1990 • 584pp • Hardcover 1-56032-042-7 • \$125.00

To Order, Call Toll Free: 1-800-821-8312



HEMISPHERE PUBLISHING CORPORATION

A member of Taylor & Francis Group

1900 Frost Road, Suite 101

Bristol, PA 19007-1598

Prices subject to change without notice.