10th International Conference on
Liquid Atomization and Spray Systems

ICLASS-2006

August 27 - September 1, 2006

Kyoto, Japan

Kyoto Citizen’s Amenity Plaza
Kyoto Terrsa

**Organized by**
- Institute for Liquid Atomization and Spray Systems - Japan (ILASS-Japan)

**Sponsors**
- International Institute of Liquid Atomization and Spray Systems
- Institute for Liquid Atomization and Spray Systems - ASIA
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- The Japan Institute of Energy
Foreword

Dear all the participants of ICLASS 2006, Kyoto!
On behalf of the Organizing Committee of 10th International Conference of Liquid Atomization and Spray Systems (ICLASS 2006) I would like to inform you with great pleasure that much papers over 230 will be presented. All the participants have the good chance to get the newest information relating to the atomization field from all the presentation and discussion.

You have the great chance to hear two kinds of key note speech given by very famous Prof. G. Gouesbet and Prof G. Reischl. Their contents are very much important for the future development of the theory and experiments of atomization. The other key note speech will be presented by also very famous researcher relating to the spray atomization, Prof. H. Hiroyasu. The contents of his presentation are the introduction of the works of the late Prof. Y. Tanasawa who was just pioneer of the field of atomization phenomena. The other main event is the invited lecture given by Prof. N. Chigier who is the first winner of the Lefebvre Award established by ILASS Europe in memory of the late Prof. A. Lefebvre. The Tanasawa Award will be given to the best paper presented at ICLASS 2003, Sorrento. Both Awards will be given at the banquet of ICLASS 2006. The late Prof. Y. Tanasawa gave by himself the first winner of Tanasawa Award at ICLASS ’88, Sendai.

The Organizing Committee plans for the first time to give the Best Presentation Award to the best presenter during ICLASS 2006. Kyoto is the hart of Japan which was founded before about 1200 years and has much many beautiful gardens, historical temples and shrines. You have the big chance to visit there after the conference. I as a Conference Chairperson of ICLASS 2006 would like to expect that all the participants will enjoy our Conference. Lastly I would like to express my appreciation to all the members of the organizing committee who strongly cooperate to get the success of ICLASS 2006. Also I would like to thank many companies which support ICLASS 2006 through the exhibition of their instruments and catalogues.

Thank you!

August 2006

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Prof. Dr. H. Gen Fujimoto
Organization of ICLASS 2006

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Japan Burner Research Association
Japan Coating Technology Association
Japan Industrial Furnace Manufacturers Association
The Japan Institution of Marine Engineering
Japan Painting Contractors Association
The Japan Petroleum Institute
The Japan Society for Aeronautical and Space Sciences
The Japan Society of Applied Physics
Japan Society of Energy and Resources
The Japan Society of Mechanical Engineers
Japan Society of Powder and Powder Metallurgy
The Japanese Society of Agricultural Machinery
The Japanese Society for Multiphase Flow
Japanese Society of Agricultural Technology Management
Japanese Society of Farm Work Research
The Japanese Society of Irrigation, Drainage and Reclamation Engineering
The Oto-rhino-laryngological Society of Japan
The Pharmaceutical Society of Japan
The Society of Agricultural Structures, Japan
The Society of Automotive Engineers of Japan
The Society of Chemical Engineers, Japan
The Society of Electrophotography of Japan
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The Visualization Society of Japan
The Water Jet Technology Society of Japan
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SHIMADZU CORPORATION
Seika Corporation
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**Background of ICLASS 2006**

The 10th International Conference on Liquid Atomization and Spray Systems (ICLASS-2006) will be held at Kyoto Citizen's Amenity Plaza (Kyoto Terrsa), Kyoto, Japan from the 27th of August to the 1st of September 2006. The first ICLASS was held in Tokyo (1978) advocated by the late Dr. P. Eisenklaum. The succeeding conference locating were Madison, USA (1982), London, UK (1985), Sendai, Tokyo (1988), Gaithersburg, USA (1991), Rouen, France (1994), Seoul, Korea (1997), Pasadena, USA (2000) and Sorrento, Italy (2003).

The theme of the conference covers all aspects of liquid and metal atomization and their sprays for droplet size orders ranging from a nanometer to as large as a micrometer. The conference program will include theoretical and experimental works and simulations related to various scientific and industrial fields, for example, steady combustion, non-steady combustion, coating, painting, cooling, medicine, agriculture, environment, etc.

The conference is a very significant event. All researchers, engineers and students in the field of atomization are strongly encouraged to attend and participate in this conference to discuss issues related to the topics mentioned above. The event should be a very rewarding experience for the attendees.

**Tanasawa Award**

The late Professor Yasusi Tanasawa was the one of the world foremost pioneers in the research of liquid atomization. He contributed greatly to this field by ascertaining the characteristics of many different kinds of spray. One of his significant contributions was the Nukiyama-Tanasawa equation for liquid droplet distribution. In addition, he proposed many different designs for different ways of atomizing. In particular, he was noted for the swirl atomizer.

In 1982, the committee members of the council of ILASS-International proposed that future conferences should have an international academic award. They suggested that it should be named the Tanasawa Award in commemoration of Professor Tanasawa's important pioneering contributions to the field of liquid atomization and spray systems. They asked Professor Tanasawa's disciples to put the award, including the fund raising, into practice.

The entire funding for the award was donated by the TOYOTA MOTOR Co.Ltd. This is due to the thanks of Dr. Shoichiro Toyoda, who was the former president of TOYOTA MOTORS Co. and is one of Professor Tanasawa's disciples.

Professor Yasusi Tanasawa presented the first winner the award at the Sendai Conference by himself.

The selection committee for the Tanasawa Award has been organized to select the best paper from each previous ICLASS conference. The committee consists of nine members who are nominated from throughout the world.

The Tanasawa Award consists of the Plaque with Silver Metal, Award Certificate and Prize Award.
**Lefebvre Award**

Professor Arthur Henry Lefebvre has been one of the most eminent and admired researchers from within our ILASS community. He was a member of both the ILASS-Americas as well as the ILASS-Europe. He became the Chairman and subsequently the first Honorary Member of the ILASS-Europe.

The global spray combustion community knew him very well through his pioneering research contributions in the area of spray atomization and airblast fuel injector design which served to underpin most major advances in gas turbine combustor technology including pollutant emissions since the early 1970's. His widely read and highly-regarded book 'Atomization and Sprays' gave him an unparalleled standing within the field as evidenced by his immensely large number of contributions both as an academic and as an industrial consultant. He held the titles of Professor, Head of Department and School, Emeritus Professor at both the Cranfield and Purdue Universities and the scientific community bestowed him with many prestigious, professional honours and awards.

One year after his passing away, the ILASS-Europe decided in 2004 to dedicate an award in his memory. Lefebvre Award is bestowed upon a scientist who has distinguished him/her/self by continuing and encouraging contributions to the field of atomization and sprays. It will normally be announced at the banquet of ICLASS Conference and consists of a gift and or a certificate to be presented by the chairman of the Lefebvre Award Committee. The Award Committee, featuring representatives from each of the regional ILASS Organizations, select the recipient from amongst the nominations received.

**MOTIVATION**

The Lefebvre Award is presented for distinguished, continuing and encouraging contributions to the field of atomization and sprays.

**REGULATION**

1. **Committee composition.** The Lefebvre Award Committee is formed of six members. Each regional ILASS appoints two members and it will communicate their names to the ILASS Europe Committee before the ILASS Europe Meeting following the ICLASS Conference. The chairman of the Lefebvre Award Committee is chosen from the two ILASS-Europe members and he coordinates the work of the Lefebvre Award Committee.

2. **Nomination of candidates.** Each regional ILASS nominates at most two candidates. They should submit a written proposal for each of the names proposed to the Award Committee for their consideration and discussion.

3. **Selection of Lefebvre award recipient.** The members of the Award Committee evaluate all the proposals against previously defined criteria and requirements. If appropriate they can ask for further information to assist them in the evaluation process. The Award Committee identifies the recipient of the Lefebvre Award on this basis.

4. **Award.** The Lefebvre Award is announced at the banquet of the ICLASS Conference and it consists of a certificate and a gift presented by the chairman of the Award Committee or by a person appointed by him.

5. **Unexpected events.** The chairman of ILASS Europe will deal with unexpected events including the nomination of additional Award Committee members in case of resignation, death or nomination for the Award for one or more of the members of the Award Committee.

6. **Changes to the regulations.** The ILASS Europe Committee can change the Lefebvre Award regulations by a majority.
Thirty Years History of ICLASS

ICLASS '78
The 1st International Conference on Liquid Atomization and Spray Systems
Sasakawa Hall, Tokyo Japan, August 27-31, 1978
Host Organization: THE FUEL SOCIETY OF JAPAN
Honorable Chairman: Yasusi TANASAWA (Professor Emeritus, Tohoku Univ.)
Chairman: Keishin MATSUNOTO (The Fuel Society Japan)
Steering Committee Chairman: Yoichi TAKASHIMA (Tokyo Institute of Technology)
General Affairs Committee Chairman: G. Takeshi SATO
Technical Papers: 53
Special Lectures: 2
1) Application of Spray Technology to Combustion and Fiber-Manufacturing
   Yasusi TANASAWA (Professor Emeritus, Tohoku Univ.)
2) Atomization Considerations in Spray Processing
   E.J. CROSBY (Univ. of Wisconsin)

GENERAL REVIEW OF THE CONFERENCE

The First International Conference on Liquid Atomization, the first attempt in this field of study, was held from August 27, 1978 and ended with great success on August 31.

The holding of the conference was finally attained after requests from scholars in many countries who had been interested in the series of domestic lecture meetings in Japan since 1972 concerning atomization technology and other related fields, supported by the Japan Fuel Society and other organizations.

Those concerned with this conference, centering on Dr. P. Eisenklam, began efforts in 1975, to hold an international conference on liquid atomization, and at the 5th JCLAS meeting in May, 1975, Dr. Eisenklam visited Japan as a guest speaker to mark the first tangible step in preparation for this conference.

Liquid atomization is an interdisciplinary subject covering a wide range of study fields. Therefore, the greatest problems in preparation of a conference at an international level were related to the organization of an administrative body and fund raising. Fortunately, the committees for domestic lecture meetings could play active roles supported by cooperation from other societies. Since this was a first attempt, committee members met some difficulties in finding efficient ways of publicizing the event and soliciting participants. In connection with this, Dr. Eisenklam, Prof. E.J. Crosby, Dr. N. Dombrowski, the Institute of Fuel, London, l'Institut Francaise des Combustibles et de l'Energie, France and other organizations extended us their whole hearted cooperation. Thanks to them, the scale of the conference was larger than what was originally expected, seeing the presentation of 53 papers. Along with this, the conference budget increased from the original ¥25 million to ¥27.8 million, ¥17.5 million of which were contributions from 97 private businesses. The committee members, in soliciting the contributions, made a pamphlet entitled “What is Atomization” to deepen the understanding of company managers, since, although the technology of liquid atomization is popularly used in many industrial fields, no business is involved in this field exclusively, and people tend to overlook the importance of the study.

After these initial activities, including eight meetings of the preparatory committee, the first organizing committee and the steering committee meetings were held on Nov. 12, 1976. Since then, three meetings of the organizing committee, 13 meetings of the steering committee and 30 meetings of other sub-committees were held before the conference was actualized.

As for the conference site, the conference hall of the Japan Science Council was originally selected, but in consideration of the number of participants and necessary facilities, it was decided later that the Technical Sessions, Special Lectures, and Panel Discussions were to be held at Sasakawa Hall, and the Registration, Early Bird Reception, and Banquet at Hotel Okura.

ICLASS '82
The 2nd International Conference on Liquid Atomization and Spray Systems
Concourse Hotel, Madison, Wisconsin, USA, June 20-24, 1982
Host Organization: Chemical Engineering, College of Engineering Univ. Wisconsin-Madison
Internal Organization Committee (Prof. Y. Takashima, Dr. P. Eisenklam and Prof. E.J. Crosby)
Conference Committee (Univ. of Wisconsin-Madison):
   Dr. C.A. Coberly, Prof. E.J. Crosby, Dr. W.R. Marshall, and W.F. Long
Technical Papers: 52
Special Lectures: 6
1) Atomization and Spray Process
   W. Robert Marshall (Chemical Engineering Dept. Univ. of Wisconsin-Madison)
2) STANDARDS FOR SPRAY EQUIPMENT AND LIQUID PARTICLES
   Robert W. Tate (Delavan Corporation, West DES Morines, Iowa, USA)
3) Recent Activities on Atomization Research in Japan
   Yoichi Takashima (Saitama Univ. Japan)
4) DROP SIZE AND VELOCITY INSTRUMENTATION
   Norman Chigier (Carnegie-Mellon Univ. USA)
5) Experience in Spray Processing
   William H. Gauvinin (Noranda Research Center and McGill Univ.)
6) THE ELECTROSTATIC ATOMIZATION OF HYDROCARBONS
   Arnold J. Kelly (Exxon Research & Engineering Company, Linden NJ, USA)

ICLASS-85
3rd International Conference on Liquid Atomization and Spray Systems
Imperial College, London, UK, 8/9/10 July 1985
Host Organization: Institute of Energy, London
Chairman of Organizing Committee: Dr. P. Eisenklam
Technical Papers: 63
Poster Papers: 7
Invited Papers: 3
1) STRUCTURE OF DIESEL SPRAY
   G. Takeshi Sato (Keio Univ. Japan)
2) DROPLET SIZE AND BIOLOGICAL EFFICIENCY OF PESTICIDES
   R.J. Courshee
3) COMPUTATIONAL FLUID DYNAMICS AND ITS APPRICATION TO LIQUID-ATOMIZATION AND SPRAY SYSTEMS
   D.B. Spalding (Imperial College, London, UK)

ICLASS-88
The 4th International Conference on Liquid Atomization and Spray Systems
Hotel Sendai Plaza, Sendai Japan, August 22-24, 1988
Host Organization: The Fuel Society of Japan
Honorary Chairmen: Yasushi Tanasawa (Emeritus Prof. Tohoku Univ. Japan)
   Kiroku Yamazaki (Emeritus Prof. Tokyo Univ. Japan)
Chairman of Steering Committee: Toshio Kurabayashi (Prof. Gunma Univ. Japan)
Chairman of Executive Committee: Nobuki Nagai (Prof. Tohoku Univ. Japan)
Technical Papers: 63
Special Lectures: 3
1) Behavior of a Liquid Jet near the Nozzle
   S. Zanelli (Prof. Dept. of Ingegneria Chimica, Universita of Pisa, Italy)
2) Study on Development of Pneumatic Type Liquid Atomizers
   S. Ohtani (Prof. Dept. of Chemical Engineering, Tohoku Univ. Japan)
3) Spray-Gas Stream Interaction in Diesel Engines
   M. Elkotb (Prof. Faculty of Engineering, Cairo Univ., Egypt)

ICLASS-91
Fifth International Conference on Liquid Atomization and Spray Systems
National Institute of Standards and Technology, Gaithersburg, MD, USA, July 15-18, 1991
Host Organization: Institute for Liquid Atomization and Spray systems (ILASS-Americas)  
National Institute of Standards and Technology (NIST)  
Conference Chairman: Norman A. Chigier  
Chairman of Papers Committee: Arthur H. Lefebvre  
Chairman of Publication Committee: Hratch G. Semerjian  
Technical Papers: 96  
Invited Lectures: 4  
1) The physics of Atomization  
   N.A.Dhigier (Carnegie Mellon Univ., USA)  
2) Experimental and Theoretical Studies on the Structure of Fuel Sprays in Diesel Engine  
   H. Hiroyasu (Univ. Hiroshima, Japan)  
3) Atomization of Liquid Metals for the manufacture of Metal Powder and Spray Forming  
   K. Bauckhage (Univ. Bremen, Germany)  
4) Twin-Fluid Atomization: Factors Influencing Mean drop Size  
   A.H. Lefebvre (Purdue Univ. USA)  

ICLASS-94  
The Sixth International Conference on Liquid Atomization and Spray Systems  
Palais des Congres, Rouen, France, July 18-22, 1994  
Host Organization: Institute for Liquid Atomization and Spray systems (ILASS-Europe) and CORIA  
Conference Chairman: Michel Ledoux  
Chairman of Organizing Committee, Christophe Dumouchel  
Chairman of Paper Committee: Andrew J. Yule  
Technical Papers: 143  

ICLASS-'97  
The 7th International Conference on Liquid Atomization and Spray Systems  
The Swiss Grand Hotel, Seoul, Korea, August 18-22, 1997  
Host Organization: Institute for Liquid Atomization and Spray systems · Korea  
General Chair: Ok Yong Yang (Inha Univ. Korea)  
General Vice-Chairs: Cung Sik Lee (Hanyang Univ.), Hyun Dong Shin (KAIST)  
Chairman of Executive Organizing Committee: Kyung Suk Park (Kyunghee Univ.)  
Chairman of Paper Committee: Chang Won Lee (Kyungpook Univ.)  
Chairman of Program Committee: Sang Yong Lee (KAIST)  
Technical Papers: 136  
Plenary Lectures: 4  
1) LDA Based Optical Particle Sizing of spherical and Irregular Shape  
   Masanobu Maeda (Prof. Keio Univ. Japan)  
2) Activities on liquid Atomization at the Research Center Lampolshausen of the German Aerospace Research  
   Establishment  
   Zoltan Farago (DLR German Aerospace Research Establishment, Germany)  
3) The Point-Particle/Continuum-Field Theory of Spray Flow  
   C.F. Edward (Stanford Univ. USA)  
4) Introduction of Aerosol Dynamics  
   Kyon Won Lee (Kwangju Inst. Sci. Tech. Korea)  

ICLASS 2000  
The Eighth International Conference on Liquid Atomization and Spray Systems  
Doubletree Hotel, Pasadena, California USA, July 16-20, 2000  
Host Organization: Institute for Liquid Atomization and Spray Systems-Americans  
Organizing Chair: Josette Bellan (California Inst. Tech. Pasadena USA)  
Program Chair: Norman Chigier (Carnegie Mellon univ. USA)  
Paper Chair: Doug Talley (USAF Research Lab. USA)  
Technical papers: 198 (12 invited papers were included)
Fifty Years of Gas Turbine Fuel Injection
Arthur LeFebvre (Stratford-on-Avon, UK, Emeritus Professor, Cranfield University, UK, and Purdue University, USA)

ICLASS 2003
9th International Conference on Liquid Atomization and Spray Systems
Hilton Sorrento Palace, Sorrento, Italy, July 13-17, 2003
Host Organization: Institute for Liquid Atomization and Spray Systems – Europe
Conference Coordinator: Antonio Cavaliere
Chair of Steering Committee: Lothar Bendig
Chair of Paper Committee: Wamadeva Balachandran
Chair of Local Organizing Committee: Baffaele Allouis
Technical Papers: 232
Plenary Lectures: 6
1) Recent Advances in Spray Science and Technology
   N. Chigier (Carnegie Mellon Univ. USA)
2) Direct Numerical Simulation of High Speed Jet Atomization
   S. Zaleski (Univ. Pierre et Marie Curie, Paris, France)
3) Sizing of Spray particles using Image Processing Technique
   S.Y. Lee (KAIST, Korea)
4) The Household Aerosol: Present and Future of the World’s largest Market for Spray Technology
   A.J. Yule (UMIST, UK)
5) Challenges and Advances in Electrodynamic Atomization and Sprays
   W. Balachandran (Brunel Univ. UK)
6) Fundamentals of Metal Atomization, Spray Forming and Deposition
   K. Bauckhage (Univ. Bremen, Germany)

ICLASS 2006 (Present Conference)
10th International Conference on Liquid Atomization and Spray Systems
Kyoto Citizen’s Amenity Plaza (Kyoto Terrsa), Kyoto, Japan
27th August – 1st September, 2006
Host Organization
   Institute for Liquid Atomization and Spray Systems · Asia
   Institute for Liquid Atomization and Spray Systems · Japan
Conference Chairperson: H.Gen Fujimoto (Doshisha Univ. Japan)
Chairperson of Technical Committee: Masataka Arai (Gunma Univ. Japan)
Chairperson of Local Organizing Committee: Jiro Senda (Doshisha Univ. Japan)
Technical Papers: 235
Keynote and invited lectures: 4
1) The Characterization of Particulate Motor Vehicle Emissions by Electrostatic Measurement Techniques
   George P. Reischl (Univ. Vienna, Austria)
2) Light Scattering theory and Practice: Beyond Velocity and Size Measurements
   G. Gouesbet (Complexe de Recherche Interprofessionnel en Aerothermochimie (CORIA), France)
3) Challenges for Future Research in Atomization and Spray Systems
   Norman Chigier (Carnegie Mellon Univ. USA)
4) Professor Tanasawa’s Achievements, an International Conference on Liquid Atomization and Spray Systems, and Tanawawa Award
   Hiroyuki Hiroyasu (Professor Emeritus, Univ. Hiroshima, Japan)

Summarized by Masataka Arai (Prof. Gunma Univ. Japan)
Chairperson of the Technical Committee of ICLASS 2006