

FIRE SAFETY SCIENCE – PROCEEDINGS OF THE EIGHTH INTERNATIONAL SYMPOSIUM

Editors

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Hughes Associates, Inc., USA

**INTERNATIONAL ASSOCIATION
FOR FIRE SAFETY SCIENCE**

Published by the International Association for Fire Safety Science

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ISSN 1817-4299

FIRE SAFETY SCIENCE – PROCEEDINGS OF THE EIGHTH
INTERNATIONAL SYMPOSIUM

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

Preface

The Eighth International Symposium on Fire Safety Science was held at Tsinghua University, Beijing, China, from 18-23 September 2005. The symposium was organized by the China Fire Protection Association (CFPA) with Tsinghua University and University of Science and Technology of China as co-organizers. There were 456 registrants attending three parallel sessions in which 123 papers and 8 invited lectures were presented and a poster session in which 61 posters were displayed. Twenty-five countries were represented: Australia, Belgium, Canada, China, Denmark, Finland, France, Germany, Iceland, Indonesia, Ireland, Italy, Japan, Korea, Kuwait, New Zealand, Saudi Arabia, Singapore, Sweden, Switzerland, Taiwan, Thailand, 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 from the host country and IAFSS. His Excellency Zhou Yong Kang, Councilor and Minister of the MPS of the People's Republic of China provided the initial remarks followed by Prof. Dougal Drysdale, the IAFSS Chairman.

Following the opening ceremony, Dr. Howard Baum, National Institute of Standards and Technology, delivered the Howard W. Emmons Plenary Lecture entitled "Simulating Fire Effects on Complex Building Structures." Seven invited papers were also presented during the course of the symposium by Prof. Jean-Marc Franssen, Prof. Dorothy Bruck, Dr. Kevin McGrattan, Prof. Fan Weicheng, Prof. Ai Sekizawa, Prof. Richard Hull (for Prof. Giovanni Camino) and Major General Guo Tienan.

At the Award Reception and Banquet, Prof. D. Drysdale, Chair of the Symposium Awards Committee, presented the Howard W. Emmons Lectureship Award to Dr. Howard Baum. The P.H. Thomas Silver Medal of Excellence for the best paper at the Seventh Symposium was awarded to D.W. Weinert, T.G. Cleary, G.W. Mulholland, and P.F. Beever for their paper entitled "Light Scattering Characteristics and Size Distribution of Smoke and Nuisance Aerosols." The K. Kawagoe Gold Medal for outstanding lifelong contributions to fire safety science was presented to Prof. Sizuo Yokoi and accepted by his son. Dr. P.A. Croce, Chair of the Forum for International Cooperation on Fire Research, presented the V. Sjolín Award to Prof. Dougal Drysdale in recognition of his contributions to fire safety science.

The proceedings include all papers delivered at the Eighth Symposium. Papers are organized in the proceedings by the session topics at the symposium. The content of the symposium proceedings have also been recorded in electronic form and provided on CD-ROM in color.

The Association would like to thank FM Global for being the principal sponsor of the symposium. In addition, the Association would like to extend its gratitude to all the organizations, committee members, and other volunteers that assisted in making this symposium so successful. A special thanks is given to the organizers, China Fire Protection Association (CFPA), Tsinghua University, and University of Science and Technology of China, who provided first class hospitality as well as an excellent forum for the exchange of ideas on fire safety science. The Association would also like to

greatly thank all of those involved in the review, selection, and editing of the papers for the conference. A special thanks is given to Dr. Craig Beyler, Chair of the Program Committee, for organizing and leading the committee on the selection of papers, and all of the program committee members who interacted with authors and reviewers as well as reviewed final manuscripts to ensure all reviewer comments were addressed. Many thanks go to Ms. Judy Hanacek-Kameid along with Ms. U. Isfahani and Ms. K. Tooren of Hughes Associates, Inc. for their great effort in assembling the printed and CD-ROM versions of the Symposium Proceedings. The Chairs of the Publication Committee also wish to thank Dr. Dave Evans, Chair of the Publication Committee of the Seventh Symposium, for his advice and suggestions in preparing this symposium volume.

Daniel T. Gottuk
Brian Y. Lattimer
Chairs, Publications Committee
Hughes Associates, Inc.
Baltimore, Maryland, United States of America
October 2005

International Association for Fire Safety Science

Since the first meeting at the National Bureau of Standards (USA), in 1985, the IAFSS Symposia have circumnavigated the globe twice. The Eighth Symposium was held in Beijing and marked the third symposium to be held in the Asia-Oceania region. It also marked the most successful event to date, in terms of the number of papers submitted, the number of delegates attending as well as the quality of the facilities made available to the IAFSS at Tsinghua University through the China Fire Protection Association (CFPA). For the first time, it gave the Chinese Fire Research community the opportunity to meet directly with colleagues from around the world. The significance of this was recognised by the Chinese Government who provided full support. This was made very clear by His Excellency Zhou Yong Kang, Councilor and Minister of the MPS, who opened the Symposium on Monday 19th September. His speech is included in these Proceedings. It is appropriate also to acknowledge the active encouragement and support of Major General Guo Tienan, Head of the Fire Department of the Ministry of Public Security. He kindly agreed to deliver a special invited lecture "The Fire Situation and the Needs for Science and Technology on Fire Protection in China," which is included in these Proceedings.

At the Seventh Symposium at Worcester Polytechnic Institute, Massachusetts, the following Committee and its officers were elected:

Professor Dougal Drysdale (UK) (Chair)
Professor Mario Fontana (Switzerland) (Vice Chair)
Dr Craig Beyler (USA) (Vice Chair)*
Dr Paula Beever (New Zealand) (Vice Chair)
Dr Robert Bill (USA) (Treasurer)*
Professor Bogdan Dlugogorski (Australia) (Secretary)
Professor Geoff Cox (UK) (Executive Member)
Professor Fan Weicheng (PR China) (Executive Member)
Professor Toshi Hirano (Japan) (Past Chairman)

Mr D Brein (Germany)	Professor P Pagni (USA)
Dr J Hall (USA)	Professor J Quintiere (USA)
Professor Y Hasemi (Japan)	Dr C Ramsay (Australia)
Professor P Joulain (France)	Dr A Sekizawa (Japan)*
Dr B Karlsson (Iceland)*	Professor O Sugawa (Japan)
Dr S Kumar (UK)*	Professor R Williamson (USA)
Professor S-E Magnusson (Sweden)	Dr D Yung (Canada)
Dr J Mehaffey (Canada)*	

New members of the Committee are indicated with an asterisk (*). At that time, the following members retired:

Dr R Friedman (USA)	Dr P Thomas (UK), First Chair
Dr T Kashiwagi (USA)	Professor Y Uehara (Japan)
Professor M Kokkala (Finland)	

After the meeting, Dr Y He (Australia) and Dr J Torero (UK) were co-opted on to the Committee to replace Professor Magnusson and Dr Ramsay who withdrew at a late stage in the process. Subsequently, Dr Torero was very active in managing the IAFSS web site in association with the Secretariat.

Since the 7th Symposium, one Committee meeting was held on 4th July 2004 in Edinburgh. In attendance were Mr Wu Qihong (CFPA) and Dr Xiao Xuefeng (MPS, PRC) who outlined the arrangements for the 8th Symposium. Two months later, in September 2004 the Chairman and Ms Carole Franks (IAFSS Secretariat) attended meetings with the CFPA in Beijing at which the arrangements for the Symposium were finalised.

At the July meeting, reports were presented on the current financial status of the Association. The changes initiated by our previous Treasurer, Dr Paula Beever, were well in hand at the time, and now the Association accounts and investments are centralised in London. Professor Cox identified Laing and Cruickshank as the investment management company best suited to our needs. This has simplified the task of the Treasurer and provides much greater transparency to the finances of the Association. Thanks to the generous sponsorship of the 7th Symposium by FM Global, NIST, NFPA, the Underwriters Laboratory and Tyco Fire Products, the huge effort put in by Dr John Hall (NFPA) and his colleagues at NFPA, FM Global and WPI, and the generosity of Worcester Polytechnic Institute, the 7th Symposium was financially very successful. This was reported fully by Dr Bill at the general meeting held during the 8th Symposium in Beijing. It has given the Association the opportunity to provide support for several other events such as the 3rd Symposium on Human Behaviour in Fire, the 4th Fire and Explosion Seminar and the 6th Asia-Oceania Symposium on Fire Science and Technology in Korea.

The most important initiative which was introduced after the last Symposium is a scheme for awarding prizes for the best PhD dissertations in the three IAFSS regions (Asia/Oceania, Europe/Africa and the Americas). This reflects one of the principal objectives of the IAFSS, namely to encourage research in Fire Safety Science and attract a new generation of scientists to the cause. In all, 17 dissertations were submitted. Under the overall Chairmanship of Professor Mario Fontana, these awards were made to individuals who successfully defended their theses during the three year period ending in September 2004. They were invited to present papers on their doctoral work at this Symposium. The winners were:

Dr Weng Wenguo (PR China)
Dr Susan Lamont (UK)
Dr Amnon Bar-Ilan (USA)

It is the intention of the Association to make such awards at every Symposium.

At the Committee Meeting held during the 7th Symposium, Dr Jim Mehaffey kindly agreed to take on the role of Editor of the IAFSS Newsletter. Thanks to his efforts combined with those of the IAFSS Secretariat, the publication rate has doubled. Six newsletters have appeared since July 2002.

Perhaps the most significant change is the way in which the Papers and Publications Committees have been combined. At the same time we have moved entirely to an electronic submission system that has streamlined the run-up to the 8th Symposium. Dr Craig Beyler (USA) undertook this task with total commitment. The successful outcome was clear to all delegates attending the Beijing meeting. For the first time a CD-ROM of all accepted papers was available to all delegates and at the time of writing, it is expected that the publication date for the Proceedings will be before the end of 2005. Dr Beyler and his colleagues – particularly Dr Dan Gottuk and Dr Brian Lattimer – are to be warmly congratulated on their efforts.

All these changes have been facilitated by the involvement and commitment of the IAFSS Secretariat, Ms Carole Franks and her colleagues (Interscience Communications Ltd). Carole's experience and initiative has been invaluable. Not only has she taken over the task of management of our membership, but we now have a centralised registration process for the symposia. Moreover, she has been extremely generous in the help and advice she has given to our colleagues in the CFPA during the preparation of the 8th Symposium. The Association owes her a great debt of gratitude.

With these changes, the IAFSS is set on a new, proactive course. Under the Chairmanship of Dr Craig Beyler (from 22nd September 2005) I am confident that the Association will grow in numbers and in status during the years ahead.

Dougal Drysdale, Chairman, 2002 – 2005
September 2005-10-04

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Award Recipients

Howard W Emmons Lectureship Award for Distinguished Achievement in Fire Safety Science

1984	J.L. de Ris
1985	E.E. Zukowski
1986	J.G. Quintiere
1988	K. Kawagoe (Medal associated with IAFSS for the first time)
1991	P.H. Thomas
1994	O. Pettersson
1997	T. Jin
1999	Y. Hasemi
2002	P.J. Pagni
2005	H.R. Baum

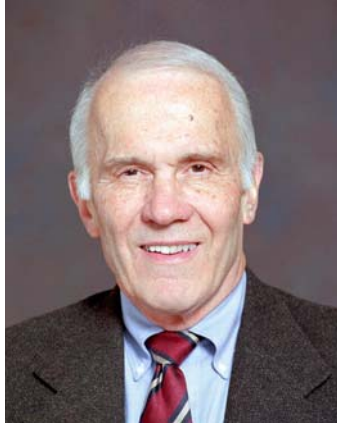
Kawagoe Gold Medal for Outstanding Lifelong Contributions to Fire Safety Science

1994	A. Robertson
1997	P.H. Thomas
1999	H.E. Nelson
2002	D. Drysdale
2005	S. Yokoi

P.H. Thomas Silver Medal of Excellence for the Best Paper of the Previous Symposium

1988	Y. Hasemi
1991	H.R. Baum & B.J. McCaffrey
1994	A. Atreya & M. Abu-Zaid
1997	B.Z. Dlugogorski, J.R. Mawhinney & V.H. Duc
1999	R.G. Rehm, K.B. McGrattan, H.R. Baum & K.W. Cassel
2002	J.P. Garo, P. Gillard, V.P. Vantelon & A.C. Fernandez-Pello
2005	D.W. Weinert, T.G. Cleary, G.W. Mulholland & P.F. Beaver

In Memoriam



**Professor Gerard M. Faeth
1936-2005**

Jerry Faeth passed away suddenly on January 24, 2005. With his death the University of Michigan lost one of its academic brightest stars, the Arthur B. Modine Distinguished University Professor of Aerospace Engineering. This is a doubly distinguished position, a mark of the esteem with which he was regarded by his colleagues. He also held an appointment as Professor of Mechanical Engineering, a position he held earlier in his career as he rose through the ranks in the Mechanical Engineering Department at the Pennsylvania State University before moving to the University of Michigan in 1985. Given his brilliance and outgoing personality, Jerry was a born teacher. He supervised 52 Ph.D. students and 28 Post-Doctoral Fellows over the course of his career, many of whom found their own way into the academic world. Among those present at the memorial service immediately following his death were former students occupying positions ranging from Associate Dean at a major research university to newly minted Assistant Professor.

Prof. Faeth is probably best known to the fire research community through his research on such diverse topics as heat transfer from wall flames, soot properties including growth, oxidation, and radiation, the development of “state relations” characterizing the combustion properties of many fuels, and fluid mechanics of turbulent jets and plumes. Impressive as this list of accomplishments is, it barely hints at the real breadth and depth of his research activities. To quote from his own description, “My interests include theoretical and experimental research concerning combustion, heat transfer, and fluid dynamics.” Not only did he perform research in all these fields, his work was so highly regarded that he held the position of Technical Editor or Editor in Chief of major research journals in each of these fields; *Combustion and Flame*, the *ASME Journal of Heat Transfer*, and the *AIAA Journal*.

Jerry was the recipient of many honors and awards. These include membership in the U.S. National Academy of Engineering, and election to the rank of Fellow in four

professional societies; the American Institute of Aeronautics and Astronautics (AIAA), the American Society of Mechanical Engineers (ASME), the American Association for the Advancement of Science (AAAS), and the American Physical Society (APS). He was also the recipient of the Combustion Institutes Alfred G. Egerton Gold Medal, and the winner of “Best Paper” awards at numerous technical meetings. His research output was prodigious. He was the author or co-author of over 500 journal articles and other papers, which were studied enough to earn him a certificate from the Institute for Scientific Information as one of the 99 most highly cited engineers in the world.

It was not only numbers though, that brought him recognition. His work was characterized by superficially very simple but elegant experiments, supported by insight gained from the use of analysis tools most likely to illuminate the experiments. The results are invariably widely understood and turned out to be useful far beyond the original intent of the investigation. Indeed, this beautiful clarity that emerges from his research is the reason it is so widely cited in the engineering community. The beautiful clarity that illuminated Jerry’s research also illuminated his personality. We will not see his like again any time soon.

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Hidemasa Yoshimura
Bert Yu
David Yung
Pieter Zeeuwen
Wei Zhang
Bin Zhao
Xiangyang Zhou

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EMMONS PLENARY LECTURE

D. Drysdale

INVITED LECTURES

M. Fontana
K. Boyce
D. Drysdale
C. Beyler
B. Karlsson
R. Hull

SPECIAL INVITED LECTURE

D. Drysdale

IGNITION

J. Yang
W. Fan

STRUCTURAL FIRE PERFORMANCE

J.M. Franssen
M. Fontana
J. Konig
D. Brein
A. Buchanan
J. Qian

PROBABILITY & STATISTICS

A. Sekizawa
B. Karlsson

FLAME SPREAD

J. Quintiere
C. Wade
W. Grosshandler
S. Welch

HUMAN BEHAVIOR

J. Woycheese
J. Hall

EVACUATION

H. Frantzich
D. Bruck

BURNING RATES

J. Mehaffey
T. Hirano
B. Lattimer
J.L. de Ris

SUPPRESSION

H. Ingason
R. Bill
G. Liao
H. Kung
B. Dlugogorski
T. Tsuruda
D. Evans
J. Newman

BURN HAZARDS

R. Phylaktou
M. Klassen

WILDLAND FIRES

R. Phylaktou
M. Klassen

RISK ANALYSIS

K. Boyce
M. Hurley

FLAMES

Y. Hasemi
A. Trouve
C. Fernandez-Pello
O. Sugawa

TOXIC HAZARD

R. Gann
P. Andersson
A. Tewarson
S. Grayson

FIRE CHEMISTRY

B. Ostman
R. Hull

COMPARTMENT FIRES

J. Torero
A. Hamins
A. Marshall
K. McGrattan
I. Thomas
H. Baum
P. Pagni

SMOKE CONTROL

W.K. Chow
T. Tanaka

EXPLOSIONS

E. Kennedy
P. Croce

MEASUREMENT METHODS

R. Bill
J. Sun

TUNNEL FIRES

M. Delichatsios
Q. Wu
G. Hadjisophocleous
V. Dowling

DETECTION

D. Gottuk
N. Li
Y. He
J. Li

Opening Address

By H E Zhou Yong Kang, State Councillor and Minister of the MPS

Respected Chairman Drysdale, dear Delegates, Ladies and Gentlemen.

In the beautiful golden autumn season, fire scientists from home and abroad gather together in Beijing to explore the key issues of Fire Safety Science and Fire Engineering, a cutting edge theme with global attention. At this valuable and memorable moment, I would like, on behalf of the Government of the People's Republic of China and in my own name, to express my heartfelt congratulations on the opening of the 8th International Symposium on Fire Safety Science and my warm welcome to all distinguished guests!

To realise a harmonious society and to construct a good society is a social ideal that human beings have long been pursuing. In the past two decades, by making full use of the platform of the International Symposium on Fire Safety Science, the International Association of Fire Safety Science has played an important role in improving international fire safety science research, advancing the worldwide firefighting development, maintaining fire safety and the direct interests of the public.

Holding this conference in Beijing is proof of the attention and support that the international fire science sector has given to the development of fire science and firefighting in China.

China is a country with an ancient civilisation of 5000 years of history and the Chinese people have created a colourful culture with their own diligence and wisdom. The fight against fire disasters has in particular accompanied the human history of using fire. The Chinese government has always attached great importance to the firefighting work and fire safety science research. Such unremitting efforts lead to a full development of firefighting cause, which has created a good fire safe environment for the working and living of the public.

At this time, under the leadership of the Chinese Communist Party, the Chinese people are devoted to the establishment of a well-off society in an all round way and the construction of a socialist harmonious society. Both firefighting work and fire safety science are not only closely linked with the safety of life and property of the people, but are bound up with the smooth realisation of the grand objective of establishing a well-off society and constructing the socialist harmonious society. Therefore, we are going to pay more attention to firefighting work and fire safety science research and make more extensive international exchange and cooperation with fire safety science research agencies and firefighting departments in the world including the International Association of Fire Safety Science and try our best to improve the Chinese firefighting work and fire safety science research.

The delegates present at this conference are world famous fire safety scientists and firefighting experts. I wish you will continue to play a vital role in driving the development of fire safety science and firefighting cause in the world.

Finally may I wish this symposium a complete success!

Contents

Preface	iii
International Association for Fire Safety Science	v
Award Recipients	viii
In Memoriam – Gerard M. Faeth	ix
Symposium Committees	xi
Reviewers	xiii
Session Chairs	xvii
Opening Address	xix

Emmons Plenary Lecture

Simulating Fire Effects on Complex Building Structures	H. Baum, National Institute of Standards and Technology, USA	3
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Invited Lectures

Structures in Fire, Yesterday, Today and Tomorrow	J.M. Franssen, Institute of Civil Engineering, University of Liege, Belgium	21
---	---	----

Sleep and Fire: Who is at Risk and Can the Risk be Reduced?	D. Bruck and M. Ball, Centre for Environmental Safety and Risk Engineering, Victoria University of Technology, Australia	37
---	--	----

Fire Modeling: Where Are We? Where Are We Going?	K. McGrattan, National Institute of Standards and Technology, USA	53
--	---	----

Progress of Fundamental Fire Research in China	W. Fan, N. Liu, H. Chen, State Key Laboratory of Fire Science, PRC	69
--	--	----

Fire Risk Analysis: Its Validity and Potential for Application in Fire Safety	A. Sekizawa, University of Tokyo, Japan	85
---	---	-----------

Fire Retardant Polymer Materials New Perspectives	G. Camino, University of Turin, Italy	101
---	---------------------------------------	------------

Fire Situation and Development of Fire Safety Science and Technology in China	G. Tienan, Ministry of Public Security, PRC	111
---	---	------------

Ignition

Transition from Forward Smoldering to Flaming in Small Polyurethane Foam Samples	A. Bar-Ilan, University of California Berkeley, USA	127
--	---	------------

A Theoretical Investigation of Surface Glowing Ignition Leading to Gas Flaming Autoignition	N. Boonmee, Kasetsart University, Thailand and J. Quintiere, University of Maryland, USA	139
---	--	------------

Validation of CFD Model for Simulation of Spontaneous Ignition in Bio-mass Fuel Storage	Z. Yan, U. Göransson, G. Holmstedt, and L. Wadsö, Lund University, Sweden; and P. Blomqvist and P. Van Hees, Swedish National Testing and Research Institute, Sweden	151
---	--	------------

Operator Independent Ignition Measurements	M.M. Khan and J.L. de Ris, FM Global, USA	163
--	---	------------

Structural Fire Performance

The Behaviour of Multi-storey Composite Steel Framed Structures in Response to Compartment Fires	S. Lamont and B. Lane, Arup Fire, UK; and A. Usmani University of Edinburgh, UK	177
--	---	------------

Experiments and Modeling of Unprotected Structural Steel Elements Exposed to a Fire	A. Hamins, K. McGrattan, K. Prasad, A. Maranghides, and T. McAllister, National Institute of Standards and Technology, USA	189
The Behaviors of H-section Steel Beam in Fire	Y. Dong and X. Li, Qingdao Technological University, PRC	201
Load-bearing Capacity of H-shaped Steel Columns under Local Buckling at Elevated Temperature	T. Hirashima and H. Uesugi, Chiba University, Japan	211
Load-carrying Behavior of Unstiffened Elements at Elevated Temperatures in Fire	M. Knobloch and M. Fontana, Swiss Federal Institute of Technology ETH Zurich, Switzerland	223
A Model for Prediction of Temperature in Steel Structure Protected by Intumescent Coating, Based on Tests in the Cone Calorimeter	Y. Wang, University of Manchester, UK; and U. Göransson, G. Holmstedt, and A. Omrane, Lund University, Sweden	235
An Investigation on Fire Performance of FRP-strengthened R/C Beams	B. Williams, Halsall Associates Ltd., Canada; L. Bisby and M. Green, Queen's University, Canada; and V. Kodur and J. Su, National Research Council of Canada, Canada	247
Effect of Top Reinforcing on the Fire Performance of Continuous Reinforced Concrete Beams	D. Bernhart, University of Karlsruhe, Germany; and A. Buchanan, R. Dhakal, and P. Moss, University of Canterbury, New Zealand	259
Fiber-reinforced High-strength Concrete under Elevated Temperature - Effect of Fibers on Residual Properties	S.L. Suhaendi and T. Horiguchi, Hokkaido University, Japan	271
Fire Performance of Timber Structures under Natural Fire Conditions	A. Frangi and M. Fontana, Swiss Federal Institute of Technology ETH Zurich, Switzerland	279

Fire Resistance of Exterior Walls: Model and Full-scale Test	H. Takeda, Fire Research Canada (Forintec), Canada	291
Structural Fire Design of Timber Structures According to Eurocode 5	J. König, Trätek/Wood Technology, SP Swedish National Testing and Research Institute, Sweden	303
Assessment of Performance-based Requirements for Structural Design	K. Hertz, Department of Civil Engineering, Technical University of Denmark, Denmark	315
Fire Test on a Non-heat-resistant Fireproof Glass with Down-flowing Water Film	C.W. Wu and T.H. Lin, National Cheng Kung University, Taiwan, ROC; M.Y. Lei, Architecture and Building Research Institute Ministry of Interior, Taiwan, ROC; T.H. Chung, Safety Technology Co., Ltd., Taiwan, ROC; and C.C. Huang and W.T. Chiang, Industrial Technology Research Institute, Taiwan, ROC	327
Probability & Statistics		
A Statistical Method to Evaluate Fire Risks in Non-residential Buildings in Japan	Y. Kobayashi, Taisei Corporation, Japan; and H. Nozaki, Aioi Insurance Company, Ltd., Japan	341
Analysis of Fire Statistics of China: Fire Frequency and Fatalities in Fires	F. Wang, S. Lu, and C. Li, University of Science and Technology of China, PRC	353
Fire Incident Characteristics of a Densely Populated Oriental Urban City	M.C. Hui, F.S.C. Tsui, and M.C. Luo, Arup Fire, Hong Kong	363
Lithium Ion Battery Fire and Explosion	Q. Wang, J. Sun, and G. Chu, University of Science and Technology of China, PRC	375

Flame Spread

A Numerical Model for Ceiling Flame Spread Beneath a Combustible Board with Charring Material	W. Weng and Y. Hasemi, Department of Architecture, Waseda University, Japan	385
Diffusion Flames Upwardly Propagating Over PMMA: Theory, Experiment and Numerical Modeling	J-L. Consalvi and B. Porterie, Polytech 'Marseille CNRS, France; M. Coutin, L. Audouin, and C. Casselman, Institut de Radioprotection et de Sûreté Nucléaire, France; A. Rangwala and S.G. Buckley, University of California San Diego, USA; and J.L. Torero, The University of Edinburgh, UK	397
Upward Flame Spread: The Width Effect	K.C. Tsai and F.S. Wan, National Kaohsiung First University of Science and Technology, Taiwan	409
Effect of Radiation Models on CFD Simulations of Upward Flame Spread	J. Zhang, S. Dembele, and J.X. Wen, Kingston University, UK	421
Transport of Disk-shaped Firebrands in a Turbulent Boundary Layer	K. Himoto and T. Tanaka, Kyoto University, Japan	433
Approximate Analytical Solutions for the Transient Mass Loss Rate and Piloted Ignition Time of a Radiatively Heated Solid in the High Heat Flux Limit	C. Lautenberger and C. Fernandez-Pello, University of California Berkeley, USA	445
Flame Spread and Extinction Over Thermally Thick PMMA in Low Oxygen Concentration Flow	Y. Kudo, M. Itakura, Y. Fujita, and A. Ito, Hirosaki University, Japan	457
From Bench-scale Test Data to Predictors of Full-scale Fire Test Results	S. Nam, J. de Ris, P. Wu, and R. Bill, Jr., FM Global, USA	469

Opposed Flame Spread in Narrow Channel Apparatus to Assist in Suppression Studies	M.A. Delichatsios, University of Ulster, Northern Ireland, UK; and H. Wang, E.M. Kennedy, B. Moghtaderi, and B.Z. Dlugogorski, The University of Newcastle, Australia	481
---	---	------------

An Example of the Use of Standard Flammability Criteria for Performance Analysis of Materials: Polycarbonate and PMMA	L. Audouin and L. Rigollet, Institut de radioprotection et de sûreté nucléaire (IRSN), France; J.L. Torero, The University of Edinburgh, UK; and O. Mangs, Brandskyddslaget, Sweden	493
---	---	------------

Human Behavior

Statistical Modelling of the Effect of Alcohol and Sound Intensity on Response to Fire Alarms	A. Hasofer, I. Thomas, D. Bruck, and M. Ball, Victoria University, Australia	507
---	--	------------

An Investigation into Staff Behaviour in Unannounced Evacuations of Retail Stores – Implications for Training and Fire Safety Engineering	D.A. Samochine, Academy of State Fire Service of Russia, Russia; and K. Boyce and J. Shields, University of Ulster, Northern Ireland, UK	519
---	--	------------

A Stochastic Approach to Occupant Pre-Movement in Fires	J. Vistnes and S.J. Grubits, Stephen Grubits & Associates, Australia; and Y. He, University of Western Sydney, Australia	531
---	--	------------

Human Behaviour in Tunnel Fire Incidents	J. Fraser-Mitchell and D. Charters, FRS/BRE Ltd., UK	543
--	--	------------

Evacuation

A Proposal for the Goals and New Techniques of Modelling Pedestrian Evacuation in Fires	T. Korhonen, S. Hostikka, and O. Keski-Rahkonen, VTT Technical Research Centre of Finland, Finland	557
---	--	------------

Coloured Flashing Lights to Mark Emergency Exits – Experiences from Evacuation Experiments	D. Nilsson and H. Frantzich, Lund University, Sweden; and W. Saunders, Victoria University, Australia	569
Agent-based Dynamic Model for Pedestrian Counter Flow	P. Zhang, X. Huang, H. Wan, and M. Liu, Shenyang Jianzhu University, PRC; S. Lo, City University of Hong Kong, Hong Kong; and M. Zhong, China Academy of Safety Science and Technology, PRC	581
Characteristics of Merging Occupants in a Staircase	N. Takeichi and Y. Yoshida, Takenaka Corporation, Japan; T. Sano, T. Kimura, and H. Watanabe, Waseda University, Japan; and Y. Ohmiya, Tokyo University of Science, Japan	591
A Refined Concept on Emergency Evacuation by Lifts	K.H.L. Wong, M.C. Hui, D.G. Guo, and M.C. Luo, Arup Fire, Hong Kong	599
An Examination of Feasibility of Elevator Evacuation Based on Risk Assessment	S. Nakahama, Taisei Corporation Technology Center, Japan; M. Ebihara and A. Sekizawa, The University of Tokyo, Japan; Y. Ikehata, Building Engineering Research Institute Disaster Prevention Research, Japan; and H. Notake, Shimizu Corporation, Japan	611
Burning Rates		
Modeling Solid Sample Burning	G. Linteris, L. Gewuerz, K. McGrattan, and G. Forney, National Institute of Standards and Technology, USA	625

Study on Melting Behavior of Polymers During Burning	J. Zhang, Y. Wang, X. Lu, and J. Yu, Key Laboratory of Rubber-Plastics for Ministry of Education, Qingdao University of Science and Technology, PRC	637
The Thick and Thin of Burning Nano-clay-nylon Composites	X. Liu, Underwriters Laboratories, USA; and J.G. Quintiere, University of Maryland, USA	647
A Vaporization Rate Model for Flammable Liquid Pool under Vertical Air Jet Impingement	H.Z. Yu, FM Global, USA; S.P. Ho, Chang Jung Christian University, Taiwan; and R. Zalosh, Worcester Polytechnic Institute, USA	659
Burning Analysis of Motor Scooters	C.J. Chen and M.J. Tsai, Ministry of Interior, Taiwan, ROC; and B.C. Ji, C.W. Wu, J.Y. Pu, and T.H. Lin, National Cheng Kung University, Taiwan, ROC	671
Numerical Study on Indoor Fire of Leaked Gaseous Fuel	W. Jinxiang, M. Qing, W. Enyu, Y. Yunzhong, L. Liansheng, and L. Qiang, Hebei University of Technology, PRC	681
Smoldering Combustion of Horizontally Oriented Polyurethane Foam with Controlled Air Supply	L. Peng, C. Lu, J. Zhou, L. Zhang, and F. You, State Key Laboratory of Fire Science, PRC	693
Suppression		
Friction Factors for Pipe Flow of Xanthan-based Concentrates of Fire Fighting Foams	B.Z. Dlugogorski, T. Schaefer, and E.M. Kennedy, The University of Newcastle, Australia	707
Dynamic Surface and Interfacial Tension of AFFF and Fluorine-free Class B Foam Solutions	B. Dlugogorski, S. Phiyalaninmat, and E.M. Kennedy, The University of Newcastle, Australia	719

Study on Three-phase Foam for Preventing Spontaneous Combustion of Coal in Goaf	Q. Bo-tao, W. De-ming, and R. Wan-xing, China University of Mining and Technology, PRC	731
Application of Water Mist to Extinguish Large Oil Pool Fires for Industrial Oil Cooker Protection	Z. Liu, D. Carpenter, and A.K. Kim, National Research Council of Canada, Canada	741
Numerical Modeling of the Effect of Fine Water Mist on the Small Scale Flame Spreading Over Solid Combustibles	A.I. Karpov and A.A. Galat, Komsomolsk-on-Amur State University of Technology, Russia; V. Novozhilov, University of Ulster, UK; and V.K. Bulgakov, Khabarovsk State University of Technology, Russia	753
Application of a Fixed Water Mist System in a Power Transformer Room	Y. Han, B. Choi, and M. Kim, Korea Institute of Machinery & Materials, Korea	765
A Numerical Study of Water Dump in Aerial Fire Fighting	K. Satoh, National Research Institute of Fire and Disaster, Japan; I. Maeda, ShinMaywa Industries, Ltd., Japan; K. Kuwahara, Japan Aerospace Exploration Agency, Japan; and K.T. Yang, University of Notre Dame, USA	777
A Study on Extinction of RDF (Refuse Derived Fuel) Pile	T. Suzuki, T. Tsuruda, Y. Ogawa, and C. Liao, National Research Institute of Fire and Disaster, Japan	789
Study on the In-situ Coating by Octadecylamine of Pyrotechnically Generated Aerosol Particles for Fire Suppression	C. Zhihui, Chinese People's Armed Police Force Academy, PRC; and Y. Rongjie, Beijing Institute of Technology, PRC	801
Maintenance Testing of Sprinkler Heads: Qualitative Analysis Causes of Failures	S. Zhuiykov and V. Dowling, CSIRO, Australia	811

Actual Delivered Density Fire Test Apparatus for Sprinklers Protecting High Commodity Storage	J.A. Schwille, H.C. Kung, M. Hjothman, G.E. Laverick, and G.W. Gardell, Underwriters Laboratories Inc., USA	823
---	---	------------

Burn Hazards

A Fabric Burn Hazard Protection Evaluation System	P. Cataldi, P. Nebolsine, J. Magill, W. Laughlin, and M. Hinds, Physical Sciences Inc., USA	837
---	---	------------

Wildland Fires

A Simple Physical Model for Forest Fire Spread Rate	E. Koo, P. Pagni, S. Stephens, and J. Huff, University of California Berkeley, USA; J. Woycheese, Worcester Polytechnic Institute, USA; and D. Weise, USDA Forest Service, USA	851
---	--	------------

Experimental Modeling of the Effect of Terrain Slope on Marginal Burning	X. Zhou and S. Mahalingam, University of California Riverside, USA; and D. Weise, USDA Forest Service, USA	863
--	--	------------

Risk Analysis

Development and Case Study of a Risk Assessment Model CURisk for Building Fires	G. Hadjisophocleous and Z. Fu, Carleton University, Canada	877
---	--	------------

Quantified Levels of Risk to Life Safety in Deemed-to-satisfy Apartment Buildings	I. Thomas and D. Weinert, Victoria University of Technology, Australia; and B. Ashe, Australian Building Codes Board, Australia	889
---	---	------------

Repeatability Tests of a Fire Risk Index Method for Multi-storey Apartment Buildings	B. Karlsson, Iceland Fire Authority, Iceland; and B. Tómasson, Línuhönnun Consulting Engineers, Iceland	901
Risk-based Attestation of Fire Safety of Wooden Façades in Concrete-framed Residential Multistory Buildings	J. Hietaniemi and T. Korhonen, VTT Building and Transport, Finland	913
Flames		
Characterizing Turbulent Ceiling Jet Dynamics with Salt-water Modeling	X. Yao and A. Marshall, University of Maryland, USA	927
Experimental Investigation of the Velocity Field in Buoyant Diffusion Flames Using PIV and TPIV Algorithm	L. Sun, X. Zhou, and S. Mahalingam, University of California Riverside, USA; and D. Weise, USDA Forest Service, USA	939
Flow Structure of a Fixed-frame Type Fire Whirl	M.I. Hassan, K. Kuwana, K. Saito, and F. Wang, University of Kentucky, USA	951
Large-eddy Simulation of a Large-scale Methane Pool Fire	S. Ferraris, J.X. Wen, and S. Dembele, Kingston University, UK	963
On the Numerical Modeling of Buoyancy-dominated Turbulent Fires by Using Large Eddy Simulation	H.Y. Wang and P. Joulain, Université de Poitiers, France	975
Effect of Fuel Sootiness on the Heat Fluxes to the Walls in Enclosure Fires	P. Tofilo, M.A. Delichatsios, and G.W.H. Silcock, University of Ulster, UK	987
Flame Heat Transfer Between Parallel Panels	J.L. de Ris, L. Orloff, FM Global, USA	999

Toxic Hazard

Effect of Oxygen Concentration on the Carbon Monoxide Yields from Methane and Methanol Flames	Y. Saso, H. Gotoda, and Y. Ogawa, National Research Institute of Fire and Disaster, Japan	1013
Formation of Dioxin During Smoldering of CCA Treated Wood Char	N. Tame, E. Kennedy, and B. Dlugogorski, The University of Newcastle, Australia	1023
FTIR Investigations of Toxic Gases in Air Starved Enclosed Fires	G.E. Andrews, B. Daham, M.D. Mmolawa, S. Boulter, J. Mitchell, G. Burrell, J. Ledger, W. Gunamusa, R.A. Boreham, and H.N. Phylaktou, The University of Leeds, UK	1035
Toxicity Assessment of Products of Combustion of Flexible Polyurethane Foam	C. Beyler, Hughes Associates, Inc., USA	1047
Correlation of Toxic Product Yields from Tube Furnace Tests and Large Scale Fires	T.R. Hull, K. Lebek, and K.T. Paul, Bolton Institute, UK	1059
Environmental Assessment of Fires in Products Using the Fire-LCA Model	M. Simonson, P. Andersson, and P. Blomqvist, SP Swedish National Testing and Research Institute, Sweden; and H. Stripple, Swedish Environmental Research Institute, Sweden	1071
Sampling and Quantitative Analysis of Smoke during a Fire Spreading through a Mediterranean Scrub	T. Barboni, E. Leoni, D. Cancellieri, X. Silvani, N. Chiaramonti, and P.A. Santoni, University of Corsica, France	1083
Calculation Method for Visibility of Emergency Sign in Fire Taking into Account of Smoke Adherence	A. Yuki, T. Takeyoshi, and S. Hidekazu, Kyoto University, Japan; and T. Tsuneto, General Building Research Corporation, Japan	1093

Fire Chemistry

Compensation Effects in the Non-isothermal Pyrolysis of Wood	S.M. Lim and M.Y. Lin Chew, National University of Singapore, Singapore	1109
Performance of Cables Subjected to Elevated Temperatures	P. Andersson and P. Van Hees, SP Swedish National Testing and Research Institute, Sweden	1121
Combustion Characteristics of Nano Hydrotalcite Flame Retarded Ethylene Vinyl Acetate Copolymer	C. Jiao, Z. Wang, Z. Ye, Y. Hu, and Weicheng Fan, University of Science and Technology of China, PRC	1133
Synergism between Deca-brominated Flame Retardants and Nano-dispersed Clay in HIPS Composites	F. You, Y. Hu, and J. Zhou, University of Science and Technology of China, PRC; and Y. Shi, Quality Inspection Station for Fire Fighting Products in Shandong Province, PRC	1145

Compartment Fires

Full-scale Fire Experiment on a Typical Passenger Train	N. White, V. Dowling, and J. Barnett, CSIRO, Australia	1157
Heat Release Rates of Fully-developed Fires in Railcars	B. Lattimer and C. Beyler, Hughes Associates, Inc., USA	1169
Experimental Study of Backdraft in a Compartment with Different Opening Geometries and its Mitigation with Water Mist	W. Weng and W. Fan, University of Science and Technology of China, PRC	1181
A Comparison between Observed and Simulated Flame Structures in Poorly Ventilated Compartment Fires	Z. Hu, Y. Utiskul, J. Quintiere, and A. Trouve, University of Maryland, USA	1193

Fire Environment in Partially Vented Automobile Crash Fires	A. Tewarson, FM Global, USA	1205
Experimental Study of Burning Rate Behaviour in Confined and Ventilated Fire Compartments	H. Pr��trel, P. Querre, and M. Forestier, Institut de Radioprotection et de S��ret�� Nucl��aire (IRSN), France	1217
Generalizations on Compartment Fires from Small-scale Experiments for Low Ventilation Conditions	Y. Utiskul and J. Quintiere, University of Maryland at College Park, USA	1229
Two-model Monte Carlo Simulation of Fire Scenarios	S. Hostikka, T. Korhonen, and O. Keski-Rahkonen, VTT Technical Research Centre of Finland, Finland	1241
Validation of a Network Fire Model Using the Ex-Shadwell Submarine Ventilation Doctrine Tests	J. Floyd, Hughes Associates, Inc., USA; F. Williams, Naval Research Laboratory, USA; and P. Tatem, ITT Industries Advanced Engineering and Sciences Division, USA	1253
Modeling Smoke Visibility in CFD	K. Kang, Hatch Mott MacDonald, USA	1265
Fire Development in a Deep Enclosure	I. Thomas, K. Moinuddin, and I. Bennetts, Victoria University, Australia	1277
The Impact of Location and Ventilation on Pool Fire in a Compartment	A.R. Parkes and C.M. Fleischmann, University of Canterbury, New Zealand	1289
Use of a Numerical Tool to Assess the Impact of the Means of Measurement on Fire	S. Desanghere, D. Joyeux, CTICM, France; A. Coppalle, UMR, France	1301

Smoke Control

Benefits of Field Modelling for Smoke Control Assessment in Large Volume	F. Demouge and P.Fromy, CSTB, France	1315
--	--------------------------------------	-------------

Smoke Control Using a Double-skin Facade	W. Ding and Y. Hasemi, Waseda University, Japan; and T. Yamada, National Research Institute of Fire and Disaster, Japan	1327
--	---	-------------

Explosions

Duct-vented Propane/Air Explosions with Central and Rear Ignition	G. Ferrara and A. Di Benedetto, University of Naples Federico II, Italy; and S.K. Willacy, H.N. Phylaktou, G.E. Andrews, and M.C. Mkpadi, University of Leeds, UK	1341
---	---	-------------

Experimental and CFD Investigations on Compartment Explosion with Ignition and Fuel Sources Located in Different Compartment	T. Konishi, Oita National College of Technology, Japan	1353
--	--	-------------

Investigation on External Explosions during Venting	B. Fan, X. Jiang, Z. Chen, J. Ye, and G. Dong, Nanjing University of Science and Technology, PRC	1365
---	--	-------------

Large Eddy Simulation Modeling of Turbulent Deflagrations	J. Williamson, J. McGill, and A. Trouve, University of Maryland, USA	1375
---	--	-------------

Measurement Methods

Temperature Field-monitoring Using Ultrasonic CT	N. Zhu, Shizuoka Institute of Science & Technology, Japan; Y. Jiang, University of Science and Technology of China, PRC; and S. Kato, Mie University, Japan	1389
--	---	-------------

Surface Temperature Measurement in a Fire Environment Using an Infrared Pyrometer	J. Urbas and W.J. Parker, Pacific Fire Laboratory, Inc., USA	1401
---	--	-------------

Heat Flux Pipe in Large-scale Fire Tests	P.K. Wu, FM Global, USA	1413
--	-------------------------	-------------

Application of Building-scale Calorimetry	J.S. Newman, C. Wieczorek, and J.M.A. Troup, FM Global, USA	1425
---	---	-------------

Tunnel Fires

Full Scale Experiments on Studying Smoke Spread in a Road Tunnel	L.H. Hu, R. Huo, H.B. Wang, and Y.Z. Li, University of Science and Technology, of China, PRC; and R.X. Yang and W.H. He, Yunnan General Fire Brigade, PRC	1437
--	---	-------------

Contribution to the Control of Fire-induced Smoke Flow in Longitudinally Ventilated Tunnels	S. Gaillot, A. Revell, D. Blay, and J.P. Vantelon, University of Poitiers, France; and P. Deberteix, RATP, France	1449
---	---	-------------

Smoke Movement Characteristics and Fire Safety in Subway Stations	S. Moriyama, Y. Hasemi, D. Nam, S. Tanaka, N. Okazawa, and W. Ding, Waseda University, Japan	1461
---	--	-------------

Acoustic Considerations Regarding Pulsations During Large-scale Fire Tests in a Tunnel	A. Lönnemark and H. Ingason, SP Swedish National Testing and Research Institute, Sweden	1473
--	---	-------------

Computational Fluid Dynamics of Hot Current from a Fire Source Near a Tunnel Wall	O. Imazeki, H. Kurioka, and R. Amano, Kajima Corporation, Japan; and Y. Oka and S. Takigawa, Yokohama National University, Japan	1485
---	--	-------------

Fire Development in Large Tunnel Fires	H. Ingason, SP Swedish National Testing and Research Institute, Sweden	1497
--	--	-------------

Modelling Fire Size and Spread in Tunnels	A.N. Beard, R. Carvel, and P. Jowitt, Heriot-Watt University, Scotland, UK	1509
---	--	-------------

Detection

A Contribution to the Simulation of the Process of Fire Detection	C. Rexfort, University Duisburg-Essen, Germany	1521
---	--	-------------

Experimental Study on Response Sensitivity of Smoke Detectors in High Flow Velocity	Q. Xie and Y. Zhang, University of Science and Technology of China, PRC; and G. Su and H. Yuan, Tsinghua University, PRC	1533
---	--	-------------

Numerical Prediction of Smoke Detector Activation Accounting for Aerosol Characteristics	W. Zhang, M. Klassen, and R. Roby, Combustion Science & Engineering, Inc., USA	1543
--	--	-------------

Research on Evaluation of Fire Detection Algorithms	J. Li, W. Dong, Z. Mei, and Z. Wang, Shenyang Fire Research Institute Ministry of Public Security, PRC	1555
---	--	-------------

Research on Early Fire Smoke Movements and Detection Method in Stable Thermally Stratified Environments	F. Jun, Y. Hong-Yong, J. Jie, Z. Yong-Ming, and W. Fan, University of Science and Technology of China, PRC	1563
---	--	-------------

Vision Based Fire Detection Using Mixture Gaussian Model	F. Yuan, G. Liao, W. Fan, and H. Zhou, University of Science and Technology of China, PRC	1575
--	---	-------------

A Video-based Cargo Fire Verification System for Commercial Aircraft: Design and Test Methods	W. Kruell and I. Willms, University Duisburg-Essen, Germany; and R.R. Zakrzewski, M. Sadok, J. Shirer, and B. Zelif, Goodrich Corporation, USA	1585
---	--	-------------

POSTER ABSTRACTS

Development of Interactive Fire Simulator by Using Walkthrough Virtual Reality Model	N. Abe and T. Yamada, National Research Institute of Fire and Disaster, Japan; S. Yamada, M. Suga, and A. Yamamura, Fujita Corporation, Japan; and Akihiko Iida, Tokyo Fire Department, Fire Science Laboratory, Japan	1599
Water Screen as Partitioning Technology	R. Amano, Y. Izushi, H. Kurioka, and H. Kuwana, KAJIMA Corporation, Japan; and T. Tsuruda, T. Suzuki, and Y. Ogawa, National Research Institute of Fire and Disaster, Japan	1600
Water Screen Fire Disaster Prevention System	R. Amano, M. Murakami, H. Kurioka, and H. Kuwana, KAJIMA Corporation, Japan; and T. Tsuruda, T. Suzuki, and Y. Ogawa, National Research Institute of Fire and Disaster, Japan	1601
Effectiveness and Thermal Breakdown Products of Fire Suppression Agents	B. Andersson and G. Holmstedt, Lund University, Sweden; and P. Blomqvist, SP Swedish National Testing and Research Institute, Sweden	1602
Waking Effectiveness of Audible, Visual, and Vibratory Emergency Alarms across all Hearing Levels	E. Ashley, J. Du Bois, M. Klassen, and R. Roby, Combustion Science & Engineering, Inc., USA	1603
A Physical Model of Fire Spread in Forest for Management Tools	J.H. Balbi, J.L. Rossi, and P.A. Santoni, Université de Corse, France	1604
Further Measurements of Fire Spread through a Room with Polyurethane Foam Covered Walls	N. Bryner, D. Madrzykowski, and W. Grosshandler, National Institute of Standards and Technology, USA	1605

The Influence of Longitudinal Ventilation on Flame Spread Between Vehicle Fires in Tunnels	R. Carvel, University of Edinburgh, UK; and A. Beard and P. Jowitt, Heriot-Watt University, UK	1606
Initial Investigation of ‘Smoke-Over’ – A New Tunnel Fire Dynamics Phenomenon	D. Charters, BRE Fire and Security, UK; and G. Ainley, Arup Fire, UK	1607
Preliminary Studies on the Effects of Longitudinally Non-uniform Temperature Distribution on Steel Beams	C. Chen, B. Yao, W. Fan, and J. Qin, University of Science & Technology of China, PRC; and R. Yuen, City University of Hong Kong, PRC	1608
Two-step Consecutive Reaction Model and Kinetic Parameters Relevant to the Decomposition of Chinese Forest Combustibles in Air	H. Chen and N. Liu, University of Science and Technology of China, PRC	1609
Numerical Study of the Air Intake System for the CSIRO New Fire Laboratory	Z. Dong Chen and D. Yung, CSIRO Manufacturing and Infrastructure Technology, Australia	1610
Investigation of Pulsating Behaviour of Buoyant Fires by Using Large Eddy Simulation (LES) Approach with Soot and Radiation	A.L.K. Cheung, S.C.P. Cheung, and R.K.K. Yuen, City University of Hong Kong, PRC; and G.H. Yeoh, Australian Nuclear Science and Technology Organisation (ANSTO), Australia	1611
Fire Response of Gypsum Board and Wood Framing	S. Craft, G. Hadjisophocleous, and B. Isgor, Carleton University, Canada; and J. Mehaffey, Forintek Canada Corp., Canada	1612
Mechanism of Surface Flash over Napped Fabrics	R. Dobashi, The University of Tokyo, Japan; and S. Charuchinda, Chulalongkorn University, Thailand	1613

Two-color Pyrometry for Soot Volume Fraction and Temperature Measurements in a Flat Plate Laminar Diffusion Flame in Microgravity	A. Fuentes, G. Legros, P. Joulain, and J.P. Vantelon, Laboratoire de Combustion et de Détonique, France; and J.L. Torero, University of Edinburgh, UK	1614
Characteristics of Spontaneous Ignition of Refuse Derived Fuel Piles	L. Gao and T. Hirano, Chiba Institute of Science, Japan; and T. Suzuki and T. Tsuruda, National Research Institute of Fire and Disaster, Japan	1615
Energy Balance in a Large Compartment Fire	A. Hamins, E. Johnsson, and M. Donnelly, National Institute of Standards and Technology, USA	1616
Fire Spread Simulation in 1976 Sakata Fire	K. Himoto and T. Tanaka, Kyoto University, Japan	1617
An Investigation on Personal Characteristics' Influence on Human Pre-evacuation Behavior in Fire	H. Huang, S. Lo, and C. Zhao, City University of Hong Kong, PRC	1618
CFD Simulation of Urban Fire Coupled with Firebrand Scattering	H. Huang, R. Ooka, and S. Kato, University of Tokyo, Japan; and Y. Hayashi, Building Research Institute, Japan	1619
Quantitative Risk Analysis for the Response of Steel Beam in Fires	P.T. Huang, M.A. Delichatsios, S.W. Chien, and T.S. Shen, FireSERT, University of Ulster, UK	1620
Prediction of Fire Severity in Long, Narrow Enclosures	Morgan J. Hurley, Society of Fire Protection Engineers, USA	1621
Online Measurement of HCl Concentration in Fire Smokes	C.S. Ji, Z.A. Lü, Z.W. Zhang, H. Peng, D.K. Li, and X.C. Xu, Tsinghua University, PRC	1622

Simple Numerical Model for Backdraft Risk Assessment	C.P. Jimenez, J.F. Cadorin, and J.M. Franssen, University of Liege, Belgium; and Björn Karlsson, Iceland Fire Authorities, Iceland	1623
Pooling Resources in Fire Safety Engineering Education – The IAFSS Education-subcommittee Website	B. Karlsson, Iceland Fire Authority, Iceland; and B. Tómasson, Línuhönnun Consulting Engineers, Iceland	1624
ESFR Sprinkler Protection of Class II Commodity in Cold Storage Warehouses Using Propylene Glycol Anti-freeze Agent	H.C. Kung, M.J. Pabich, and K.M. Bell, Underwriters Laboratories Inc., USA; and E. Jackson and S.T. Franson, The Viking Corporation, USA	1625
Thermal Properties for Material Decomposition Modeling	B. Lattimer and J. Ouellette, Hughes Associates, Inc., USA	1626
The DIVA “Multi-room” Experimental Facility and the DIVA-0 Program	W.L. Saux, H. Pretrel, and J.M. Such, Institut de Radioprotection et de Sûreté Nucléaire (IRSN), France	1627
Yields of Toxic Decomposition Products of Burning Whole Cables According to IEC 60695-7-50 and BS 7990 Standards	K. Lebek, T.R. Hull and D. Price, University of Bolton, UK	1628
Application of Soft Computing Techniques to Compartment Design for Fire Safety	E.W.M. Lee, K.K.Y. Yuen, R.K.K. Yuen, and S.M. Lo, City University of Hong Kong, PRC	1629
Evaluation and Optimization of the Additives on the Fire Suppression Effectiveness of Water Mist	G. Liao, B. Cong, X. Zhou, and J. Qin, University of Science and Technology of China, PRC	1630
Forest Fire Environment and Occurrence in China	S. Lifu, W. Mingyu, and T. Xiaorui, Chinese Academy of Forestry, PRC	1631
A Model for the Optimization of Evacuation Planning in Building	P. Lin, S. Lo, and H. Huang, City University of Hong Kong, PRC	1632

A Quantitative Predictive Model of Pre-Evacuation Human Behavior in Domestic Building Fire Based on SMO Algorithm	M. Liu and S. Lo, City University of Hong Kong, PRC	1633
Life Safety Issues in Tunnel Fires	Y. Liu, V. Apte, Y. Luong, X. Liu, and D. Yung, CSIRO Manufacturing and Infrastructure Technology, Australia	1634
The Effect of Smoke Temperature on CO Yield in Fires and Fire Tests	Z.A. Lü, C.S. Ji, Z.W. Zhang, H. Peng, D.K. Li, and X.C. Xu, Tsinghua University, PRC	1635
An Approach to Modeling Flame Spread over Polyurethane Foam-covered Walls	D. Madrzykowski, S. Kerber, N. Bryner, and W. Grosshandler, National Institute of Standards and Technology, USA	1636
Urban-wildland Fires: On the Ignition of Fuel Beds by Firebrands	S.L. Manzello, T. Cleary, J. Shields, and J.C. Yang, National Institute of Standards and Technology, USA	1637
Fire Performance of a Non-load Bearing Steel Stud Gypsum Board Wall Assembly	S.L. Manzello, R.G. Gann, S.R. Kukuck, K. Prasad, and W.W. Jones, National Institute of Standards and Technology, USA	1638
Energetic Materials and the Fire Problem	G. Marlair, M.A. Kordek, and R. Branka, INERIS, France	1639
Analysis on the Risk of Residential Fires by Type of Houses under Aged Society—Study on Measures for Mitigating the Risk of Residential Fires and Fire Fatalities	H. Notake, Shimizu Corporation, Japan; A. Sekizawa, M. Kobayashi, and M. Ebihara, The University of Tokyo, Japan; and A. Mammoto, Hochiki Corporation, Japan	1640
Invisible Information Imposed Monitoring System	Y. Ogawa, T. Tsuruda, and T. Suzuki, National Research Institute of Fire and Disaster, Japan; and R. Amano, H. Kurioka, and Y. Izushi, Kajima Corporation, Japan	1641

CFD Modeling of Smoke Movement in Subway Stations- Validity of the Modeling by Experiments and Application for the Assessment of Effectiveness of Fire Safety Measures	N. Okazawa, Y. Hasemi, S. Moriyama, S. Tanaka, W. Ding, and D.G. Nam, Waseda University, Japan	1642
Fire Performance of Multi-storey Wooden Facades	B. Östman, SP Träteknik/Wood Technology, Sweden	1643
Influence of Global Equivalence Ratio on Soot Volume Fraction and Size Distribution	F.X. Ouf and J. Vendel, IRSN/DSU/SERAC, France; and A. Coppalle and M.E. Weill, CORIA, France	1644
Design Methods for Overall Buckling of Aluminum Alloy Columns at Elevated Temperatures	F. Ozaki, Swiss Federal Institute of Technology Zurich, Switzerland; T. Someya, Nikken Sekkei Ltd., Japan; and Hideki Uesugi, Chiba University, Japan	1645
Heat of Gasification of Char Forming Materials	W.J. Parker and J. Urbas, Pacific Fire Laboratory, Inc., USA	1646
Simulating the Coupled Fire-thermal Structural Response of Complex Building Assemblies	K. Prasad and H.R. Baum, National Institute of Standards and Technology, USA	1647
Analysis on the Performance of Optimum Fire-fighting Operation against Simultaneous Multiple Post-earthquake Fires	A. Sekizawa and H. Ide, The University of Tokyo, Japan; M. Endo and S. Zama, National Research Institute of Fire and Disaster, Japan; T. Yamase, Institute for Fire Safety and Disaster Preparedness, Japan; and H. Shinohara and K. Sasaki, Oyo Technical Center of Oyo Corporation, Japan	1648
Particle Size Measurement of Fire Smoke based on Multiwavelength and Multiangle Light Scattering Method	X. Shu, G. Su, and H. Yuan, Tsinghua University, China; and Q. Shao and Z. Ni, University of Science and Technology of China, China	1649

Fire Experiment at Field Scale: Effects of Wind Turbulence on Radiant Heat Transfer	X. Silvani, F. Morandini, L. Rossi, E. Innocenti, J-L. Rossi, P-A. Santoni, F. Bosseur, A. Simeoni, T. Marcelli, E. Leoni, and D. Cancelieri, Università di Corsica, France	1650
Experimental Study on Nuisance Alarms of Smoke Detectors Caused by Steam	G. Su and H. Yuan, Tsinghua University, PRC; and Q. Xie and Y. Zhang, University of Science and Technology of China, PRC	1651
Fire Spread Mitigation for Closely-spaced Houses	J. Su, G. Lougheed, and B. Taber, Fire Research Program, National Research Council of Canada, Canada; and D.Yung, CSIRO Manufacturing and Infrastructure Technology, Australia	1652
Simulation Method for Evacuation Reliability under Building Fire Based on Artificial Neural Networks	J. Wang, L. Shouxiang, and F. Ren, University of Science & Technology of China, PRC	1653
On the Distribution and Danger Rating of City Fires in Huludao City	S. Weiguo and W. Jian, University of Science and Technology of China, PRC; and K. Satoh, National Research Institute of Fire and Disaster, Japan	1654
A CFD-based Methodology to Predict Flame Spread and Toxic Products Using Bench-scale Test Data	S. Welch, University of Edinburgh, UK; and S. Kumar, BRE, UK	1655
Estimation of the Direct Carbon Emissions from Chinese Forest Fires	T. Xiaorui and S. Lifu, Chinese Academy of Forestry, PRC	1656
Movement of Fire Smoke and Its Hazard in a Long-hallway Building Structure	L. Yang, W. Feng, T. Fang, R. Huang, and W. Fan, University of Science and Technology of China, PRC	1657

Characterizing of Design Fires for Clothing Stores	E. Zalok and G. Hadjisophocleous, Carleton University, Canada	1658
Study on the Effect of Color in Wayfinding during Emergency Evacuation	C. Zhao and S. Lo, City University of Hong Kong, PRC	1659
Author Index		1661
Subject Index		1667