

FIRE SAFETY SCIENCE – PROCEEDINGS OF THE SEVENTH INTERNATIONAL SYMPOSIUM

Editor

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Gaithersburg, Maryland, USA

**INTERNATIONAL ASSOCIATION
FOR FIRE SAFETY SCIENCE**

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The cover flames were drawn by Prof Y Hasemi of Waseda, Japan based on photographs taken by Prof. E.E. Zukoski of California Institute of Technology Pasadena, California, USA.

Preface

The Seventh International Symposium on Fire Safety Science was held at Worcester Polytechnic Institute (WPI), Worcester, Massachusetts, United States of America, from 16-21 June 2002. The symposium was co-hosted by WPI, NFPA, and FM Global. There were 259 registrants attending two parallel sessions in which 117 papers were presented and 2 poster sessions in which 53 posters were displayed. Twenty-six countries were represented: Australia, Austria, Belgium, Brazil, Canada, Chile, China, Finland, France, Germany, Iceland, Israel, Italy, Japan, Korea, New Zealand, Nigeria, Norway, Russia, Slovenia, South Africa, Spain, Sweden, Switzerland, United Kingdom and United States of America. Papers and poster abstracts were accepted on the basis of their quality and originality in the science of fire safety and its applications.

The opening ceremony was conducted by representatives of the three host organizations: Dr. J. Hall, Assistant Vice President of National Fire Protection Association (Chairman of the Arrangements Committee), Professor D. Lucht, Director of Center for Fire Safety, WPI (Co-Chair Arrangements Committee) and Dr. R. Bill, Director, Materials Research, FM Global (Co-Chair Arrangements Committee).

Following the opening ceremony, Prof. P. J. Pagni, University of California at Berkeley, delivered the Howard W. Emmons Plenary Lecture entitled "Thermal Glass Breakage". Five invited papers were also presented during the course of the Symposium by Dr. R.G. Rehm, Dr. R. Alpert, Dr. M. Delichatsios, Prof. R. Zalosh, and Dr. D. Purser. A special panel presentation on new fire laboratories was chaired by Prof. D. Lucht and included presentations by Dr. P. Croce, Professor T.J. Shields, Mr. K. Steckler, Dr. J. de D. Rivera, Professor E. Weckman.

At the Award Reception and Banquet, Dr. Y. Uehara, Chair of the Symposium Awards Committee, presented the Howard W. Emmons Lectureship Award to Prof. Patrick Pagni, and Prof. W. Fan of the Symposium Awards Committee presented the P.H. Thomas Silver Medal of Excellence for the best paper at the Sixth Symposium to Profs. J.P. Garo, P. Gillard, J.P. Vantelon, and A.C. Fernandez-Pello for their paper, "On the thin layer boilover." Dr. T. Hirano, Chair of the IAFSS Awards Committee, presented the K. Kawagoe Gold Medal for outstanding lifelong contributions to fire safety science to Prof. D. Drysdale.

Dr. P. A. Croce, Chair of the Forum for International Cooperation on Fire Research, presented V. Sjolin Awards to Dr. V. Babrauskas, Fire Science and Technology, in recognition for his pioneering work in the practical measurement and utilization of heat release rate data in fire safety engineering, Dr. P. Beever, New Zealand Fire Service, in recognition for her work to foster the utilization of modern fire safety engineering principles by the New Zealand Fire Service, and Prof. J. Quintiere, University of Maryland, in recognition for his contribution to the understanding of flame spread, fire growth, and fire dynamics. Also at the Formal Luncheon, Dr. T. Hirano, outgoing President of IAFSS, gave special awards of recognition for long-time service and support to Dr. R. Friedman and Dr. Y. Uehara.

The proceedings include all papers delivered at the Symposium. Papers presented in sessions with similar topics have been grouped together in the volume for the convenience of the reader. For the first time, the content of the Symposium proceedings have also been recorded in electronic form and provided on CD-ROM along with the printed copy. The content of the CD-ROM may be viewed and searched using the Adobe Acrobat reader Version 5.0 that is supplied on the CD-ROM.

The Association would like to record its gratitude to all the committees appointed to organize the various aspects of this successful symposium. It would particularly like to thank: Dr. J. Hall, Mr. A. Sears, Ms. A. Thompson, and Ms. J. Hall of NFPA; Profs. D. Lucht and J. Barnett, Dr. T. Lynch, and Ms. L. Looft, J. Grant, J. Griffiths, K. Sirkin, M. Plunkett, J. Kenary, C. Delaney, P. Sansom, A. Marr, P. Turgeon, and E. Baker of WPI; and Dr. R. Bill, Ms. P. Sullivan, Mr. S. Zenofsky, and Ms. R. Butler of FM Global, for their efficient organization of an enjoyable and valuable symposium. Prof. Patrick J. Pagni, Chair of the Program Committee for his assistance and that of the Program Committee members – Drs. C. Beyler, J. Hall, W. Grosshandler, and A. Sekizawa, and Profs. D. Drysdale, M. Fontana, Y. Hasemi, S-E. Magnusson, J. Quintiere, J. Shields, O. Sugawa, and T. Tanaka – who agreed to continue their efforts with the paper authors through the collection of final manuscripts. Mrs. K. Beall and Mr. W. D. Walton of NIST who overcame countless barriers to assemble the printed and CD-ROM version of the Symposium Proceedings from the electronic files submitted. The Chair of the Publication Committee also wishes to thank Dr. M. Curtat, Chair of the Publication Committee of the Sixth Symposium for his advice gained in the publication of the previous symposium volume. The Chair also recognizes the enthusiastic assistance of Mrs. Heather Law in gathering information for the publication.

The Association acknowledges the support of the following organizations which, as Principal Sponsors, helped ensure the success of the Symposium.

FM Global
National Institute of Standards and Technology
NFPA
Underwriters Laboratories
WPI

The banquet was sponsored by Tyco Fire Products.

David D. Evans
Chair, Publications Committee
Gaithersburg, Maryland, United States of America
June 2002

International Association for Fire Safety Science

Since the Association was founded in 1985 at its first Symposium in Gaithersburg, a series of six Symposia have been held, in Tokyo (1988), Edinburgh (1991), Ottawa (1994), Melbourne (1997), Poitiers (1999), and Worcester (2002) (This Symposium). Through these Symposia, the Association has successfully fulfilled its primary objectives of encouraging research in the science of preventing and mitigating adverse effects of fires and of providing a forum for presenting the results of such research. Membership is open to all having these interests.

The Association, which became a registered charity in England and Wales in 1988, is governed by an elected Committee and its officers. At the general meeting held during the Sixth Symposium, the following Committee and its officers were elected.

Prof. T. Hirano (Japan), Chair
Prof. D. D. Drysdale (UK), Vice Chair
Prof. P. J. Pagni (USA), Vice Chair
Prof. Y. Uehara (Japan), Vice Chair
Dr. P. Beever (New Zealand), Treasurer
Dr. R. Friedman (USA) Secretary
Prof. G. Cox (UK) Executive Member
Prof. Fan Weicheng (China) Executive Member
Prof. J. G. Quintiere (USA) Past-Chair

Dr. D. Brein (Germany)	Prof. S. E. Magnusson (Sweden)
Dr. B. Z. Dlugogorski (Australia)	Dr. J. Mehaffery (Canada)
Dr. M. Fontana (Switzerland)	Dr. C. Ramsay (Australia)
Dr. J. Hall (USA)	Dr. O Sugawa (Japan)
Dr. Y. Hasemi (Japan)	Dr. P. H. Thomas (UK, First Chair)
Prof. P. Joulain (France)	Prof. R. B. Williamson (USA)
Dr. T. Kashiwagi (USA)	Dr. D. Yung (Canada)
Prof. M. Kokkala (Finland)	

Also, Dr. B. Karlsson (Iceland) and Dr. Sekizawa (Japan) were appointed as auditors, and Prof. J. Barnett (USA) and Dr. V. Molkov (UK) were appointed as scrutineers.

After the Sixth Symposium, the Association has elected members of the Committee whose term is from the General meeting at this Symposium to that at the next Symposium based on the Article 13 of the Rule of the Association. New members of the Committee are

Dr. C. Beyler (USA)
Dr. R. Bill (USA)
Dr. B. Karlsson (Iceland)
Dr. S. Kumar (UK)
Dr. A. Selizawa (Japan).

The officers will be elected at the first Committee meeting after the General meeting where these members should be approved. The auditors and scrutineers for new terms will be elected at the General meeting.

The following members of the Committee will be retired:

Dr. R. Friedman
Dr. T. Kashiwagi
Dr. M. Kokkala
Dr. P. H. Thomas
Prof. Y. Uehara

The association would like to express its appreciation for their many contributions.

During the period of three years between the Sixth and Seventh Symposia, the Association has lost several distinguished members, including Mr. George Toshiaki Tamura, Prof. Wolfram Becker, and Prof. Jonathan Sime. Many members of the Association would wish to remember these senior colleagues. Indeed, their contribution to the Association was great and their influence will be felt in the future. All the members of the Association would be aware of what they have done for the Association.

Two Committee Meetings were held on July 29, 2000 at Edinburgh and on June 17, 2001 at Worcester, where the members discussed the Association's future activities. The most important item on the agenda was how to manage the Association. Based on the results of extensive discussion, the Association changed the site of the Administration office from Society of Fire Protection Engineers to Interscience Communications Ltd.

The Association started the investment of IAFSS funds. The investment was proposed by the IAFSS Treasurer Dr. Beever at the Committee meeting on June 17, 2001. After the meeting the Vice Chair of the Association, Prof. Drysdale and the Executive member of the Association, Prof. Cox investigated a number of possible investment advisors. The Association expects the success of this action.

For last three years, the Association and/or its members organized and/or participated in several regional meetings related to fire safety science and were able to provide partial support for management and/or awards.

Members of the Association would have received three newsletters (Nos. 11, 12, and 13), edited by Dr. Hall (USA). These have acted as a unique means of communication for fire researchers and engineers and have carried announcements of the activities of the IAFSS. Dr. Hall is to be congratulated on his efforts on behalf of the Association.

A report from Prof. Vantelon (France), the Arrangements Committee Chair of the Sixth Symposium, was received by the Association. Although the Sixth Symposium generated only a little surplus, all those who attended will remember the success of the meeting. We should thank our French colleagues represented by Prof. Vantelon and Prof. Joulain for their efforts and Region Poitou-Charentes and Renault Company for their support.

The IAFSS is concentrating on making improvements in the way in which it operates, particularly extending its activities to every corner of the world. Any comments to the Association are welcome

June 2002

Toshisuke Hirano, Chair IAFSS (March 1997 – June 2002)

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In Memoriam



Wolfram Becker
1929 - 1997

Professor Wolfram Becker passed away on February 2, 2001. He gained great merit in research and standardisation on fire safety of materials and fire safety engineering, and took care of education in this field as a Visiting Professor at the University of Kaiserslautern and through numerous presentations and publications.

In 1956, Professor Becker finished his studies as a civil engineer at the Technical University of Berlin. He started his career at the Reaction-to-Fire Building Products Testing Department of the German Federal Materials Testing Establishment (Bundesanstalt für Materialprüfung) in Berlin. In 1966, he joined BASF AG in Ludwigshafen where he became Director of the Fire Technology Department. In this position, he was responsible for testing and developing a great number of products and mainly contributed to the development of new test methods. Already during his work at BASF AG, since 1976, he gave lectures at the University of Kaiserslautern, and in 1991, he became a Visiting Professor (Honorarprofessor). After he retired from BASF AG in 1994, he continued his academic work in research and education as well as his involvement in international standardisation.

He was convinced that fire safety couldn't simply be achieved by improving materials and products. He understood very early that only the cooperation of building engineers, architects and fire safety engineers could really lead to reasonable fire safety concepts for the future. As a chairman of ISO/TC 92 SC 4, he achieved the publication of a first series of basic standards for fire safety engineering. For his outstanding merits in national and international standardisation and scientific development of fire safety science, in 1990, he was honoured with the "Heinrich Henne" Medal of the Association for the Promotion of German Fire Protection VFDB.

Many of us remember Professor Becker as a colleague with a great knowledge and expertise in fire science, as well as a friend who through his open character, his credibility and reliability was able to settle conflicts and find new solutions. His passion was not only research and education in fire science, but also his contagious enthusiasm for German wines and related history. This wonderful mix made out Wolfram Becker. We will miss him.

In Memoriam



George Tamura
1928 - 2000

George Toshiaki Tamura, one of the international pioneers in fire safety research, died in Toronto, Ontario, Canada, on April 1, 2000, after a battle with cancer. Born in Vancouver in 1928, he received a BSc degree in Mechanical Engineering from the University of Manitoba, Canada, in 1951. He worked on aircraft gas turbine engine design for Orenda Engines, A.V. Roe Canada.

He joined the Institute for Research in Construction, National Research Council of Canada, in 1959. His early research was on building infiltration and ventilation, with emphasis on airflow and pressure distribution in high-rise buildings. This research led him to realize that the techniques he was developing could also have application in dealing with a growing international problem – fire and the spread of smoke in high-rise buildings. In the late 1960s, he produced landmark papers on this subject, often with his fire research colleagues.

His research at NRCC and his publications would win a number of best paper awards from the American Society of Heating, Refrigeration and Air-Conditioning Engineers and form the basis of the ASHRAE Design Guides for smoke control – the foundation documents for the design of smoke control systems throughout the world. His work was also incorporated in other standards and guides for smoke management produced by ASHRAE, the National Fire Protection Association, and the National Building Code of Canada.

He received the ASHRAE Distinguished Service Award in 1983 and was elected an ASHRAE Fellow in 1986. In 1992, the Society of Fire Protection Engineers bestowed its highest award, the Arthur B. Guise Medal, on him for his eminent achievements in the advancement of the science and technology of fire protection engineering. In 1994, as a culmination of his career's research, George wrote an authoritative text entitled "Smoke Movement and Control in High Buildings." This book, published by the National Fire Protection Association, has become one of the most authoritative texts for the design and operation of smoke management systems in high rise buildings and atria. He was a member of SFPE, ASHRAE and IAFSS.

In Memoriam



Professor Ove Pettersson
1923 - 2002

Professor Ove Pettersson unexpectedly passed away on July 27, 2002. In the fire science world he will be remembered as a pioneer and visionary in the area of structural fire engineering, in fire engineering education and as one of the founders of IAFSS. In the Swedish University community he was a principal figure in the organization of a new major technical university, Lund Institute of Technology (LTH). Born in 1923 and trained as a structural engineer at the Royal Institute of Technology (KTH) he became a professor at KTH in 1959 and then at LTH in 1964. LTH was then in a starting up and expansion phase and as the executive member of the organizing committee (in reality Vice Chancellor) he played a major part in its rapid and successful establishment and consolidation. Later, he was again leading LTH during 1984-87 as Dean for the Institute of Natural Science and Technology at Lund University. As a professor, you are - at least in theory - expected to demonstrate high calibre capabilities as a scientist, as an administrator and as a teacher. Very few people are able to live up to all three requirements; Ove Pettersson was one of these remarkable and rare persons.

The major contribution by structural engineers to the young subject of fire safety engineering, other than the refinement of their analysis of the behaviour of structures in fire, has been their demand for the study of fire to be quantitative so that it could be integrated with structural engineering. Ove Pettersson recognized and formulated this need explicitly in an inaugural lecture in 1959. He was commissioned to develop his ideas into a national fire research programme. This activity quickly brought him into the centre of international fire research. Participation in committees for the production of codes for fire safe design for steel and for concrete construction soon followed. He became active in CIB W14 and ISO TC92 and later was elected Vice Chairmen of the IAFSS on its formation in 1985.

At LTH he initiated a vigorous research programme covering both the pre- and postflashover stages of fire and their interactions with buildings and people. As a result, seven fire research Ph.D. dissertations were successfully defended over a 15 year period from 1966. He was anxious for his graduate students to become involved in the international research world as soon as possible. As a thesis supervisor, he was outstanding. If the student found himself in difficulties and stuck with an apparently insoluble problem, a conversation with Ove was usually enough to get the work going again. His door was always open. When the student eventually produced a draft report, Ove would offer, in his words, to “read it carefully”. Many a graduate student remembers with awe and delight how the draft was sent back full of very neatly written truly invaluable and helpful comments.

Many people in the fire field will remember him in particular for his inaugurating in 1986 the first and still the only under-graduate course in Europe for Fire Safety Engineers.

He was immensely well liked by undergraduate and research students as well as by staff and colleagues for his consideration, humour and social competence in general. Many of his students considered him the best lecturer they had ever had. He took an active part in student life, was an inspector of the student union and took great pleasure in participating in the yearly song contest between student sections. This was initiated by him in 1967 and is still a tradition very much alive. He had a life long love for music and he played the piano himself. He seemed always to have the right suggestion at the right time in committee to produce consensus. Those among us privileged to be included amongst his friends will remember him as an outstanding scholar and a gentleman.

In Memoriam



Professor Jonathan Sime
1950 - 2001

Professor Jonathan Sime passed away on January 16, 2001. His sudden death shocked colleagues around the world. He was fifty years old. All his professional life was dedicated to research, particularly fire related research and education. His vast reservoir of knowledge and understanding of human behaviour in fire and his infectious enthusiasm for the subject will be greatly missed. He sought always to bridge the frequently mutually exclusive emphasis on people and built environments in engineering. For him it was not important whether human behaviour theory and concepts were considered as aspects of one discipline or another. Far more important to Jonathan was that the essential factors, which influence patterns of human behaviour, were identified, reviewed, modelled, validated and addressed in a transparently accountable manner. He was extremely well published with seminal works to his name. He graced many international symposia with his presence and presentations. As a consultant he was employed by multinational organisations and worked on many prestigious projects. His contribution to knowledge transfer was enormous. Jonathan lectured at seventeen different universities. At the time of his death he was taking up a new university appointment in Utah in the USA.

In 1999 Jonathan joined the Fire Safety Engineering Research Centre (FireSERT) at the University of Ulster as a Visiting Professor in Human Behaviour in Fire. Prior to his appointment as Visiting Professor he was a Visiting Lecturer at FireSERT always full of new ideas and engaging with the students. He contributed to FireSERT's successful £5.7m Joint Infrastructure Award and the new fire safety engineering research laboratories at FireSERT appropriately include a Human Behaviour in Fire Research Suite. Jonathan had a wide variety of interests and gave generously of his time to many things. He was the Secretary of the International Association for People – Environment

Studies from 1988 – 1994 and served on many national and international boards and committees. As a member of the British Psychological Society he was often heard on radio and seen on television. Jonathan contributed so much to the understanding of human behaviour in fire and had so much still to contribute that we feel robbed by his sudden untimely passing.

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Y. Uehara

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R. Bill

T.J. Shields

J. Hall

R. Fahy

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D. Lucht

FLAME SPREAD

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FIRE DETECTION

J. Woycheese

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FIRE PHYSICS

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D. Drysdale

N. Dembsey

P. Joulain

RISK AND DECISION ANALYSIS

D. Yung

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COMPARTMENT FIRES

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W. Fan

SUPPRESSION

H-C Kung

W. Fan

MATERIALS FIRE BEHAVIOR

A. Tewarson

O. Sugawa

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R. Zalosh

E. Galea

P. Gandhi

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G. Heskestad

I. Thomas

PERFORMANCE-BASED DESIGN

G. Heskestad

I. Thomas

TEST METHODS AND MODELING

J. de Ris
G. Cox

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R. Fahy
T.J. Shields

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R. Friedman
Y. Hasemi

HUMAN BEHAVIOR MODELING

R. Fahy
T.J. Shields

STRUCTURES

J. Barnett
M. Fontana
P. Gandhi

STATISTICS AND PROBABILITY

D. Beller
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