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REPORT OF THE FOURTH CIB W14 WORKSHOP ON FIRE MODELING; CONSEIL INTERNATIONAL DU BATIMENT (CIB) COMMISSION W14 ON FIRE

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Robert A. Mosbacher, Secretary
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TABLE OF CONTENTS

REPORT OF THE FOURTH CIB W14 WORKSHOP ON FIRE MODELING

Conseil International du Batiment (CIB)
Commission W14 on Fire

James G. Quintiere
National Institute of Standards and Technology
Gaithersburg, MD 20899
February 12-14, 1990

SUMMARY

The CIB Workshops on Fire Modeling began as a natural consequence of the recognition that fire behavior in buildings could be predicted by mathematical models. Research results in the USA and in Japan in the late 1970's demonstrated this capability. Consequently, others became attracted to the work. As a result of this interest, the CIB W14 Commission on Fire organized the First Workshop on Fire Modeling in Paris of 1981. That Workshop illustrated that significant modeling efforts were underway in Europe as well. The Second Workshop was held in Boras, Sweden and emphasized the need to predict the fire growth of interior finish materials in rooms. The Third Workshop, Berlin in 1986, displayed a proliferation of models being developed, used, or modified around the world among the developed countries. Whereas zone models captured the early interest of fire modelers, the advent of faster and more accessible computers made field models viable for the complex geometries and characteristics of fire in enclosures. This was the state of the art that brought us to the Fourth Workshop hosted by the Center for Fire Research (NIST) in Gaithersburg during February 12-14, 1990.

The stated purpose of the Fourth Workshop was to provide an international forum to exchange recent information on research, development, and the application of predictive models for fire in buildings and other complex systems. As with the past Workshops, no formal papers were required, and the proceedings are not meant to be archival. It is fully expected that many of the contributions offered to the Workshop will eventually be published in the archival literature. The summary of the proceedings presented here is meant only to inform and stimulate others interested in this subject.

The Workshop was organized into three primary topic areas:

A. Complex System Fire Models,
B. Algorithms and Phenomena, and
C. Fire Growth and the Use of Test Data.

Forty-seven presentations were made; and special discussions on modeling accuracy (led by Howard Emmons), modeling material fire performance (led by Henri Mitler), and Workshop conclusions (led by Philip Thomas) were also held.

Several distinct conclusions could be drawn from the Workshop. These are listed below.

1. Zone fire modeling is very active, being widely developed, and being applied to complex systems.

2. Field modeling is being demonstrated as both an alternative and complementary tool to zone modeling.

3. Models are being extrapolated beyond the range of completely understood physics and complete data; and issues of accuracy, validity, and standardization need to be addressed.

4. Models are serving to guide the use of data from new test methods for predicting the performance on interior finish materials and other commodities. This is being done using state of the art scientific principles to express the results in meaningful engineering terms suitable for quantitative fire safety hazard analysis as opposed to traditional fire test rankings from empirical indices. Various studies are demonstrating the viability of predicting flashover time in terms of test data in conjunction with modeling.

I. Introduction

Background

The CIB Workshops on Fire Modeling began as a natural consequence of the recognition that fire behavior in buildings could be predicted by mathematical models. Research results in the USA and in Japan in the late 1970's demonstrated this capability. Consequently, others became attracted to the work. As a result of this interest, the CIB W14 Commission on Fire organized the First Workshop on Fire Modeling in Paris of 1981. That Workshop illustrated that significant modeling efforts were underway in Europe as well. The Second Workshop was held in Boras, Sweden and emphasized the need to predict the fire growth of interior finish materials in rooms. A full scale test was run, and participants were challenged to predict flashover time. Some made estimates, but no serious models were put forth. Since then work in Sweden in cooperation with the other Nordic countries has shown methods could be developed to predict some aspects of a standardized room fire test for interior finish materials. The Third Workshop, Berlin in 1986, displayed a proliferation of models being developed, used, or modified around the world among the developed countries. Whereas zone models captured the early interest of fire modelers, the advent of faster and more accessible computers made field models viable for the complex geometries and characteristics of fire in enclosures. This was the state of the art that brought us to the Fourth Workshop hosted by the Center for Fire Research (NIST) in Gaithersburg during February 12-14, 1990.

Each of the preceding Workshops had a special character, and it was not clear what new surprises might develop. Those that were in Paris for the First Workshop, felt a special excitement and satisfaction that people who had not met before, nor who had not been aware of their mutual interest in fire modeling, were meeting for the first time. In Boras, at the Second, university scientists who had examined the fundamentals of fire growth were now engaged in productive discussions with engineers who sought to apply theory to improve the world of fire testing. The transfer of knowledge from the research of the 1970's was beginning to occur. Finally, the Third Workshop in Berlin clearly showed that fire models were beginning to move from the domain of research to real world applications. These applications have increased since, and questions of model applicability and accuracy remain. In this atmosphere, the Fourth Workshop was held.

Purpose

The stated purpose of the Fourth Workshop was to provide an international forum to exchange recent information on research, development, and the application of predictive models for fire in buildings and other complex systems. As with the past Workshops, no formal papers were required, and the proceedings are not meant to be archival. It is fully expected that many of the contributions offered to the Workshop will eventually be published in the archival literature. The summary of the proceedings presented here is meant only to inform and stimulate others interested in this subject.

Scope and Organization

The Workshop was organized into three primary topic areas:

A. Complex System Fire Models,
B. Algorithms and Phenomena, and
C. Fire Growth and the Use of Test Data.

Forty-seven presentations were made; and special discussions on modeling accuracy (led by Howard Emmons), modeling material fire performance (led by Henri Mitler), and Workshop conclusions (led by Philip Thomas) were also held.

A numbered list of the presentations is contained in this report and will serve as a basis of reference for the discussion to follow. Also, in most cases, abstracts are available in the Appendix of this report. They contain the names and affiliation of the authors, and more information on the presentations can be obtained directly from the authors.

II. Summary of Presentations and Discussions

In view of the fact that many of the presentations described work in progress, much of which will subsequently be published, this report does not contain substantive results from the presentations. This will be left for the authors to claim credit for directly. Instead, a narrative of the subjects is presented to illustrate the nature of the work, and to give some impressions from this author's viewpoint. Also an attempt to relate the viewpoints of others made during the discussions will be made. This was based on personal note taking and may not fully contain the viewpoints of all who contributed. Nearly all of the presentations will be addressed in the summary to follow, but the reader should refer directly to the abstracts for a more complete description of the Workshop presentations. If an intending participant did not attend, the abstract was not included. In a few cases, substitute presenters were arranged and some late presenters did not submit an abstract. All the papers presented are included in the List of Presentations.

A. Complex System Fire Models

Mathematical models for "complex systems" are models which synthesize many coupled processes representative of a distinct environment or apparatus. Most complex system models for fire are discrete zone or network models consisting of ordinary differential equations in time. In contrast, field models solve the basic conservation laws over space as well as time. Until recently, field models have been limited in their applications to simple enclosure systems. However, their ability to address complex enclosure geometries is being enhanced by the increase in computing capabilities. We shall get some impressions of the state of development in this fire modeling area by examining the nature of some of the presentations.

New Models

MFIRE [1]* is a computer simulation of a mine fire and its ventilation system. A novel exploration has been the consideration of using it to help locate the position of the mine fire. FPETOOL [4] represents a computer tool kit containing formulas and simple models that an engineer can hopefully learn from and use. It is in contrast to more detailed multi-room zone models being developed [2,3]. Indeed, it seemed that models were being developed with a similar framework, but tailored to meet a specific task -- a fire model for risk and cost analysis purposes [5], and a model for roof venting in a fire [8]. In Europe, due to the 1986 chemical warehouse fire in Basle, Switzerland which led to pollution of the Rhine River, there is an increase in attention to analyzing the hazards of major industrial accidents. Two presentations [7,8] suggest that fire modeling may need to focus more attention on industrial fires and their impact on the environment. These were recent attempts to model fire risk in industrial applications.

Applications

It was impressive to hear about the extent to which models are being applied. The applications represent special and significant building structures and they indicate the general confidence held in the models by the sponsors of the projects. In all cases these models are predicting the consequences of a prescribed fire in terms of its transport of smoke and heat. Structural impact or fire growth predictions were not discussed.

The field model, JASMINE [9], was successfully applied to analyze the smoke control strategies in a very large six-story atrium. The Japanese model, BRI2 [10], was used to analyze the consequences of fire in New York City's Pennsylvania Railroad Station. This analysis addressed the terminal and the connecting tunnels under the Hudson River. A systematic study of experimental fires in a decommissioned nuclear reactor facility in West Germany has provided the means to evaluate many modeling approaches [11,12]. Since 1988, researchers have used the reactor experimental fire data to evaluate two field models, four zone models, and three system codes. The reactor facility is a closed structure of 11,000 m^3 in volume, 60 m high, and contains 62 compartments. Finally, two presentations illustrated the application of models to the reconstruction of real accidental fires. The models FIRST, HARVARD 6, and FAST were used to analyze a hotel fire to deduce lessons learned [13]. The other application [14] was a two story residential house fire in which three victims perished due to carbon monoxide poisoning on the second floor. In this case, a partial full scale reconstruction was conducted along with a scale model similitude study. Several computer models were then run and compared with the experimental test [14].

*Numbers in brackets refer to the Presentation Listing

Data Needs

There was a great sensitivity to the data needs of the models. Some feel that it is important to provide computer accessible fire test and property data so that others might benefit from it. Others questioned the type of data that might be stored. Janssens spoke of a systematic data base being developed for wood products involving room wall/corner tests and small scale fire property test results [15]. Babrauskas presented a framework for a generalized fire data computer-based management system [16]. He reported that its development has already begun in the UK.

Discussion of Accuracy and Validity

This discussion was led by Prof. Howard Emmons. He said that 40 years ago a fire protection engineer said that you can not model fire; it is chaotic. Specification codes and regulations are needed. These codes form the basis for the current state of fire regulation in every developed country. But in each country, either by a sub-clause or by a more recent government policy, the current regulatory requirements can be replaced by an alternative equivalent set of practices. This equivalency option could be used as the basis of a performance fire safety code, but it requires a wide spread acceptance and understanding of fire science. This science and its technology transfer has not yet progressed sufficiently to make such a practice common. Prof. Emmons recalled that fire modeling began about 13 years ago, and now it has produced many international examples. This wide spread demonstration of fire modeling testifies that fire is not chaotic. However, we do not know how general our models are, they do not have high precision in agreement, and their limitations and capabilities have not been made completely clear. Prof. Emmons said that we should attempt to develop a performance fire safety code that would have as its basis a computer model that would be able to address all of the relevant fire safety issues for a building. Perhaps the computer model could be developed internationally. Becker pointed out that this prospect offered the possibility of making current fire safety better at a lower cost. This is a distinct challenge to fire modelers, and will require a great deal of more research, demonstration and education.

B. Modeling Algorithms and Phenomena

All of the fire zone models are comprised of sub-models which describe the phenomenological pieces of the process. Even field models need to be embellished with special features if they are to address, for example, water sprays and pyrolyzing objects. All of these pieces or phenomena require the development of algorithms which need to be imbedded in these computer codes. Each of these require the proper physics and their validation through specific experiments. Without sufficient pieces, the models can be deficient for a certain task. A number of presentations were given on a variety of fire phenomena that offer the potential for inclusion as a subroutine in a computer fire code. These presentations will be cited below.

Fluid Mechanics

Two analyses were offered [17,24] which give some new results for correlating room fire temperatures with other variables. A calculation method was described for computing fire induced flows through vents in horizontal room partitions [18]. This component would be a necessary subroutine to expand the domain of zone fire models, for example, to predict basement fires. A model is also being developed for fire whirls, a phenomena usually associated with large external fires, but which may not be uncommon in building fires [20]. The application of the JASMINE field model code with the inclusion of radiant heat transfer showed excellent agreement with data for temperature and flow field of a steady room fire [19].

Heat Transfer

Several studies addressed heat transfer in fire: convective heat transfer to ceilings [21], radiant heat transfer through coatings [23], and heat transfer in test furnaces [22].

Burning Behavior

Prof. Kawagoe displayed a video tape of a "ghosting flame", a thin persisting filament floating flame, as a result of oxygen being consumed in a closed compartment while burning a liquid pool [25]. Several other presentations addressed underventilated fires [26,27,30]. This is a subject area which is not fully understood, and its modeling approach is not resolved. A related unresolved area is the production of carbon monoxide and other products of incomplete combustion. Two presentations offered some useful modeling approaches to this area [28,29], but a generally modeling strategy for carbon monoxide production in fire is still lacking.

Detection

A number of presentations addressed problems and methods dealing with the early behavior of fire flows and the response of thermal detectors and thermally activated elements [31-34, 36].

Suppression

A sprinkler suppression model for wood cribs was described that will be incorporated into a zone fire model [35], and it was illustrated how a field model might be used to develop correlations for sprinkler spray and fire plume interactions [36].

C. Fire Growth and the Use of Test Data

This session opened with Mr. Becker describing a proposal to the International Standards Organization (ISO) for a new Sub-committee in TC 92 to address methods in fire safety engineering [38]. Thomas pointed out that this will be an item for discussion at the May CIB W14 meeting in that CIB would have to take a position on it. Traditionally ISO has been concerned about standards and test methods and CIB is concerned about the review and dissemination of research to support design methods and the prestandardization process for ISO.

The theme of the remaining presentations focused on various aspects of how to use material property data to generalize predictions of fire growth on the materials. The principal emphasis was fire spread on room wall and ceiling linings.

Prof. Pettersson described a joint research program in Sweden to develop models for fire growth based on small scale reaction to fire tests, and to correlate these to full scale tests [45]. It was also mentioned that there is a cooperative U.S. - Japan experimental effort [39,42,43] with similar objectives, and collaboration among all three countries is occurring. Large scale lining experiments have been conducted in Japan [39], and a special large radiant panel facility for upward flame spread has been constructed [43]. Two models for upward flame spread were described [42,44], and Karlsson [40,41] described a model that led to an excellent correlation in terms of reaction to fire test data with predicted flashover time due to room lining fires. Another presentation described how ignition data could be readily analyzed to produce a derived critical heat flux for ignition, and thereby eliminate a tedious trial and error procedure [46].

Henri Mitler led a discussion on the reactions to this set of presentations and on the prospect of modeling material fire performance. Prof. Kawagoe stated that the session left an impression that lining fires, which was thought to be one of the most complicated processes in fire, is not beyond engineering understanding. Others pointed out that material effects of swelling and melting are still not fully accounted for, and that more experimental validation is needed. Despite these limitations, bench scale test data were effectively being used in modeling of fire growth on linings and the results looked very promising.

III. Conclusions

Dr. Thomas led a discussion to close the workshop. He cited the apparent plethora of fire computer codes, the need for validation, and the need to advise users on the limitations. Some thought the issue of validation could be addressed by more widespread peer review from experts, and that the accuracy of the subroutines individually and the overall system model should be checked with quality comprehensive data. The issue of model standardization may need to be faced sometime in the future, and it was not clear how this could be done. Models are still evolving and standardization must not be premature.

Several distinct conclusions could be drawn from the Workshop. These are listed below.

1. Zone fire modeling is very active, being widely developed, and being applied to complex systems.

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Acknowledgements

In addition to the participants who presented papers, the following session chairmen contributed to the success of the Workshop: Dr. P. H. Thomas, Dr. R. Friedman, Prof. U. Schneider, Prof. O. Pettersson, and Prof. K. Kawagoe. Also Dr. Thomas, Prof. H. Emmons and Dr. H. Mitler were instrumental in leading stimulating topical discussions.

LIST OF PRESENTATIONS

1. MFIRE: A Computer Simulation Program for Mine Ventilation and Fire Modeling, R. E. Greuer, USA.

2. The Consolidated Compartment Fire Model (CCFM) Computer Code, L. Y. Cooper and G. P. Forney, USA.

3. Numerical Characteristics of a Zone Fire Model, G. P. Forney, L. Y. Cooper and W. F. Moss, USA.

4. FPETOOL - A Simplified Approach for Fire Hazard Estimation, H. E. Nelson, USA.

5. Simplified Fire Growth Models for Risk-Cost Analysis, H. Takeda and D. Yung, Canada.

6. Outline of an Expert System for Risk Analysis of Gas Fired Power Plants, G. Holmstedt, Sweden.

7. Consequence Analyses of Some Fire Related Major Industrial Hazards, S. E. Magnusson, Sweden.

8. The Capabilities of a New, Single Compartment, Zone Fire Computer Program Lavent W. D. Davis and L. Y. Cooper, USA.

9. The Application of Field Modelling to a Practical Building Design Problem, G. Cox, S. Kumar and P. Cumber, UK.

10. Use of the Building Research Institute, Multi-room, Multi-floors Building Simulation Version 2 (BRI2) to Describe Fire Flows in a Large Open Plan-Form Building, J. A. Rockett, USA.

11. Fire Simulations in Industrial Buildings by Using the MRFC Fire Code, U. Schneider, Germany, FR.

12. Fire Experiments in a Decommissioned Nuclear Power Plant, M. Rowekamp, Germany, F.R.

13. Modelling the Backpacker Hotel Fire of September 17, 1989, Kings Cross, Sydney, Australia, D. Q. Duong and S. J. Grubits, Australia.

14. Model Precision in a Seven Room Fire Test, R. S. Levine and H. E. Nelson, USA.

15. Data Reduction of Wall/Corner Tests for Zone Model Validation, M. L. Janssens, USA.

16. Fire Data Management System, V. Babrauskas, USA.

17. Some Problems in Zone Modelling Flows from Wide Openings and in Plumes, P.H. Thomas, UK.

18. Calculation of the Flow Through a Horizontal Ceiling/Floor Vent, L. Y. Cooper, USA.

19. Effect of Radiation on the Fluid Dynamics of Compartment Fires, G. Cox, S. Kumar, UK, and A. Gupta, India.

20. Modeling of Fire Whirls, M. Vedha-Nayagam, S. Venkatesh, K. Saito and G. Fairweather, USA.

21. Enhanced Features for the Hazard Room Fire Code: Ceiling Jet Effects and Boundary Heat Transfer, J. R. Barnett, USA.

22. Experimental Investigations into Heat Transfer from Compartment Fires into Surrounding Building Components, C. Steinert, Germany, FR.

23. A Study on the Effect of Infrared Optical Properties of Coatings on an Opaque Substrate - A Thermal Point of View, J. C. Khanpara and P. L. Hunsberger, USA.

24. Correlating Temperatures in Preflashover Room Fires, S. Deal and C. Beyler, USA.

25. Burning Behavior in a Poorly-Ventilated Compartment Fire -- Ghosting Fire, O. Sugawa, Y. Oka and K. Kawagoe, Japan.

26. Laser Diagnostics of Underventilated Fires, G. Holmstedt, Sweden.

27. Simplified Zone Model for Underventilated Fires, B. Karlsson, Sweden.

28. CO Generation in Hexane Compartment Fires, R. Roby and C. Beyler, USA.

29. Chemistry of Two-Layer Fires, E. Zukoski, USA.

30. An Algorithm for Burning in a Vitiated Atmosphere, W. W. Jones, USA.

31. Experimental and Numerical Study of Smoke and Heat Spread at Early Stage of Room Fires, K. Satoh, Japan.

32. A Comparison of Ceiling Jet Temperatures Measured in an Aircraft Hanger Test Fire with Temperatures Predicted by the DETACT-QS and LAVENT Computer Models, W. D. Walton and K. Notarianni, USA.

33. Penetration Behavior of Upward Current from an Early Stage Fire into the Hot Stratified Zone, Y. Oka and O. Sugawa.

34. Estimating the Environment and the Response of Sprinkler Links in Compartment Fires with Draft Curtains and Fusible Link-Actuated Ceiling Vents - Theory, L. Y. Cooper, USA.

35. Wood Crib Fire Based Suppression Model, D. D. Evans, USA.

36. A Sprinkler Response Prediction Model, H. Z. Yu and H. C. Kung, USA.

37. Planned Use and Development of a Spray-Fire-Interaction Field Model and an Upward Fire Spread Zone Model, R. L. Alpert, USA.

38. Progress in Joint CIB W14 and ISO TAG 5 Activities Toward ISO Work in Fire Safety Engineering (Status Report), W. Becker, Germany, FR.

39. Large Scale Experiments on Interior Finish Fires, S. Yusa, Y. Hasemi, I. Nakaya, M. Yoshida and T. Goto, Japan.

40. Room Fires and Combustible Linings, B. Karlsson, Sweden.

41. Analytical Design Model for Wall Lining Fires, B. Andersson, B. Karlsson and S.E. Magnusson, Sweden.

42. Predicting the Spread Rates of Fires on Walls, H. Mitler, USA.

43. Wall Burning Tests for Upward Flame Spread, Y. Hasemi, Japan.

44. An Upward Flame Spread Flammability Hazard Parameter, M. A. Delichatsios, USA.

45. The Compartment Fire Growth Process - A Swedish Joint Research Program, O. Pettersson, Sweden.

46. Use of Bench-Scale Piloted Ignition Data as Input to Mathematical Fire Models and Algorithms, M. L. Janssens, USA.

47. Use of Property Test Data, J. G. Quintiere, USA.

APPENDIX: ABSTRACTS

1

MFIRE: A COMPUTER SIMULATION PROGRAM FOR MINE VENTILATION AND FIRE MODELING

By Rudolf E. Greuer[1]

*** ABSTRACT

MFIRE is a computer simulation program that performs normal ventilation network planning calculations and dynamic transient-state simulation of ventilation networks under a variety of conditions. The program is useful for the analysis of ventilation networks under the influence of natural ventilation, fans, fires, or any combination of these. MFIRE simulates a mine's ventilation system and its response to altered ventilation parameters such as the development of new mine workings or changes in ventilation control structures, external influences such as varying outside temperatures, and internal influences such as fires. Extensive output enables detailed, quantitative analysis of the effects that the alteration will cause to the ventilation system.

The program was developed at Michigan Technological University (MTU) with support from the Bureau of Mines. A PC (personal computer) version of the program was completed under contract for the U.S. Bureau of Mines by MTU. The purpose of this report is to document the installation and use of the PC version of the program MFIRE.

[1]Mining engineer, Twin Cities Research Center; professor of mining engineering, Michigan Technological University, Houghton, MI.

2

THE CONSOLIDATED COMPARTMENT FIRE MODEL (CCFM) COMPUTER CODE

by

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for presentation at the

Fourth CIB W14 Workshop on Fire Modeling
National Institute of Standards and Technology
Center for Fire Research
February 12-14, 1990

ABSTRACT

A priority project was carried out at The National Institute of Standards and Technology (NIST) to study the feasibility of developing a new-generation, multi-room, compartment fire model computer code, called the Consolidated Compartment Fire Model (CCFM) computer code. The idea was that such a code would consolidate past progress in zone-type compartment fire modeling, and allow readily for integration of future advances with the greatest possible flexibility. Desired features of the CCFM would include: comprehensive documentation, user-friendliness, significant modularity, numerical robustness, and versatility in the sense that the code would provide a capability of analyzing a particular compartment fire problem by using any one of a range of physical-phenomena-modeling sophistication, from the most basic to the most comprehensive.

The project led to the development of a prototype multi-room CCFM product called CCFM.VENTS. CCFM.VENTS involves a model formulation and code structure that allows for the required future CCFM growth flexibility. It has a relatively sophisticated and very general room-to-room forced and unforced vent flow capability. Finally, the CCM.VENTS code uses the simplest possible, point-source-plume, smoke-filling fire physics in the rooms-of-fire-origin and a very simple heat transfer calculation there and in other spaces. CCFM.VENTS is supported by four-part documentation including Part I: Physical Basis; Part II: Software Reference Guide; Part III: Catalog of Algorithms and Subroutines; and Part IV: User's Reference Guide.

During the talk an overview of the CCFM project will be discussed and the features of the prototype CCFM.VENTS code will be presented.

NUMERICAL CHARACTERISTICS OF A ZONE FIRE MODEL

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ABSTRACT

In this paper we will describe some numerical characteristics of the zone fire model, CCFM.VENTS. Two factors that influence the numeric behavior of CCFM.VENTS are the choice of solution variables and stiffness of the Ordinary differential equations being solved.

Past models have sometimes used layer densities and combustion product concentrations as solution variables. We chose to use layer masses and combustion product masses. There are several technical reasons for choosing mass. One is that there is less chance for cancellation error in computing the right hand sides of the differential equations. A second is that upper layer densities and concentrations are generally indeterminate at the beginning of a simulation, but upper layer masses are zero. Indeterminate initial densities and concentrations require a start up heuristic which has been shown to cause slow start up.

The system of ordinary differential equations which must be solved are unstable and stiff. We show that the evolution of this system is characterized by a series of stiff transients separated by periods of mild instability. Stiff transients occur at start up and when a layer crosses a vent boundary. We show that this system requires the use of a stiffly stable ordinary differential equation solver. Finally, we discuss how the structure of the Jacobian of this problem can be used to improve the efficiency of the numerical integration of the differential equations.

FPETOOL - A SIMPLIFIED APPROACH FOR FIRE HAZARD ESTIMATION

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FPETOOL is a package of simple engineering equations and models targeted for use by the practicing fire safety professional. Within the FPETOOL package is a model, FIRESIMULATOR. This model expands the approach initiated by Cooper in ASET to cover a wide range of situations not addressable by ASET. The approach, equations used, format, and results obtained will be presented.

SIMPLIFIED FIRE GROWTH MODELS FOR RISK-COST ANALYSIS

H. TAKEDA and D. YUNG

National Fire Laboratory
Institute for Research in Construction
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The National Research Council of Canada is presently developing a risk-cost assessment model for evaluating the life risks and protection costs in highrise apartment buildings. This computer model evaluates the life risks and fire costs over the lifetime of a building by assessing the characteristics of fire growth and spread and human response. One of the models being developed as part of this risk-cost assessment model is the fire growth model. The fire growth model is used to characterize the actuation times of smoke detectors and sprinklers and the time allowed for evacuation under various fire scenarios.

With a large number of calculations required in order to assess the life time performance of a building, only simple, first order, mathematical models that can characterize the essential features of fire growth and human response are used in the risk-cost assessment model. For this reason, the present fire growth model (the "NRC" model) uses a simple, one-zone model, which is simpler than those used in the "FIRST" and "FAST" computer codes.

The model is used to predict the fire growth of smoldering fire and flaming fire for room-sized and apartment-sized compartments, and for door open or closed conditions. The results show that the "NRC" model is comparable to "FIRST" and "FAST", and in some cases even better than "FIRST" and "FAST" in terms of suitability for use in conservative risk assessment.

7

ABSTRACT

DEPT. OF FIRE SAFETY ENGINEERING
LUND UNIVERSITY
S E Magnusson

<u>Consequence Analyses of Some Fire Related Major Industrial Hazards</u>

During 1989 consequence calculations were carried out for objects in

* Chemical industry
* Frozen food industry
* Pharmaceutical industry
* Production plant building materials

Types of activity included in the analysis were

* Storage of solid chemicals
* Storage and distribution of LPG
* Storage and handling of solvents
* Production of building materials

Quantified risk analysis (QRA) is now regarded as an essential component in the analysis of risks arising from installations and activities classified as major hazards. Some of the basic legaslation background is listed below

<u>Europe</u>

Council directive on the major accident hazards of certain industrial activities (82/501/EEC)

2nd amendment, Dec 7 1988

Sweden (1989)

Directives by National Board of Rescue Services (external safety)

Directive by National Board of Occupational Health and Safety (worker safety)

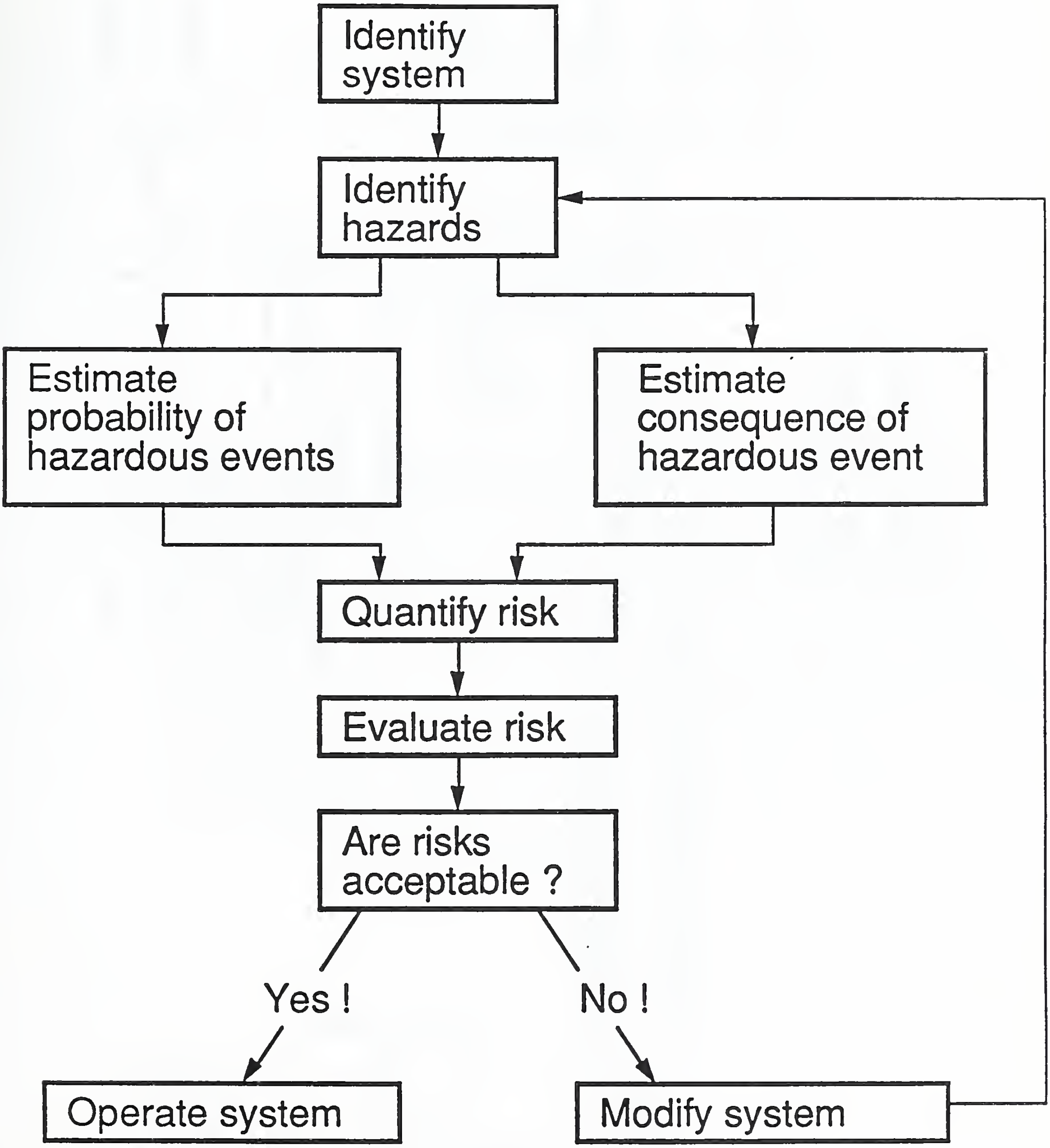
A key requirement is the compilation of a safety report. The main objective of a safety report is the generation and transmission of information as the basis for accident prevention and risk management.

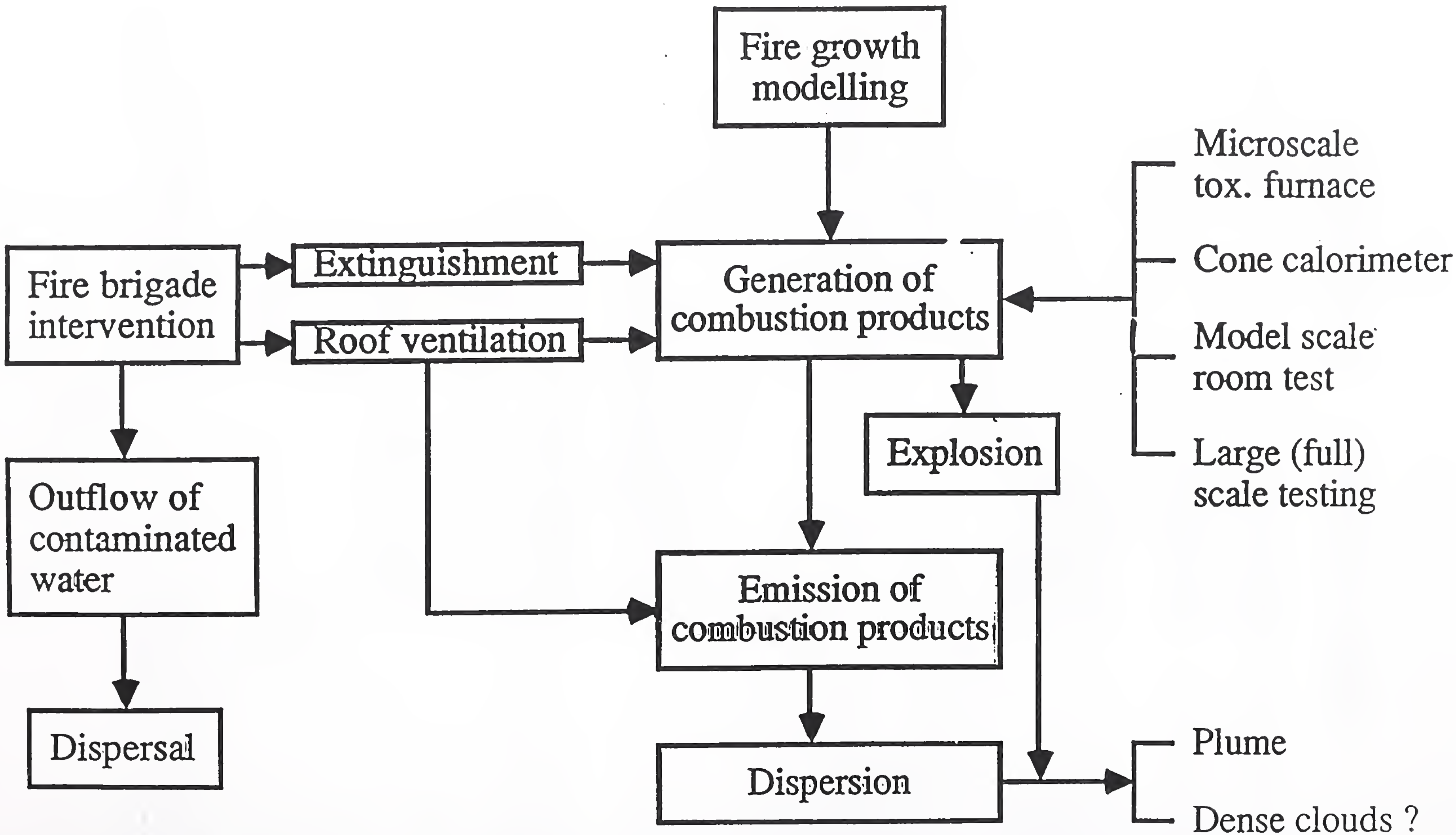
A safety report should comprise

Which dangerous substances are involved
What quantities
Which processes
Sources of hazards
On site emergency planning
Authority off site emergency planning
QRA

Use of QRA varies from country to country. The methodology was demonstrated by application to dispersion of toxic combustion products from a burning building storing chemicals.

Risk analysis - structure




Fire growth modelling
Microscale tox. furnace
Cone calorimeter
Model scale room test
Large (full) scale testing
Fire brigade intervention
Extinguishment
Roof ventilation
Generation of combustion products
Explosion
Outflow of contaminated water
Emission of combustion products
Dispersal
Dispersion
Plume
Dense clouds ?

8

THE CAPABILITIES OF A NEW, SINGLE COMPARTMENT, ZONE FIRE COMPUTER PROGRAM LAVENT

by

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for presentation at the

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National Institute of Standards and Technology
Center for Fire Research
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ABSTRACT

A new, single compartment, zone fire computer program, LAVENT (Link Actuated VENTs), is now available to the fire community. The significant features of this program include a rotationally symmetric model of the fire plume driven ceiling jet and its effect on the thermal response of ceiling mounted fusible links. The effect of roof venting on the upper layer and the effect of the presence of the upper layer on the fire plume and ceiling jet are included in the program. The ceiling vents open in response to the fusible links. The radial temperature distribution of the ceiling in response to radiation from the fire and convection from the ceiling jet is computed. Examples of applications of this program will be presented in order to display the features available in this computer program. Additional information concerning the computer model may be obtained by referring to the NIST publications NBSIR 88-3734 and NISTIR 89-4122.

THE APPLICATION OF FIELD MODELLING TO A PRACTICAL BUILDING DESIGN PROBLEM

G Cox, S Kumar and P Cumber

Fire Research Station, UK

The presentation will illustrate the use of the computer field model JASMINE in the evaluation of smoke control strategies proposed for a very large, six storey, atrium complex designed for use as a indoor leisure park.

By studying growing fires on galleries open to a central atrium and also on the floor of the atrium (containing stratified ambient air) an illustration is given of how operating times for proposed detector and sprinkler head placements can be determined.

The time available for safe escape of the occupants is determined before the powered extraction systems are overcome by the quantities of smoke involved.

Modeling Fire in Large Floor Area Buildings

Dr. John A. Rockett
Mr. William Hanbury
Mr. James Howe

As a part of an overall fire safety analysis of AMTRAK's Pennsylvania Station, New York and its connecting under river tunnels, three simulators were used: BRI2, the Japanese Building Research Institute's (September 1989 version) multi-room, multi-floor building fire model was used to model a fire on the platform level of the station; MFIRE, the U.S. Bureau of Mines mine ventilation model, and SES3, the U.S. Department of Transportation Subway Environment Simulation, version 3 were used to model the air flows in the connecting tunnels. It was necessary to include some of the tunnels as "rooms" in the station simulation so that the proper induced air flows at the platform level could be obtained. These rooms and their vents were adjusted to give the flows predicted by MFIRE and SES3.

The three floors of the station proper were modeled, but only the platform level was considered in detail. The platform level, actually a single, very large room, was modeled as six rooms connected by large area vents. One room, 100 x 100 feet in plan, was the fire room containing a fire growing in two steps to 5 and then 15 MW. Additional rooms represented the numerous stairs connecting the platform level with the two concourse levels above. Both open and partially enclosed stairs existed, some extending only to the lower concourse, some to both. Forced exhaust from the ceiling of the platform level was provided at four locations. Each exhaust port was in a different pseudo room. Fresh air entered from the open storage yards to the west of the station.

The simulations showed that, if the existing exhaust capacity were efficiently used, smoke could be confined to the platform if all the stairs were partially enclosed (fitted with trunks extending down from the ceiling); clear air to well above head level would be found on all the platforms.

Fire Simulation in Large Buildings with the Code MRFC

U. Schneider, University of Kassel

Abstract

The new fire code MRFC (Multi-Room-Fire-Code) has been developed as to meet theoretical and practical needs for fire simulations in buildings in one code. The area of application comprises e.g.

- single and multi compartment fires
- ranch house fires
- industrial buildings
- traffic buildings and tunnels
- nuclear reactor containments.

MRFC has been designed as to simulate the gas flow, gas concentrations (6 gases), energy flows, temperatures of gases, temperatures of structures either in open buildings or in closed containments of nuclear power plants, respectively. The horizontal and vertical gas flow in up to ten rooms or building sections is being simulated whereby the fire source occupies one of the rooms or sections. A maximum of 100 ventilation openings is being provided by the code.

The physical basis of MRFC is being described in |1]. Basically it has been developed as a zone model i. e. each room or building section contains hot and cold gas layers which transfer or exchange energy with the surrounding structures and adjacent openings. Natural and forced ventilation is taken into account as well as the time dependance of openings. For industrial buildings the roof venting area may be simulated by

- prescribed opening times for each vent
- prescribed pressure differences for each vent
- vent opening according to the ceiling surface temperature
- vent opening according to the upper gas layer temperature.

A broad spectrum of burning models is available in MRFC. It comprises

- wood crib fires
- oil fires
- cable tray fires
- burning rate models
- energy rate models
- fire spread in buildings.

The fire compartment comprises a fire plume whereby the plume area varies according to the burning model and a post-flashover scenario

The applicability of MRFC has been proved by a comparison of fire test results with computer simulations. The large scale fire experimental station HDR of Kernforschungszentrum Karlsruhe has been used for the fire tests. The experimental station comprises a 11000 cubicmeter reactor containment with more than 20 rooms. From 1985 to 1989 more than 20 full scale tests with

- gas burners
- wood cribes
- oil pools

have been performed in the containment. Up to 400 different data points have been continuously recorded during each test. The test data were handled by the central computer work station and comprehensive data files were provided as to the perform the code verifications. The comparisons between test results and calculations indicated - after several extentions and changes of MRFC - that the code is being able to simulate different fire scenarios in complex building geometries. The temperature development within the fire compartment and the adjacent rooms was simulated within an accuracy of less than 15 %. The difference in surface temperatures of building structures was of the same order. Gas concentrations and the pressure development indicated somewhat larger decrepancies but were still in an acceptable range. As the test arrangements were comparatively complex the code is assumed to be applicable for practical applications of any simpler configaration or design. In the meantime a large number of fire simulations in industrial buildings were performed. The calculations indicated consistent and logic results compared to reports on pratical observations with building fires.

Therefore MRFC is believed to be an advanced practically orientated fire code with a wide range of possible applications. Compared to field models the application needs less specific knowledge or experience of the user. The simulation times and costs are comparatively small as the code may be run on a micro VAX computer or similar computer work stations.

[1] Max, U.: Zur Berechnung der Ausbreitung von Feuer und Rauch in komplexen Gebäuden. Dissertation, University of Kassel, Kassel, 1990.

FIRE EXPERIMENTS IN A DECOMMISSIONED NUCLEAR POWER PLANT

Assessment and Comparison of the Codes

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Abstract

Several problem-oriented computer codes are presently available for the computation of fire induced thermal loads on plant components within the containment of a nuclear power plant.

Since 1982, a number of experiments have been carried out at a decomissioned nuclear power plant, the HDR, in FRG; these include experiments for assessment of the fire hazard and the related development of fire codes.

The research program consisted of large scale fire experiments in the containment under real conditions. The experiments were carried out at different levels of the reactor building to study time dependent temperature sequence and smoke spread in the containment using a forced ventilated fire (gas fire) or natural ventilated fires (wood crib fires, free burning hydrocarbon oil pool fires). The effects of outlet openings at different locations in the fire compartment were studied to determine the hot gas flow and its influence on the convection pattern inside the containment.

The HDR research program involved the development of fire codes for multiple fire room scenarios in a containment. These codes were verified by comparison with experimental data.

A preliminary qualitative evaluation of the various fire codes was carried out based on this comparison. This paper deals primarily with this aspect. Criteria for the evaluation were the accuracy of the analyses, the error margins of the results and time and expenses involved in modelling and computation.

PRESENTATION

1) Title: Modelling the Backpacker Hotel fire of September 17 1989, Kings Cross, Sydney, Australia"

2) Authors: Duy Q. Duong and Stephen J. Grubits

3) Organisation:

Division of Building, Construction and Engineering
Commonwealth Scientific and Industrial Research Organisation
P.O. Box 310 North Ryde 2113 Australia.

4) Abstract:

The Backpacker Hotel is located at Kings Cross, a nightlife area of Sydney, Australia. It provides cheap, dormitory type accommodation for low-budget travellers. The hotel is an old, three-storey building.

On the day of the fire, there were fifty guests. The fire in the three-seat lounge on the lobby floor, believed to have occured between 4 am and 5 am, caused six deaths. All were on the top floor. This analysis, using computer modelling technique together with data obtained after the event, attempts to reconstruct the fire and seeks to explain the cause of the deaths.

Model Precision in a Seven Room Fire Test

by

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ABSTRACT

A two story, seven room full scale test was carried out to simulate conditions in a fire in which one of the fatalities had over 90% carboxyhemoglobin in her blood. Data from this highly instrumented test were then compared with predictions from two multiroom fire models, Harvard VI, and FAST 18.

A ceiling layer gravity current was traced by oxygen analysis which carried toxic gas (CO/CO_2 ratio = 0.45) from the burn room to the upstairs hallway. This flow is not in the models. Nevertheless, both models did accurately predict the time for toxic hazard to occur in the two bedrooms that connected to the hallway.

The radiation heat loss from the burn room ceiling layer was over-predicted by both models, resulting in ceiling layer temperatures significantly lower than the data. Thermocouple tree measurements showed that a sharp demarkation between the ceiling layer and the floor layer did not exist. Layer height predictions by FAST 18 agreed roughly with an approximation that the calculated layer corresponds to the height where the temperature increase is 15% of the total increase. Predictions by HARVARD VI agreed best with a height based on enthalpy.

The approximations in the model inputs needed to achieve these results will be described, and recommendations made to improve the models. The run data can be used to validate other models.

Data Reduction of Wall/Corner Tests for Zone Model Validation

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National Institute of Standards and Technology

A series of over 30 full-scale wall/corner tests were done in the ASTM room at the Forest Products Laboratory in Madison WI between June of 1988 and April of 1989. This test series consists of two parts. Part one is a sensitivity study to find the optimum test conditions for evaluating wood products in wall/corner tests. Part two consists of tests on five wood products according to the optimum protocol found in part one. The tests were done as part of a research program of the National Forest Products Association. The ultimate goal of the program is the development of a zone fire model to predict fire growth in a room corner scenario. The full-scale test data will be used to validate the model. This presentation discusses the data reduction procedures developed to obtain results in a format suitable for zone model validation. Two problems are addressed more in detail: 1) Heat and smoke release rate and rate of species production 2) translation of measured temperature profiles in terms of variables compatible with the 2 layer model concept. A particular problem associated with 1) is the synchronize predicted and measured data so that they have a common time base. The proposed solution for problem 2) is a procedure to interpret measured temperature profiles in terms of a lower layer temperature T_l (not necessarily equal to the ambient), an upper layer temperature T_u and the interface height Z_i. The procedure conserves mass in the compartment and also yields the neutral plane height Z_n.

16

THE FIRE DATA MANAGEMENT SYSTEM (FDMS)

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Several fire research institutions have been cooperating recently to establish the foundations of a new software system for the fire design professional. This system has been termed the Fire Data Management System (FDMS). The FDMS is a software program, currently in the planning and program definition stages. It will provide for:

- An integrated database for fire test data.
- Uniform standards for exchange of fire test data.
- Both uniform and customized means of issuing reports on materials fire properties.
- Means of automated fire test data input into fire models.

The FDMS is intended for wide use within the fire research and testing community, specifically:

- Fire test laboratories
- Fire protection engineers
- Product manufacturers
- Architects
- Building officials.

Background

The concepts needed to design FDMS had their beginnings in practical needs. It was observed by many workers in the field that:

- No standard computer data format is currently available for any fire test.
- Interchange of fire data is currently not possible within any one laboratory, nor among different laboratories.
- Users/designers in one site have no ready access to fire data held at another site.
- A need exists for a single computer program which will allow the user to input fire test data, examine the data (including graphs to be displayed), search for data by manufacturer, product type, etc., and generate reports or search results.
- No single, unifying means is available for entering test data into various fire models.

Capabilities of FDMS

FDMS was conceived as a means of remedying the above shortcomings of the *status quo* fire data operations. Specifically, for such a system to be truly universal and satisfactory, it also had to handle both older types of fire tests, *e.g.*,

Fire resistance
- ASTM E 119
- BSI BS 476 parts 8 and 20-23
- ISO 834

Flame spread and related tests
- ASTM E 84 (Steiner tunnel)
- BSI BS 476 parts 6, 7
- DIN 4102 Teil 1 (Brandschacht)
- NF P92-501 (Épiradiateur)

Non-combustibility
Smoke density chamber (ASTM E 662)
Radiant Panel test (ASTM E 162)

and newer ones,
- Cone Calorimeter
- Flame spread apparatus (LIFT)
- NBS Toxicity Test
- Furniture Calorimeter (NORDTEST NT FIRE 032)
- Full-scale fire tests (condensed data).

Whereas some of the older tests had fairly simple data requirements, the newer tests typically have the characteristic that they deal with vector, not just scalar, information. By **vector** data we mean columns of number, *e.g.*, the rate of heat release values, recorded every 5 s. **Scalar** data, by contrast, are simple numbers, *e.g.*, a thickness of 12.5 mm. For the system to be of maximum utility to the user, it is clear that equally high capabilities must be provided for **graphics operations** on the vector data, and **database operations** on the scalar data.

The graphics operations typically entail
- Screen and hard copy plots.
- Scaling, zooming, overlays, axes labelling, etc.

The database operations typically entail
- Adding new information
- Searching, correcting, deleting test data.
- Establishing searching criteria; scanning the database for tests that meet the criteria; then performing Plot, Report, Export, etc., operations on the selected data.

The searching operation requires that complex conditions can be posed, for instance, "What specimens greater than 25 mm thick have been tested for manufacturer XYZ prior to the year 1986?"

Now that we have discussed what **is** stored in FDMS, it is also appropriate to mention what will **not** be stored. Raw data will not be stored in FDMS, since the only utility of raw data is for the original test lab to reduce it to engineering-units form. The originating lab must, of course, keep a safe copy of the raw data files, but they are not needed for daily use, nor are they ever exchanged with other laboratories.

Instruments calibration management

An issue faced by every testing laboratory is the effective management of the calibrations program for its instrumentation. Most of the instruments used (*e.g.*, gas analyzers, heat flux meters, load cells, etc.) need periodic re-calibration. The laboratory must maintain records and a tracking system which makes it easy to retrieve calibrations data and also to ascertain when the next re-calibration is needed. The FDMS forms a suitable vehicle for carrying out these database operations. While it is true that such data never need to be shared with others outside of the laboratory, by adopting the calibrations tracking as an element within FDMS, it is possible to simplify the task for the user. Furthermore, since the identifying and purging of bad data is integrally tied in to the management of the calibrations database, it becomes natural to subsume this as a task under the FDMS.

Daily laboratory testing

The FDMS will be accompanied by companion programs for gathering data from fire tests in the standard FDMS format. The test operator will use one of these programs, for example, CONERUN for taking data from the Cone Calorimeter. The program will query the operator for most of the needed information, *e.g.*, the thickness of the specimen, the name of the sponsor, etc. When the test is completed, the information (= raw data) will be stored on a floppy disk. If the testing laboratory is equipped with a local area network (LAN), the data will be automatically transmitted to the computer where the main FDMS database is resident. Otherwise, the operator will take the raw data floppy disk over to the computer running the FDMS. Using FDMS, he will select the IMPORT option. The FDMS will accept the raw data, automatically identify it as Cone Calorimeter data, and proceed to do the data reduction. The operator will, at this point, be asked only a very few questions, namely information that is available only after the test is completed (such as soot filter masses). The FDMS will finish the data reduction and create the appropriate test tables and vector files for this new test within the FDMS database.

Current hardware supported

Prior to formulating the scope for FDMS, a number of fire test laboratories around the world were queried to determine the type of computer hardware that they are using. A wide variety of answers was found, ranging from mainframe computers to inexpensive PC's. The most common hardware, however, was found to be IBM-compatible PC's. Early PC models, of course, did not have speed, capacity, nor graphics to be suitable. Current-day 80386-based machines, by contrast, are entirely satisfactory in all these respects. Thus, the hardware chosen comprises: IBM-compatible[1] computers using the 80386 microprocessor, with 80387 co-processor; 3.5" floppy disks (1.44 MB) for normal data exchange; 150 MByte tape cartridges for massive data exchange; VGA graphics; Microsoft-compatible mouse; and Hewlett-Packard LaserJet II printer/plotter.

[1] Certain commercial products and materials are identified in order to adequately specify the experimental procedure. Such identification does not imply recommendation by the National Institute of Standards and Technology, nor does it imply that these products or materials identified are necessarily the best available for the purpose.

Structure of the database

The database is organized into a number of relational database tables, plus accompanying DOS files where vector data are kept.

- Vector data
  - Reduced data are stored as DOS files.
- Scalar data (Stored as relational data tables)
  - Index table to available Main tables
  - Main tables
  - Secondary tables

The Main tables comprise a table for each test type: CONE (Cone Calorimeter), FURN (Furniture Calorimeter), LIFT (LIFT apparatus), Room fire tests, ... etc. In addition to such physical tests, information can also be stored output of computer fire models, in case it is desired to compare their results with values actually measured in room fire tests.

The Secondary tables comprise information which may be useful for more than one test type:

ORGANISE — Table identifying laboratory, producer, and test sponsor organizations
PERSONEL — Table similarly identifying individuals at these organizations
PRODUCT — Table identifying the products tested
INSTRUM — Table for in-house use at the testing laboratory to manage instruments
CALIB — Table for in-house use at the testing laboratory to manage calibrations.

User interface

The FDMS is built around a modern user interface, using a mouse, pull-down menus, pop-up listings, etc. It is also designed so as to be intuitively obvious to the user and to, generally, not require a user manual. A user manual will be developed, but it is intended that the information there will only be needed for advanced users who are developing add-on program routines.

At each point in FDMS operations, the HELP key will be available to give context-sensitive help, that is, information pertinent to details the particular operation being done, not just general program use information.

While FDMS will encompass quite a few standard test types, there is no intention that data reduction routines would be supplied for every fire test which conceivably could be used by a laboratory. A standard programming interface, however, will allow the user to add on test import routines to handle such additional tests as may be needed. It will be asked that users send in these routines to NIST for incorporation into the next release.

The FDMS, in its original issue, will include standard report formats for the tests included in the Main test tables. Users will also have occasional need to develop customized reports for various special purposes. The FDMS structure permits such customized report formats to be conveniently integrated into the menu system, so that they become fully 'built-in.'

Language versions

FDMS is being developed and written in English. Since it is expected that the world fire testing and engineering community will wish to make use of it, the program design provides for the installation of other-language versions. A specific language shows up in 3 instances: (1) Actual program code, names of variables, etc. (2) Screen displays and messages to the user. (3) The language of the printed report. It is not feasible to make #1 alterable. However, it is readily possible to make #2 and #3 variable. Furthermore, it can be seen that the screen language does not necessarily have to be the language of the report — the user may wish to prepare a report for a client who speaks a language different than his own. Thus, provision is made to configure, separately, the language of the screen communications and the language of the printed reports. The actual messages will be contained within a specific message file, thus to develop a non-English language version it will only be required that someone translate the messages to the new language.

Data disseminated on floppy disk

The ultimate user of FDMS will be the fire protection engineer, the architect, or the building official. Under the existing order of affairs, this user can obtain laboratory test data from the product manufacturer only in printed form. Furthermore, the data generated by each testing laboratory are very different in format, and it can be quite difficult to compare data on two products.

With FDMS, it is foreseen that the testing laboratories will issue the data to the test sponsor not only in printed form, but also on floppy disk, in standard FDMS export format. A manufacturer, trade group, etc., can then assemble a series of test results on his products and produce a floppy disk of data to hand out the professional users. Once this method of data dissemination is available, it will become very easy for these users to find information quickly and to compare products.

Some data will also be made available freely to designers from non-commercial sources, *e.g.*, the government research institutes of various countries. Provisions are made for even older data to be converted to FDMS format and issued to designers.

A very important related advantage will be the integration of data into computer models. Great strides are also being made these days in introducing the use of computer fire models into design offices. At the moment, however, the appropriate fire test data for actual products is both difficult to find and requires substantial effort to key in. With the FDMS in place, by contrast, the designer will very readily be able to import the needed product data directly into FDMS, then export into the needed fire model.

World lists

One special feature of FDMS is that it will facilitate the keeping of world-wide "telephone books." In fact, it turns out convenient to separate information into two datatables: ORGANISE for listing organizations (testing laboratories, product manufacturers, etc.) and a separate table PERSONEL, where individuals are listed. A similar, but related, concept pertains to the tracking of products for which fire test information may be available. A secondary datatable named PRODUCT is used for this information. There will need to be some organization(s) which undertakes to actually administer these datatables by receiving contributed information from users, consolidating and correcting entries, and distributing the tables to the participants. FDMS, in turn, will incorporate features whereby a new copy of these master datatables automatically updates the user's local version.

Participation in FDMS:

A number of institutions have already made plans to participate in FDMS. These include NIST; U.S. Navy; Fire Research Station (England); Underwriters Laboratories; the laboratories participating in EUREFIC: SP (Sweden), DANTEST (Denmark), SINTEF (Norway), VTT (Finland); Warrington Research Centre; and Dark Star Research.

Acknowledgements

Richard Peacock (NIST), Nigel Batho (Dark Star Research Ltd), and Marc Janssens (Research Associate of the National Forest Products Association at NIST) have been the nucleus of the persons involved in the initial stages of FDMS.

Philip H. Thomas

Some problems in zone modelling flows from wide opening and in plumes

Various equations connected with convection flows into and out of compartments are compared on a common basis of evaluating

$$M' \Big/ \left[\frac{g\,Q'}{\rho_A\, C_p\, T_r}\right]^{1/3} \rho_A\, H$$

as a function of the upper gas layer temperature

where

M′ and Q′ are respectively the mass and convected energy outflows for unit width of opening,

H is opening height,

g is the acceleration due to gravity,

ρ_A, C_p and T_r are respectively the density, specific heat and the absolute temperature of the ambient gases.

The scaling laws of Blay, Turhault and Joubert[1] are considered, as is the regression equation of McCaffrey, Quintiere and Harkleroad[2] which is recast in terms excluding heat loss to the walls etc so as to be based on the outgoing Q′ .

In addition attention is drawn to some questions connected with conventional plume equations.

(1) Blay D, Turhault J L and Jourbert P. "Modelling Smoke Movement in Corridors". New Technology to Reduce Fire Losses and Costs ed. S J Grayson and D A Smith, Elsevier Appl. Sci. Publishers 1986.

(2) McCaffery B J and Quintiere J G. Fire Technol. 1981 17 2.

/8

CALCULATION OF THE FLOW THROUGH A HORIZONTAL CEILING/FLOOR VENT

by

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for presentation at the

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National Institute of Standards and Technology
Center for Fire Research
February 12-14, 1990

ABSTRACT

Calculation of the flow through a horizontal vent located in a ceiling or floor of a multi-room compartment is considered. It is assumed that the environments of the two, vent-connected spaces near the elevation of the vent are of arbitrary relative buoyancy and cross-vent pressure difference, Δp. An anomaly of the standard vent flow model, which uses Δp to predict stable uni-directional flow according to Bernoulli's equation (i.e., flow rate is proportional to $\Delta p^{1/2}$), is discussed. The problem occurs in practical vent configurations of unstable hydrostatic equilibrium, where, for example, one gas overlays a relatively less-dense gas, and where $|\Delta p|$ is relatively small. In such configurations the cross-vent flow is not uni-directional. Also, it is not zero at $\Delta p = 0$. Previously published experimental data on a variety of related flow configurations are used to develop a general flow model which does not suffer from the standard model anomaly. The model developed leads to a uniformly valid algorithm, called VENTCL, for horizontal vent flow calculations suitable for general use in zone-type compartment fire models. Based on an assumption of total consumption of net oxygen flow rate, the algorithm is used in an example application where steady-state rate-of-burning in a ceiling-vented room is estimated as a function of room temperature, vent area, and oxygen concentration.

EFFECT OF RADIATION OF THE FLUID DYNAMICS OF COMPARTMENT FIRES

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This presentation concerns the application of a numerical field model to the problem of fire induced flows in rooms. Particular attention is paid to the effect on air entrainment of fire location, and of thermal radiation. The comprehensive set of full scale room fire experiments reported by Steckler, Quintiere and Rinkinen have been used for comparison with predictions.

It is shown for corner fires that in addition to the jet of hot combustion products leaving under the top of a doorway opening, there is, below it, a significant outflow of heated air apparently resulting from the redistribution of energy between hot and cool layers by thermal radiation. A comparison of the predicted doorway flow rates (requiring no empirical input to describe entrainment) with measurements is shown to be in good agreement.

Abstract prepared for the Fourth CIB W14 Workshop on Fire Modeling, February 12-14, 1990, National Institute of Standards and Technology.

Modeling of Fire Whirls

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Abstract: Renewed interest in the prediction of fire whirls in buildings and mass fires revealed a need to understand conditions of fire whirl generation. To this end, previously we performed a series of scale-model tests and a basic character of the fire whirls were presented. This study describes a theoretical model to explain those experimental data. Mean mass burning rate of fuel placed on a rotating solid disk is investigated as a function of mass transfer number, B and vorticity, ω assuming a laminar flow condition. The fire whirl is a double structure - forced vortex inside the core and free vortex outside the core, and the theory is made for the inside core. The model predicts that: (1) fuel vapor may penetrate the flow boundary layer, mix with air and eventually burn slowly generating a large convection column. (2) inside the convection column incomplete combustion may take place which causes escape of incomplete combustion products.

Current addresses:
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3. Department of Mathematics.

ENHANCED FEATURES FOR THE HARVARD ROOM FIRE CODE: CEILING JET EFFECTS AND BOUNDARY HEAT TRANSFER

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ABSTRACT

The Harvard Room Fire Computer Code has been extended to account for the impact of a ceiling jet and to enable users to do a detailed finite difference heat transfer analysis of walls and ceilings.

The ceiling jet algorithm enables the computer model to account for the change in heat loss from the hot gas layer to the ceiling due to the presence of the ceiling jet using a detailed ceiling convective heat transfer analysis. This is done during the running of the modified Harvard Code.

The finite difference heat transfer analysis is conducted after the Harvard Code analysis is completed. During the running of the Harvard Code the boundaries are treated as homogeneous zones for purposes of calculating the impact of the heat loss from the room on the energy in the hot gas layer. The heat transfer analysis is done using information collected during the running of the Harvard Code. This information, such as the heat fluxes from the ceiling jet, from the hot gas layer and from various objects to the boundaries is then used in the detailed heat transfer analysis.

Use of these enhanced features enables the user to predict local wall and ceiling temperatures. This is particularly useful in predicting ignition in adjoining spaces due to a local hot spot, or in predicting the tempera ure distribution in a location where a critical component, such as an electrical wire or communications cable is imbeded in a wall or ceiling.

Univ.-Prof. em. Dr.-Ing. Dr.-Ing. E. h. KARL KORDINA
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TECHNISCHE UNIVERSITÄT
BRAUNSCHWEIG

13. Dezember 1989

Experimental investigations into heat transfer from compartment fires into surrounding building components

C. Steinert:
Institut für Baustoffe, Massivbau und Braunschutz der Technischen Universität Braunschweig

Fire modelling in a compartment needs informations concerning the conditions of heat transfer to the surrounding structural elements. On the other hand the reaction of these elements to the proceedings of combustion is an important matter of interest. The current fire models work with rather distinct appropriations of the heat transfer which are established by insuffcient exploration of the physical coherences.

To get new information about this subject an experimental project has been started at the Technical University of Braunschweig (West Germany). On the base of about 30 fire experiments in furnaces of ordinary room dimensions it is intended to clear up the convective and radiative conditions of heat transfer to structural elements as a function of

- the size and shape of the compartment
- the material properties of its surrounding structure
- the location, the quantity and the material properties of the fuel
- the ventilation conditions
- the material properties of the regarded structural element.

Up to now 20 experiments have been realized in three furnaces of different dimensions with fuel of either wood, polyethylen or a mixture of wood and polethylen. In this first series of tests the furnaces were made of aerated concrete. The heat absorption of the walls as well of unloaded columns of variing types at different location in the fire compartment was examined.

The results of these investigations refer to

- amounts of rate of heat flow and heat transfer coefficient for concrete columns
- the increase in time of the gas temperature for different fuel compositions
- the quote of convective and radiative heat-absorption of concrete columns in the different phases of the fire.

It must be considered that the results of these first series of experiments are only of general quality and have to be confirmed with phase II of the test series.

C. Starck

A Study On The Effect Of Infrared Optical Properties Of Coatings On An Opaque Substrate: A Thermal Point Of View

By

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Armstrong World Industries, Inc.
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Lancaster PA 17604

ABSTRACT

Usage of variety of coatings on an opaque substrate has been in practice for long time. These substrates, when exposed to wide range of temperatures behave differently due to the difference in their optical properties. In some engineering applications, the fundamental understanding of the propagation of heat through a coated substrate is important. Therefore, this study on the impact of the optical properties of coatings on the coated substrates was undertaken. In reality, these coatings may be applied on the face and/or on the back of the substrate, however, in this paper the discussion is limited to the coatings applied to the face of the substrate.

This study was divided into two parts: 1) understanding of the impact of optical properties of the coating on an opaque substrate using an analytical model, and 2) experimental observation of the rise in temperature of coated substrate exposed to high temperatures.

The analytical model incorporating various optical properties (such as emissivity, transmissivity, and reflectivity) concluded that the increase in the thickness and the reflectivity of transparent coatings reduces the net amount of radiant heat flow through the coated substrate.

To observe the transient impact of the analytical model stated above, experimental study was undertaken using an absorptive (black) paint, a reflective (silver) paint, and two other commercial paints (paint A and B). The experiments were conducted on substrates subjected to two different radiant

heat sources: a speed-foil radiant heater, and a bench scale high temperature (approximately 1500 deg. F) exposure. In general, the substrates coated with black absorptive paint resulted in the highest surface temperatures and higher heating rates. The converse was noted for the samples coated with reflective paint B. Also, the larger temperature difference in the early part of the test was observed.

In summary, the optical properties of a coating depend on the amount of the coating provided on a substrate. Also, the impact of the optical properties of coating is more significant in the early part its exposure to high temperature. Specifically, the substrates coated with reflective paint resulted in rather slower and lower rise in its surface temperature when exposed to high temperatures.

Correlating Temperatures in Preflashover Room Fires

by

Scot Deal and Craig Beyler

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Abstract

While current efforts in fire modelling are dominated by computer based zone fire models, simpler models which can provide estimates of fire conditions in a compartment continue to be of value to the fire protection engineering community. In particular it is of interest to predict whether a particular room/fuel combination will lead to flashover. This is commonly done by estimating the room temperature using a model and comparing the resulting temperature to a critical temperature for flashover, usually taken to be 500-600°C.

In this work we have compiled a database of experimental compartment fire data. The final database contains 559 data points extracted from over 200 fire experiments, including both transient and steady fires, and forced and natural ventilation..This data has been used to evaluate the performance of the McCaffrey, Quintiere, Harleroad(MQH) model and the Foote, Pagni, Alvares(FPA) model. The MQH model performed well with a standard error of 52°C. The standard error

increased with the predicted temperature such that at 500°C the standard error is about 100°C. The FPA model showed systematic errors in the prediction room temperatures.

A new model for predicting room temperatures is developed based directly on the simple quasi-steady energy equation which first motivated the MQH model. The heat loss model used by MQH was also modified based on the available experimental results. The new model is the same for forced and naturally ventilated compartments, with an additional submodel for the naturally ventilated case to estimate the exhaust rate.

The new model is shown by comparison with the database to perform better than the FPA method for forced ventilation fires. This is accomplished with a model which contains one less fitting constant that the FPA model. The model for naturally ventilated compartment fires is more complex than the MQH model, due to a more detailed and direct estimation of the vent exhaust rate. The new model, which includes only one fitting constant, performs comparably to the MQH model which includes three fitting constants. In addition a conservative model has been developed for use where the number and extent of room vents cannot be determined as is typical in design situations.

These new models are based more directly on conservation laws and models of physical phenomena in fire. This feature increases our confidence the the results and will allow the new methods to be refined as our knowledge of fire and fire effects increases.

ABSTRACT Draft for CIB w14 held in 12 - 14 Feb., 1989

Burning Behavior in a Poorly-ventilated Compartment Fire
-- Ghosting Fire --

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Abstract

Fire behavior in a poorly ventilated compartment was investigated using a methyl alcohol pool fire as a source in a box of 2m(W) x 3m(L) x 0.6m(H). Temperatures, gas concentrations of CO, CO_2, and O_2, fuel consumption rate were measured. The fuel surface level was kept constant during the tests. The turbulent flame figure changed to thin film-like flame. Then, the lower part of the film-like flame detach from the fuel surface when the oxygen concentration decreased to about 16 vol.%, and its color then become pale blue. The flame later detached completely from the fuel surface and a blue "ghosting flame" was observed just under the ceiling like an aurora. The oxygen concentration measured under the ceiling in the ghosting period was 9 - 10 vol.%, CO_2 gas was 4.5 vol.%, and CO was negligible low concentration. In actual fires, such fuel rich condition must be occurred. Modeling of chemical reaction must become important especially on upper flammability limits.

key words : ghosting, poor ventilation, compartment fire, detached flame

CO Generation in Hexane Compartment Fires

by

Richard Roby and Craig Beyler

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Abstract

Carbon Monoxide is known to be the most important toxic gas generated in most fires, with CO contributing to a majority of fire deaths. The generation rate of CO is strongly dependent on the combustion mode. CO yields are generally an order of magnitude greater for oxygen limited compartment fire conditions than for the same fuel burned under conditions with excess oxygen.

In this investigation the generation rates of CO and CO_2 and the depletion rate of O_2 are determined for a series of hexane pool fires in a compartment with a specially designed flow system. All air is provided to the compartment through an instrumented ducted inlet and all outflow is through a window type vent. The pool fire is burned on a load cell, so that the fuel supply rate and the air inflow rate are measured directly. A range of pool sizes and outlet vent sizes are utilized.

By measuring the CO generation as a function of the fuel to air ratio, previous correlations of CO yield as a function of fuel to air ratio in a hood experiment are evaluated in a compartment fire environment. These results demonstrate the effect of compartment fire flows, interlayer mixing, and wall flows on CO yields.

An Algorithm for Burning in a Vitiated Atmosphere

Walter W. Jones

Center for Fire Research
National Institute of Standards and Technology

One of the outstanding problems with modeling fire growth and spread is the ability to handle burning of volatiles in a vitiated atmosphere. We have developed such an algorithm for combustion in a gaseous material in the context of a zone model. There are two parts to the phenomenon, first the combustion itself, and second the relative production of species, for example the co/co_2 ratio. Our algorithm is structured so that both can be changed as our understanding of this phenomenon improves.

The actual prescription that we use is a reasonable choice for limited burning, but is certainly not definitive. We assume that the combustion processes are fast compared to time scales of interest so that the details of the kinetics do not concern us. For these processes, a fully ventilated fire is merely a limiting case of vitiated burning.

A problem with invoking a complete description of a mechanism for burning is that experiments which have been used to obtain rates and branching ratios (for species production) do not allow for an unambiguous choice. These problems will be discussed. Also we will show some example calculations, discuss possible improvements, and what experimental data would aide the most in improving our model.

31

3/3

Title: Experimental and Numerical Study of Smoke and Heat Spread at Early Stage of Room Fires

By Kohyu Satoh (Fire Research Institute of Japan)
(Presentation by T. Yamada (Guest worker at CFR/NIST))

ABSTRACT: The objective of this study is to investigate the behavior of smoke and heat spread at early stage of room fires in relation to the development of intelligent fire detection system. In this study the temperature and smoke decay with variation to heat release rate, fire location and distance between fire and fire detector were discussed.

Fourth CIB W14 Workshop on Fire Modeling

Title: A Comparison of Ceiling Jet Temperatures Measured in an Aircraft Hanger Test Fire with Temperatures Predicted by the DETACT-QS and LAVENT Computer Models.

Authors: William D. Walton and Kathy Notarianni

Organization: Center for Fire Research, NIST

Abstract: Temperature measurements were made during two test fires conducted in a 37 m by 40 m by 14 m high (122 ft by 132 ft by 46 ft high) aircraft hanger. A 3 m^2 (36 ft^2) isopropyl alcohol pool fire was used by a private contractor to verify the operation of the heat detection system in the hanger. During these tests the Center for Fire Research made temperature measurements using thermocouples along the centerline of the plume and near the ceiling radially away from the fire. These temperature measurements are generally in good agreement with the predictions of both the DETACT-QS and LAVENT computer models. The measurements point out the failure of both models to account for the transport time of hot gas from the fire to the point where the temperature is predicted.

ABSTRACT Draft for CIB W14 will be held in 12 - 14 Feb. 1990

Penetration Behavior of Upward current from an early Stage Fire into the Hot Stratified Zone

by

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Abstract

A study was conducted on the smoke and flow behavior subject to an early stage fire in an atria with presence of hot zone in its upper space. The study was carried out using an enclosure of 11m(L) x 8m(W) x 4.15m(H) with stratified zone of 2 - 3 ^{0}C hotter from an ambient temperature in the enclosure. The upward flow behavior was visualized by white smoke of mainly titanium dioxide. By this means, the stratification and penetration behavior of the buoyant plume into the hot zone was clearly observed. The smoke concentrations, temperatures, velocities of the updraft, and temperature gradient between the hot and lower zones were recorded while the weak buoyant draft (about 1.5 kW at the source) was maintained as a model fire source. The results show that the smoky plume can penetrate into the hot zone through the thermal interface when the temperature of the impinging part of the updraft almost equal to the temperature of hot zone. A numerical simulation, based on two-dimensional field model, was also conducted focusing on the penetration behavior at the thermal interface. The penetration model dealt with the collapse of thermal interface considering the Richardson number based on the valance of inertia and buoyant forces. Numerical results were compared with the experimental ones and the high validity of the penetration model was performed.

ESTIMATING THE ENVIRONMENT AND THE RESPONSE OF SPRINKLER LINKS IN COMPARTMENT FIRES WITH DRAFT CURTAINS AND FUSIBLE LINK-ACTUATED CEILING VENTS - THEORY

by

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for presentation at the

Fourth CIB W14 Workshop on Fire Modeling
National Institute of Standards and Technology
Center for Fire Research
February 12-14, 1990

ABSTRACT

A physical basis and associated mathematical model for estimating the fire-generated environment and the response of sprinkler links in well-ventilated compartment fires with draft curtains and fusible link-actuated ceiling vents has been developed. Complete equations and assumptions for this model will be presented. Phenomena taken into account include: the flow dynamics of the upward-driven, buoyant fire plume; growth of the elevated-temperature smoke layer in the curtained compartment; the flow of smoke from the layer to the outside though open ceiling vents; the flow of smoke below curtain partitions to building spaces adjacent to the curtained space of fire origin; continuation of the fire plume in the upper layer; heat transfer to the ceiling surface and the thermal response of the ceiling as a function of radial distance from the point of plume-ceiling impingement; the velocity and temperature distribution of plume-driven near-ceiling flows and the response of near-ceiling-deployed fusible links as functions of distance below the ceiling and distance from plume-ceiling impingement.

WOOD CRIB FIRE BASED SUPPRESSION MODEL

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Most fire hazard assessment fire models are limited to evaluation of conditions during the growth phase of a fire. These models are lacking in prediction of fire suppression effects and therefore cannot evaluate the potential impact of sprinkler systems on building fire safety. This work examines one means to extend fire hazard assessment models to include fire suppression with ordinary sprinkler systems. Quantitative methods for prediction of sprinkler system activation, spray distribution, and extinction of wood cribs fires are presented.

A SPRINKLER RESPONSE PREDICTION MODEL

by

Hong-Zeng Yu and Hsiang-Cheng Kung

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ABSTRACT

The ability to predict sprinkler response accurately in different fire situations is critical in the design of an effective sprinkler. In this regard, a sprinkler response prediction model has been developed which accounts for the heat gain of the sprinkler link (thermal sensing element) through convective heat transfer from hot ceiling gas flow and radiative heat transfer from the fire plume, and heat loss from the sprinkler link through conductive heat transfer to sprinkler body and radiative heat emission to its surroundings.

The knowledge of ceiling flows induced by fires is required to evaluate the convective heat transfer from the hot ceiling gas to the sprinkler link. For many high-challenge fires, the initial fire growth is so rapid that the ceiling-flow development lags behind the fire-growth development. Therefore, the present prediction model incorporates both the transient ceiling flow correlations and quasi-steady ceiling flow correlations, depending on the ceiling flow conditions in different time periods of fire development. The maximum ceiling gas temperature, maximum ceiling gas velocity, and depths of vertical temperature and velocity profiles have been correlated independently for the transient ceiling flow in this study, and for the quasi-steady flow in a previous study. The effect of the movement of plume virtual origin on flow development during fire growing period is also included.

The prediction model has been verified with recorded sprinkler actuation times and measured thermal responses of simulated sprinkler links in a series of fire tests.

Abstract for Presentation at the Fourth CIB-W14 Workshop on Fire Modeling

PLANNED USE AND DEVELOPMENT OF A SPRAY-FIRE-INTERACTION FIELD MODEL AND AN UPWARD FIRE SPREAD ZONE MODEL

Ronald L. Alpert
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Norwood, MA 02062

Numerical models for predicting fire propagation and sprinkler spray performance in a fire environment have been developed at FMRC. These models are now being prepared for use in practical programs for the evaluation of material flammability and the design of new sprinkler protection concepts. To predict fire propagation on vertical materials surfaces, a zone model for planar (two dimensional) upward fire spread has been developed. Both the material heatup and pyrolysis processes are accurately approximated by integral formulations in the zone model along with the full-range of flame heat transfer processes. High accuracy can be maintained even with a relatively coarse numerical grid, allowing for future inclusion of the algorithm in comprehensive models of fire growth. A concurrent experimental program involving a segmented, instrumented, vertical surface gas burner and scanning radiometer is generating the flame heat transfer distributions required by the model. Information on material pyrolysis response to heat flux also required by the model can be obtained from flammability apparatus operated by several groups within and outside FMRC. To predict how a sprinkler spray interacts with a fire of known intensity in a large enclosure, a field model of a steady, axisymmetric protection situation (downward facing spray axis centered on the fire plume axis) has been developed. This situation has been found to be a critical test of sprinkler performance when direct extinguishment by the first few activated sprinklers is desired. Analysis of several hundred numerical calculations with the field model has led to the identification of the relative importance of spray and fire plume parameters controlling the penetration of larger droplets through the plume flow (to the fuel source location) and the deflection of smaller droplets into the ceiling-jet (to additional sprinkler locations). Techniques are currently being tested for obtaining the spray and plume characteristics required by the field model so that real sprinkler devices and the fire plumes generated by practical fuel arrays can be simulated accurately. The field modeling of droplet spray interactions with a fire is now being extended to transient, three-dimensional flow situations through the use of the PHOENICS computational software package.

PROGRESS IN JOINT CIB/W 14 AND ISO/TAG 5 ACTIVIITES TOWARD ISO-WORK IN FIRE SAFETY ENGINEERING - A STATUS REPORT

Wolfram Becker, Neustadt - Hambach / Weinstraße, Germany,F.R.

LAUNCHING PERIOD

1987 : 3rd CIB / W 14 workhop, Berlin
As one of the results of the workshop it was stated " that there is obviously a need for making use for fire models and it seems clear that the point has reached now where CIB should formulate the state of the art in a small expert group and should start drafting guidelines for practical engineering. This proposal was accepted and Ms.Law, Dr.Kendik, Mr. Favre and Mr.Becker were nominated. It was agreed that W 14 propose to ISO that a standard be produced for the documentation of computer codes for fire related design and assessment calculations. It should, for example, include references to the basic scientific sources, data and validation process."

1988 : 18th CIB/W 14 meeting, Kyoto
The report of the 3rd workshop including the suggestions mentioned above was discussed and accepted.

1989, February : 4th meeting of ISO/TAG 5, Geneve
The group took notice of the intentions of CIB/W 14 and discussed the relevant document presented by Dr.Woolley. As outcome of this discussion Resolution 2/1989 was formulated :
"ISO/TAG 5 recognizes the great importance in the future of fire safety engineering and the role of mathematical modelling, and takes note of a specific recommendation of CIB/W 14 that ISO should produce a standard(s)for the documentation of computer codes for fire related design and assessment calculations which should include references to basic scientific sources, data and validation processes. Following detailed dicussions, ISO/TAG 5 requests Dr. Woolley to convene a small group of experts - Mr.Becker, Mr. Woolliscroft, Prof.Dr.Pettersson and Prof.Dr.Thomas (CIB) - to develop terms of reference for this new area of technical activity, and proposals for ISO TAG 5 submission to the ISO Technical Board. In particular, consideration to be given to the incorporation of this work into the TC 92 programme of work, or the creation of a new Technical Committee."

1989, May : Meeting of the joint TAG 5 and CIB/W 14 ad-hoc group, Lund
Present: Dr. Woolley (convener), Mr. Becker, Prof. Dr. Pettersson, Prof. Dr. Thomas.
Apologies: Ms.Law. Ms.Dr.Kendik, Mr.Favre, Mr.Woolliscroft. Comments were received from Dr. Kendik.
Two solutions were formulated, one in favour of having the work done in ISO TC 92, because a new TC structure might not be in line with ISO protocol, since its working brief would cover responsibilities already existing in other ISO/TCs. The other favoured by the majority of the participants a new Technical Committee, because of restrictions imposed by the terms of reference of TC 92. Detailed proposals covering objectives, achievement, operating structure and time tables were sent to TAG 5.

1989, September : 5Th meeting of ISO/TAG 5, London
The group discussed the report of the ad-hoc group (doc.N 109) and a Proposal for a New Work Item presented by DIN, and prepared Recommendation 23/1989 : "TAG 5, having dicussed doc.TAG 5 N 109 requests that a proposal is circulated relating to a new work area of technical work on fire safety engineering. In connection with this, TAG 5 proposes that Annex 2 of N 109 be used as basis for defining the scope of the new work area." This annex is enclosed (no 1).

1989, October : 14th meeting of ISO/TC 92, North York / Ontario
Following a discussion in ISO/TC 92/WG 7 the main committee took notice of a revised Proposal for a New Work Item presented by DIN. It was stated that the DIN proposal did not match the TAG 5 proposal completely especially in relation to active fire precautions. The secretary of TC 92 was requested to circulate the DIN proposal for formal ballot and at the same time to draw attention to the TAG 5 recommendations and the possible need to consider changes in the terms of reference of TC 92.(Annex 2 : DIN Proposal)

PRESENT STATE

January 1990
Ballot in TC 92 : 13 replies, 10 in favour, 3 against.
Next meeting of ISO / BT : March 1990.

ANNEX 2

NEW ISO TECHNICAL COMMITTEE (TC XYZ) : STANDARDS AND CODES OF PRACTICE FOR FIRE SAFETY

Objectives

To develop an ISO Code or Codes of Practice which will address the overall problem of fire safety principally in buildings but with acknowledgement of the relevance of other structures (transport, offshore, etc).

Such treatments to include, inter alia, the quantitative assessment of:

(i) initiation and fire growth

(ii) detection

(iii) production, movement and control of smoke and toxic gases

(iv) compartmentation of fire

(v) fire extinguishment and control

(vi) building management, and means of escape and information systems

(vii) interactions with other essential features (security etc)

and

The integration of these into the total design concepts for fire safety, with computer aided engineering.

Note: An important part will be to consider the environmental aspects of fires, and fire control (pollution of water, earth, air and space(?)).

To achieve this by:-

(i) A study of international development of science and engineering methods, and an examination of how these can be incorporated into existing codes.

(ii) Drawing on existing ISO TCs to present their expertise to TC XYZ in the form of comments and standards applicable to engineering solutions by new methods of measurements, and the overall design solutions.

(iii) Preparing guidance documents on the appropriate use of fire engineering solutions, and the associated risk and hazard assessments; this work to include the developments of supporting documents for existing mathematical codes.

(iv) Developing documents on fire engineering terminology.

PROPOSAL FOR A NEW WORK ITEM	
date of presentation of proposal 89-10-06	proposer DIN
secretariat BSI (UK)	ISO/TC 92

A proposal for a new work item shall be submitted to the secretariat of the technical committee concerned, with a copy to the Central Secretariat. The proposer may be a member body, another technical committee, a sub-committee, a Council committee, the Secretary-General or an organization outside ISO.

Presentation of the proposal — to be completed by the proposer

Guidelines for proposing and justifying a new work item are given in ISO Guide 26. For ease of reference an extract is given overleaf.

Title (subject to be covered and type of standard, e.g. terminology, method of test, performance requirements, etc.)

Fire Safety Engineering

Scope (and field of application)

see Annex 1

Purpose and justification — attach a separate page as annex, if necessary

see Annex 2

Relevant documents to be considered

--

Liaison organizations

--

Preparatory work offered with target date(s)

DIN is prepared to undertake the preparatory work required for the new wor

Concerns known patented items (see annex 1E of the Directives)

☐ yes ☒ no

If yes, provide full information at annex.

NORMENAUSSCHUSS BAUWESEN IM DIN

Signature [signature]

Comments and recommendations of the TC secretariat — attach a separate page as annex, if necessary

Comments with respect to the proposal in general, and recommendations thereon

see Annex 3

Voting on the proposal

As stated in 2.5.1 of the Directives for the technical work of ISO, each P-member of the technical committee has an obligation to vote within the time limits laid down (normally three months after the date of circulation)

Date of circulation	Closing date for voting	Signature of the TC secretary
89-10-20	90-01-20	[signature]

89/45

BSI
Secretariat ISO/TC92

ISO/TC92 N 72

Date: 6 October 1

PROPOSAL FOR NEW WORK AREA: FIRE SAFETY ENGINEERING

1. INTRODUCTION

There has been discussion of the question of fire safety engineering in ISO/TAG5 Fire Tests for some time and a recent meeting adopted a recommendation suggesting that ISO/CS should circulate a proposal for a new area of work. At the same time, Germany F.R. proposed that TC92 should form a new Sub-Committee 4 to deal with the subject of Fire Safety Engineering. These matters and the questions regarding the motion of ISO/TAG5 posed by ISO/TB to ISO/TC92/-WG7 were discussed at length at the meeting of TC92/-WG7 on 3 October 1989. Based on this discussion the member for Germany F.R. revised its original proposal.

2. PROPOSAL

With the support of TC92/-WG7, Germany F.R. proposes the formation of a new Sub-Committee 4 "Fire Safety Engineering".

The main subject areas of the new SC are proposed as the fire engineering principles (including mathematical modelling) related to:

1. Initiation and growth of fires in compartments.
2. Developed fires in compartments.
3. Behaviour of structures (in fire).
4. Production, transport and removal of the "messenger" of fire (e.g. heat, smoke, toxic effluents, corrosive effluents).
5. Environmental hazards from fire.
6. Interaction of fire safety systems.

Subject to the agreement by TC92 following circulation of a Proposal for a new work item (see enclosure) the new SC4 will be formed and DIN will be appointed Secretariat. As a first priority, the SC will:

1. Allocate priorities in the above subject areas, taking particular note of the current knowledge available so that progress can be made.
2. Identify those areas where pre-standardization research is required with a view to an approach being made to, for example, CIB.
3. Ensure full and proper liaison with other SC's (e.g. TC21, TC38, TC45, TC61 etc.).
4. Arrange the transfer of those work items currently being dealt with by TC92/SC1/WG8, SC2/WG2 and SC3/WG5, subject to the agreement of the relevant SC's, with a view to incorporating the work of those WG's into the SC4 programme.
5. Prepare and submit for ballot such proposals for New work items as are required to fulfill those items identified as of priority.

VOTE ON A PROPOSED NEW WORK ITEM

date	reference number
89-10-20	ISO/TC 92 N725

This ballot duly completed shall reach the TC secretariat by: 90-01-20

ISO/TC 92

Title "Fire tests on building materials, components and structures"

Secretariat BSI

Circulated to P-members of the technical committee for vote, in accordance with 2.1.3.7, part 1 of the Directives for the technical work of ISO

Please send this form duly completed to the secretariat of the technical committee

Subject of the ballot

Proposal for a new work item

re Fire Safety Engineering

Any proposal to add a new item to the programme of work shall be voted on by correspondence, even if it has appeared in the agenda of a meeting. (See 2.1.3.7, part 1 of the Directives.)

- ☐ We support the addition of the proposed new work item to the programme of work of the technical committee
- ☐ We agree to the scope proposed
- ☐ We suggest that the scope be modified (as indicated in an annex to this ballot paper)
- ☐ We do not support the addition of the proposed new work item

The reasons for our disagreement are the following (use a separate page as annex, if necessary)

- ☐ We are prepared to participate actively in the proposed new work (even if voting against)
- ☐ At present, we wish to abstain from participation in this new work (invoking the provisions of 2.5.3, part 1 of the Directives)
- ☐ Standard(s), regulation(s) and other relevant documentation existing in our country, with any remarks concerning the application if necessary, are attached

P-member voting:	date	signature

Attachment: Proposal for a new work item

r, 04 30 000

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Annex 1

Scope for the proposed ISO/TC 92/SC 4 "Fire safety engineering"

1. Initiation and growth of fires in compartments

2. Developed fires in compartments

3. Behaviour of structures in fire

4. Production, transport and removal of heat, smoke, toxic effluents, corrosive effluents etc.

5. Environmental hazards from fire

6. Interaction of fire safety systems

Annex 2

Proposal for a new work item

From Document ISO/TAG 5 N 106 Rev.

AGENDA ITEM 7 - FIRE MODELLING

25 The Chairman referred to Doc. ISO/TAG 5 N 100 circulated earlier.

26 Dr. Woolley gave information on the document N 100 and on activity in CIB W14 and its limitations.

27 Further in the discussions, all aspects of fire modelling were consider It was noted that "fire modelling" is missing from the Glossary of fire ter In fact "fire modelling" is laboratory simulation of fires according to a given scenario. The relations between fire tests - fire modelling - fire engineering were discussed.

28 Prof. Pettersson underlined the importance of computer codes for fire-related design and assessment calculations. He proposed that the scope of ISO/TC 92 should be extended. Probably a new SC should be formed. The oth possibility would be the formation of a new TC.

29 Mr. Becker supported the idea that the scope of ISO/TC 92 be extended.

30 After further consideration, Recommendation 2/1989 was drafted.

RECOMMENDATION 2/1989

ISO/TAG 5 recognizes the great importance in the future of fire safety engineering and the role of mathematical modelling, and takes note of a specific recommendation of CIB W 14 that ISO should produce a standard(s for the documentation of computer codes for fire related design and assessment calculations which should include references to basic scienti sources, data,and validation processes.

Following detailed discussion, ISO/TAG 5 requests Dr. Woolley to convene small group of experts - Mr. Becker, Mr. Woolliscroft, Professor Petters and Dr. Thomas (CIB) - to develop terms of reference for this new area c technical activity, and proposals for ISO/TAG 5 submission to the ISO Te nical Board. In particular, consideration to be given to the incorporat of this work into the TC 92 programme of work, or the creation of a new technical committee.

DIN proposes - following ISO/TAG 5 Recommendation 2/1989 - to allocate the work concerning "Fire safety engineering" to ISO/TC 92 "Fire tests on building materials, components and structures".

ANNEX 3

Reasons for treating "Fire Safety Engineering" within ISO/TC92.

1. Fire safety engineering is the more general framework containing as one classical approach fire testing. In the future more and more weight will be given to alternative analytical procedures. Therefore also the work of TC92 has to be pushed towards this direction.

2. Fire safety engineering has its basis in the experience from fire tests. It has to use input data produced in fire tests and has to be consistent with the present safety level based on fire tests.

3. A big part of the fire engineering work is already going on in TC92, e.g. in SC1/WG8 (on fire initiation and growth), in SC2/WG2 (on behaviour of structures in fire) and in SC3/WG5 (on toxic effluents). This work can be stimulated by placing it into the generalized framework.

4. By adding those subjects presently missing for an overall fire safety engineering approach but leaving outside problems which are still subjects of ongoing research, it will be possible to create technical reports and standards on analytical procedures and input data within a reasonable period of time.

5. Also for practical reasons, to avoid a split-up of activities of the same institutes and laboratories into different TC's, it is favourable to keep the work within TC92 and to form a new sub-committee 4.

LARGE SCALE EXPERIMENTS ON INTERIOR FINISH FIRES

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As a technical basis for the development of rational fire safety design method of interior linings, two series of full scale experiments were made on interior finish fires, in an open corner and in a 12.2m x 2.6m x 2.6m enclosure with a large opening.

In the open corner experiments, influence of material thickness, size of fire source, lining construction method, etc on fire spread was examined on local woods and plywood. The following conclusions were drawn from the experiments.

(1)significance of the thickness of lining materials

Time from ignition to the arrival of the flame to the open end and time from ignition to the whole involvement of the ceiling by flame is strongly dependent on the thickness of lining materials. However, the time from ignition to the arrival of the flame to the ceiling does not seem to depend on the thickness. These imply a significant influence of the thickness of lining materials on the horizontal fire spread along the ceiling surface.

(2)size of fire source

Fire spread along the wall above the fire source seems to depend considerably on the size of fire source.

(3)effectiveness of fire-protective backing

Use of gypsum board for the backing resulted in the prevention or considerable delay of the flame invasion to the back side of the lining material.

The "room corner experiments" were conducted using a 30cm square propane burner with heat release rate 100kW for the first 10min and 150～200kW for the following 10min as the fuel. Measurements were made on surface and air temperatures and heat flux to wall and ceiling surfaces. In these experiments, wood or plywood were applied only to the walls; the experiments were made to examine the effectiveness of the use of noncombustible ceiling for the prevention of rapid fire spread within a relatively large enclosure. The conclusions from the experiments are:

(1)burnt area

Fire spread took place only within 3m in horizontal distance from the burner.

(2)flame spread limit in terms of heat flux

Heat flux at the limit of fire spread is not far from the critical heat flux for horizontal flame spread in the IMO flame spread test.

ABSTRACT

DEPT. OF FIRE SAFETY ENGINEERING
LUND UNIVERSITY
B Karlsson

Room Fires and Combustible Linings

An extensive research program on combustible wall lining materials has been carried out in Sweden.

Several lining materials were tested in full scale room tests and 1/3 scale model room tests for two different scenarios, A and B. Scenario A refers to the case where walls and ceiling are covered by the lining material, scenario B where lining materials are mounted on walls only.

A model is presented using material properties derived from standardized bench–scale tests as input data. The model predicts the fire growth in the full or 1/3 scale tests, which includes predicting the rate of heat release, gastemperatures, radiation to walls, wall surface temperatures and downward flame spread on the wall lining material.

No sensitivity testing has so far been carried out with respect to the different assumptions and procedures just enumerated. Changes will certainly be introduced, especially regarding the horizontal concurrent flame spread. Certain other areas in the procedure need to be looked at more closely, a sensitivity analyses with regards to emission coefficients and heat transfer coefficients, as well as other input parameters, will need to be carried out.

The ISO surface spread of flame test seems to correlate well with room test behavior when directly comparing times to ignition and rates of opposed flow flame spread. For the RHR–test the correlation is more implicit. A simple model incorporating data from this test and the ignitability test is capable of predicting the first phases of room fire growth in scenario A. The basic structure of the model for prediciting fire growth in scenario B seems acceptable although it needs improving. This is valid for both full scale and the 1/3 scale test room.

ABSTRACT

DEPT. OF FIRE SAFETY ENGINEERING
LUND UNIVERSITY
B Andersson – B Karlsson – S E Magnusson

Analytical design model for wall lining fires

In the previous presentation, Björn Karlsson discussed a computer model for wall–lining fires with basic material flammability input parameters provided by bench–scale ISO tests. These parameters are thermal inertia $k\rho c$, flamespread parameter ϕ, ignition temperature T_{ig} and RHR–parameters $\dot{Q}''_{max}$ and λ. (Time variation of RHR is assumed to be written $\dot{Q}''(t) = \dot{Q}''_{max}\ e^{-\lambda t}$). In order to investigate problems like

– the relative importance or weight of these parameters
– the influence of the variance inherent in the derivation procedure of the parameters
– the influence of the modelling uncertainties

time to flashover t_{fo} was derived as an analytical function by regression analysis. The methodology was to use the computer program to derive serveral hundreds of values of t_{fo} and to approximate the result by an analytical expression.

$$t_{fo} = f(k\rho c,\ \phi,\ T_{ig},\ \dot{Q}''_{max},\ \lambda)$$

Disregarding the influence of T_{ig} (the range of variation is rather limited) theresultant expression was

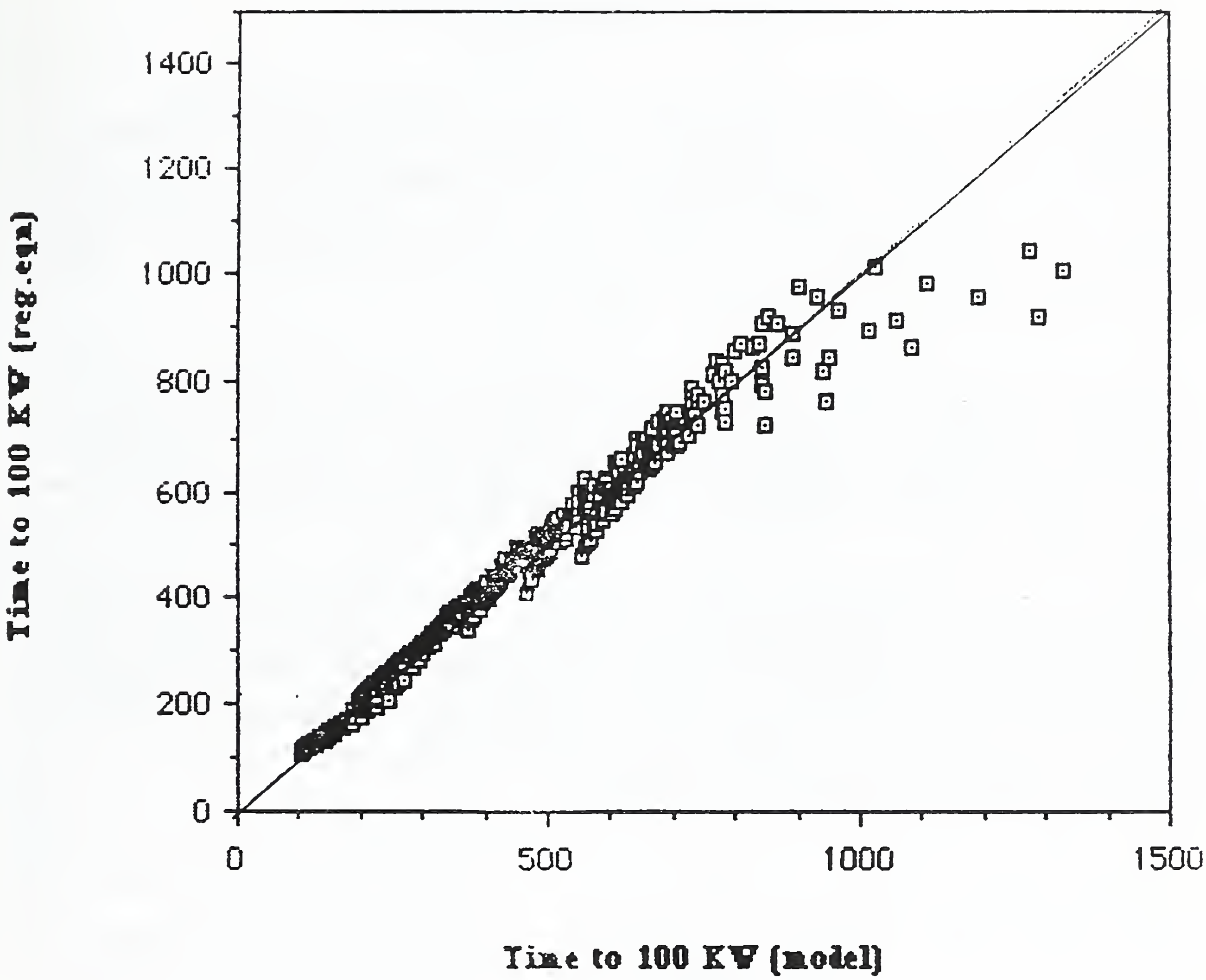
$$t_{fo} = 1.59 \cdot 10^3\ k\rho c^{0.83}\ \phi^{-0.25}\ \lambda^{0.10}\ (\dot{Q}''_{max})^{-0.44}$$

with the coefficient of determination $R^2 = 0.99$ (see figure).

A corresponding expression was derived excluding ϕ.

Modelling uncertainties was derived by comparing experiments and calculated values and the component uncertainties (as a percentages of total uncertainty) determined.

The presentation outlined a procedure to introduce reliability based design based on fixed failure probabilities (described by the β–index) and first order reliability methods, including the derivation of rational partial safety coefficients.



Time to 100 KW (reg.eqn)
1400
1200
1000
800
600
400
200
0
0
500
1000
1500
Time to 100 KW (model)

PREDICTING THE SPREAD RATES OF FIRES ON WALLS

Henri E. Mitler

Center for Fire Research, NIST

The problem is how to understand and then model the burning and spread rates of fires on walls. Analytic approaches are first discussed for finding expressions for the upward spread rate, then the present numerical approach: the object, of height h_w, is divided into N slabs of height $\Delta z = h_w/N$ by N+1 equally-spaced nodes. Expressions for the heating fluxes at the wall, due to the flame, are found for all cases of interest. The resulting surface temperature of the object at each node is then found, at each time step. When the surface temperature at node m is calculated to reach T_{ig}, the pyrolysis front is taken to have progressed to that height.

The computer program offers two options for the mass-loss rate; the first uses an algebraic model of the steady-state pyrolysis of simple, non-charring materials. The second takes the experimental mass-loss rate from the Cone Calorimeter at a given irradiance level, and transforms it into what the rate would be at the level found during the actual fire. This method automatically includes the effects of charring, of transient heating, etc, to a first approximation..

Using the fluxes found above, results were obtained for the upward spread on PMMA. Markstein has found that he gets better results in characterizing flame heights with a square-root dependence on $\dot{Q}$, rather than the usual 2/3ds power. Runs were then made assuming 1, 2, and 4 kW igniting burners. The results of each run were compared with the results of experiments carried out in 1975 by Orloff et al. The results, using either mass-loss rate option, were in excellent agreement with the observed rate.

AN UPWARD FLAME SPREAD FLAMMABILITY HAZARD PARAMETER

by

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One of the objectives of material flammability research is to investigate what and how material flammability properties measured in various laboratories in the world can be used to 1) evaluate small-scale flame spread tests, and 2) predict flame spread rates and growth rates in large-scale configurations (e.g., room tests, corner tests). The ability to use key material flammability data for predicting flame spread rates at different geometric scales will reduce the cost of testing and provide a solid basis for fire risk analysis. An approach being followed recently is the development of numerical modeling methods for predicting flame spread rates in different geometries and scales based on a few key flammability properties measured in the laboratory. In a parallel effort various attempts have been made to characterize the upward flame spread propensity of materials based on small-scale material flammability and flame spread test data. We present here an analysis which emphasizes the physics and provides a characteristic upward flame spread parameter appropriate for large-scale luminous fires by investigating the flow between two parallel burning walls. In this configuration, reradiation losses cancel out and the pyrolysis of charring materials can be readily modeled. The effects of vertical scale and burnout (i.e. finite fuel supply) are also included. The proposed upward flame spread parameter is consistent with flame spread experience in large-scale tests (e.g., FM corner tests).

THE COMPARTMENT FIRE GROWTH PROCESS – A SWEDISH JOINT RESEARCH PROGRAM

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The research program, which has been in progress since 1980, is carried out in collaboration between the departments of Fire Safety Engineering and Nuclear Physics at the Lund Institute of Science and Technology, the Fire Engineering Laboratory at the National Swedish Testing Institute at Borås, and the Wood Technology Centre at Stockholm. The research program has a central position in the total national program of activity of the Swedish Fire Research Board by generating knowledge and methods which have a broad field of application and therefore form the basis for several other Swedish Fire Research Board projects.

The long term object of the joint research program is to contribute to the international development of small scale tests for reaction to fire of materials and related analytical tools required for a prediction – from the results of the small scale tests – of the characteristics and hazards of the compartment fire growth process at various properties of the fire load and fire compartment. The structural scheme of the program defines the following project components:

* Collaboration in international development, calibration and evaluation of new small scale material tests for fire reaction,
* development of models that simulate the compartment fire growth process due to the participation of either combustible wall and/or ceiling linings, or combustible units of furniture,
* tests at full or reduced scale for verification of the simulation models,
* correlation analyses of the results of the small scale material tests and the fire compartment tests, and
* formulation of performance requirements and related criteria for requirements compliance.

46

Use of Bench-Scale Piloted Ignition Data as Input to Mathematical Fire Models and Algorithms

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National Institute of Standards and Technology

A theory is presented in interpret piloted ignition data obtained in a bench-scale test in terms of fundamental properties of the material. The theory is applicable to data obtained with any bench-scale ignitability test, but the only test method considered here is the Lateral Ignition and Flame spread Test (LIFT) developed at NIST. The theory is a refinement of the original procedure to reduce LIFT data developed by Quintiere and co-workers. It is based on the assumption that the specimen can be considered as a semi-infinite solid. However, property data for most thin or intermediate materials can be obtained by extrapolation from the region where the material behaves as a semi-infinite solid (i.e., where time to ignition is smaller than the time required by the heat wave to reach the back surface). The suggested form of equations to correlate experimental data are the result of a systematic analysis of numerical solutions to the piloted ignition problem. The data required for the analysis are the time to ignition over a range of irradiance levels. The material properties obtained as a result of the analysis are effective thermal inertia $k\rho c$ (over the temperature range between ambient and ignition temperature), surface temperature at ignition T_{ig}, critical flux for ignition $\dot{q}''_{cr}$ and minimum flux for ignition $\dot{q}''_{min}$. These fundamental properties are used as input to model algorithms to predict ignition and flame spread. Application of the theory is illustrated for a number of wood products.

Use of Property Fire Test Data

by

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ABSTRACT

A mathematical model was developed to calculate the rate of energy release from wall, ceiling or floor oriented materials. The effect of an igniting fire is included. The necessary material "property" data includes peak-average, rate of energy release per unit area, ignition time, burning time, and a parameter for lateral flame spread. The data are derived from the Cone Calorimeter and the Lateral Ignition and Flame Spread Test. Also, threshold values of critical temperature for lateral flame spread are needed. Preliminary results were presented for illustration.

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☐ DOCUMENT DESCRIBES A COMPUTER PROGRAM; SF-185, FIPS SOFTWARE SUMMARY, IS ATTACHED.

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

A summary of presentations are presented for the 4th Conseil International du Batiment (CIB) Workshop on Fire Modeling. The scope of the presentations, 47 in number, include reports of recent developments and applications of zone and field models, presentations on specific phenomena needed by computer algorithms, and presentations on the subject of interior finish flammability. The Workshop showed that a variety of models are in international use, that data is lacking to confirm the accuracy of the models for applications beyond their base of development, and that it is becoming evident that the fire growth hazard of interior finish materials can be predicted from small scale test data.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

CIB Workshop; field models; fire modeling; flammability; interior finish; zone models

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