Extended Abstracts and Presentations from the Workshop on Fire Growth and Spread on Objects, March 4-6, 2002, National Institute of Standards and Technology

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This document contains the proceedings of a workshop held at the National Institute of Standards and Technology on Fire Growth and Spread on objects typically found in residential settings. The focus of interest is the period from the ignition of the initial object up to the point where the fire results in the ignition of a second item. The purpose of the workshop was to obtain an understanding of the current status of experimental characterization and modeling capability, and to provide guidance for future research efforts.

The workshop was organized into several sessions with specific topics areas. Several presentations were included in each session, with an extended period for discussion at the end of each session. For each presentation, an extended abstract by the author is included along with any visuals used for the presentation. For each workshop session, the session moderator prepared a summary of key points of research interest from the presentations and discussion.

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Workshop Agenda

Introduction, Dr. William M. Pitts, NIST/BFRL (Presentation)

Ignition and Flammability
Moderator: Dr. Thomas J. Ohlemiller, NIST/BFRL

- "Some Specialized Areas Where Research Is Needed," Dr. Vytenis Babrauskas, Fire Science & Technology Inc. (Abstract / Presentation)
- "Will It Support a Self-Propagating Fire?" Dr. John L. De Ris, FM Global (Abstract / Presentation)
- "A Revisit to the Fire Hazard Assessment of Lining Materials Based on the Asymptotic Behavior of Concurrent Flame Spread--An Interim Note," Professor Yuji Hasemi, Waseda University (Abstract / Presentation)
- "Radiant Ignition of Adjacent Upholstered Furniture - A Simple Approach," Professor Charles M. Fleischmann, University of Canterbury (Abstract / Presentation)

Session Summary

The session covered specific topics from wall fire growth to furniture fires and specific material test methods. However, the themes that emerged in the presentations and discussion were broader than these specific areas. These themes fall under two main categories: A major theme was the need to deal with real fires on real materials and composites (beyond wall linings which are fairly well understood). The Cone Calorimeter was developed for the express purpose of developing fire model input data for the complex layered materials characteristic of the real objects which show up as problematical in fire incidence statistics. However, there was no consensus (in this session or in others) on the most accurate way to transform Cone data (acquired at one or more constant heat fluxes) into “material property data” needed as inputs to fire growth and/or burning rate models.

Other aspects of real room fires were repeatedly raised but generally not addressed in the work discussed here. Thus there were calls for carefully observed fire tests in fully furnished rooms to get quantitative data on how fires actually spread from object to object. The role of fire radiation in fire spread among objects is clear but quantifying and predicting its level versus distance is in need of further work. The actual mode of second object ignition in this radiant field (in a room fire) is not clear. The sensitivity of the overall fire growth in a room to object placement is also quite unclear. One of the most difficult problems of real object burning, generally ignored by modelers, is the drastic change in geometry which occurs as elements of the fuel melt and flow or collapse, possibly forming a pool fire under the remains of the object. The point was made that such changes can dominate the heat release curve of objects such as chairs. Thus it is necessary to come to some understanding of the role of such changes in real object burning.

Materials and Response
Moderator: Dr. Gregory T. Linteris, NIST/BFRL

- "Solid-State Thermochemistry of Flaming Combustion," Dr. Richard E. Lyon, FAA W.J. Hughes Technical Center (Abstract / Presentation)
- "Effects of Ventilation on Material Properties," Dr. Archibald Tewarson, FM Global (Abstract / Presentation)
- "A Numerical Model of Bubbling Thermoplastics," Dr. Kathryn Butler, NIST/BFRL (Abstract / Presentation)
- "Impact of Glazing on Growing Compartment Fires," Professor Patrick J. Pagni, and Dr. Bernard R. Cuzzillo, University of California, Berkeley (Abstract / Presentation)

Session Summary

After the session, the discussion addressed several themes that serve as an effective summary. These fall under two main categories:

Better material characterization is needed, in particular: 1. Bridging the gap between simple material parameters (such as the heat release capacity) and room-scale modeling. 2. Understanding the ways in which scale and ‘real product’ effects (including non-homogeneity) in materials affect the parameters that are input to models. 3. Understanding if the heat release capacity is a useful parameter.

Better understanding of the effects of ventilation on material characterization is required, namely: 1. The effect of ventilation on the global material properties (including the gas pyrolysis products and fire-material interactions). 2. The utility of local as compared to global equivalence ratio. 3. Better characterization of the glass fall-out phenomenon and the subsequent changes to the modeling boundary conditions.

Fundamental Flame Spread and Flame Spread on Surfaces
Moderator: Dr. Kathy A. Notarianni, NIST/BFRL

- "Fire Growth and Spread Models" Professor Arvind Atreya, University of Michigan (Abstract / Presentation / Visuals)
- "Detailed Modeling of Flame Spread Processes over Solids: Progress and Prospect," Professor James S. T'ien, Case Western Reserve University (Abstract / Presentation)
- "Fire Spread on Walls and Ceilings to Flashover," Professor James G. Quintiere , University of Maryland (Abstract / Presentation)
- "Predicting Fire Growth Involving Interior Finish Materials Including the Effects of Lateral Flame Spread and Layer Heating," Brian Y. Lattimer and Craig L. Beyler, Hughes Associates, Inc. (Abstract / Presentation)

Session Summary

After the session, the discussion addressed several themes that serve as an effective summary. These fall under three main categories:

Main questions are: Will it propagate? How far and how fast? How approximate is it? We agreed that this is a function of parameters such as: ignition source and strength, heat flux, and ignition temperature. However, model approaches vary (gas phase, solid phase, and material property-based).

Different models are needed for various applications and levels of detail – no interest in creating one “super-model.”

Our ability to do theory exceeds our willingness to do experiments needed as a “reality check.” An experimental program should: 1. Burn real materials that are well-characterized by components and repeatable. 2. Experiments should be heavily instrumented including radiative feedback to burning item, temperature, and flame height. 3. No room consensus, some advocate no room, some a realistic room (with floor and ceiling materials and a window), some additional ISO room tests. 4. Experiments should be a team effort, include multiple partners in test design, multi-year tests with lessons learned.

Flame Spread on Objects
Moderator: Dr. Kathy A. Notarianni, NIST/BFRL

- "Progress in 3-D Modeling of Wood Fire Growth Using a PC," Dr. Mark A Dietenberger, USDA Forest Service - Forests Products Laboratory (Abstract / Presentation)
- "A Methodology to Create a Design Fire, NIST Workshop Gaithersburg 2002-03-04--2002-03-06," Dr. Björn Sundström, SP (Abstract / Presentation / Visuals)
- "Development of FDMS Tools to Generate Data for Fire Safety Engineering and Modeling," Professor Marc L. Janssens, The University of North Carolina at Charlotte (Abstract / Presentation)

Session Summary

After the session, the discussion addressed several themes that serve as an effective summary. These fall under four main categories:

Need relatively simple pyrolysis models for empirical parameters and relatively cheap and reliable tests to determine these. Current wood pyrolysis models need 20-30 parameters per material.

We should recognize material science as a discipline and borrow some of their ideas (as we did from fluid dynamics) – still might get 6 or more parameters, but based on physics.

Each model now contains a handful of properties: 1. Are these models sufficient? 2. Which properties can we already measure well? 3. Where do we need to invest in better measurement methods? 4. Add all propertied to FDMS database, publish NIST monogram of measured properties. 5. How do we differentiate between charring materials and thermoplastics?

Think about the effect of fire retardants in a real fire scenario (ex. Bromine that works in the gas phase).

Field Models
Moderator: Dr. Howard R. Baum, NIST/BFRL

- "Development and Validation of a Comprehensive Model for Flame Spread and Toxic Products in Full-Scale Scenarios," Dr. Stephen Welch, Building Research Establishment (Abstract / Presentation)
- "Modeling Fire Growth and Spread in Houses," Dr. Kevin B. McGrattan, NIST/BFRL (Abstract / Presentation / Visuals)
- "Calculation Tools at SP Fire Technology," (CECOST, The Centre for Combustion Science and Technology) Dr. Patrick Van Hees, SP (presented by Dr. Björn Sundström, SP) (Abstract / Presentation / Visuals)
- "Research and Modelling Activities at VTT," Dr. Matti Kokkala, VTT (presented by Dr. Kevin B. McGrattan, BFRL/NIST) (Abstract / Presentation)

Session Summary

After the session, the discussion addressed several themes that serve as an effective summary. These fall under three main categories: under-ventilated fires, soot modeling, and pyrolysis models.

Current field models are based on one form or another of the “mixed is burnt” hypothesis. For example, the Fire Dynamics Simulator (FDS) uses a Mixture fraction variable to characterize combustion, with the option to terminate burning at a preset minimum oxygen concentration. The burning rate itself is set by the rate at which oxygen mixes into the flame zone. Models which respond more realistically to the local oxygen concentration are essentially non-existent.

Sooting tendency is another manifestation of oxygen deficiency. Currently, the soot formation rate is effectively prescribed either as a fraction of the fuel consumed locally or through a “state relation” connecting the soot concentration to the local value of the Mixture fraction. There is ample evidence, however, that the soot formation and oxidation rate processes occur on time scales that are quite similar to those associated with convective transport in fires. Simplified models of these rate processes suitable for use with models like FDS are needed. These models must represent rates observable for ``real'' materials. There was some question about the role of Halogens in these processes.

Finally, there was considerable interest in the development of “simple” pyrolysis models based on fire test data. It was argued that given the present state of knowledge, this remains the best way to characterize the ignitability and burning properties of real materials. A cautionary note that these models should be “physics based” was expressed.

Workshop Summary

During the final session of the workshop each presenter who was present was asked to provide a single impression or conclusion that they derived from the workshop. The following is a summary of these remarks.

Professor Yuji Hasemi When trying to predict fire growth and spread it is critical to consider real materials (wood and PMMA are two typical examples), real behaviors and the fire scenario.

Professor Arvind Atreya In order to develop better predictive capabilities for fire growth and spread it is critical that better models be developed for predicting the mass flux for the generation of gaseous fuels from solids. This requires a better understand of the pyrolysis processes that lead to gaseous fuel generation.

Dr. John de Ris Dr. Sundstrom's description of how small changes in conditions in a room configuration can have a large effect on the outcome of a fire was very interesting. A room fire is complicated, and we have to respect this complexity.

Professor Patrick J. Pagni Plots of heat release rate versus time for growing fires tend to have the same general shape (e.g., a t2 curve). If allowed to grow unchecked, the fire will eventually reach flashover. There exist three approaches for mitigation: 1) detection followed by intervention, 2) controlling fuels to limit fire growth rate, and 3) controlling the ventilation to limit fire growth rate. Ventilation needs to be considered because it changes the rate of fire growth towards flashover. It should be kept in mind that each of the three strategies for limiting flashover can be effective on its own.

Dr. Richard E. Lyon He seconds the comments of Pat Pagni. He feels that more effort should be given to developing a focused mission statement for the Reduced Risk of Flashover Program. As an example, when he considers fire in aircraft cabins, he wants to utilize materials that limit the fire growth and prevent flashover. What is the focus of the Reduced Risk of Flashover Program? Is the objective simply to do more research?

Prof. Charles M. Fleischmann In mitigating flashover it is important to consider human factors. In New Zealand the poor, drunk, and children are most often killed. Improving furniture can make some reduction in fire losses. Is it possible to legislate these changes? He doesn't believe cost will be a limiting factor.

Professor James S. T'ien He learned a lot and felt the workshop was worthwhile. It is obvious that computations have reached a point where they can be very useful for predicting fire growth and spread. With respect to flashover, it would be very useful to use the model to develop guidelines on how to modify material properties to reduce the chance of flashover.

Dr. Brain Lattimer 1. Test methods need to be developed that measure properties that differentiate between materials with regard to fire growth and spread. 2. More experimental data are required to validate models and confirm they are working as expected. 3. Models must be developed that engineers can routinely use. These should range from simple algebraic formulas to complicated CFD models that engineers can use to deal with the particular problem they face.

Dr. Archibald Tewarson He agrees with Pat Pagni concerning approaches for limiting flashover, but adds that not only are materials important, but that geometry must also be considered. In his experience he has noted that there is an inverse correlation between the personal comfort of a chair and its heat release rate. People generally choose comfort. How can we bring comfort to products that are not capable of initiating flashover?

Dr. Vytenis Babrauskas 1. A product cannot cause flashover if it doesn't ignite. There is a need for ignition studies. 2. Should we decide on next year's funding based on previous year's Combustion Institute volume? We have to consider real fires. It is there that we should look to find questions to that need to be answered. 3. The NIST/BFRL Fire Dynamics Simulator has reached a point in its development where it can be useful for predicting fire growth and spread.

Dr. Björn Sundström It is important to consider how the products of pyrolysis burn. Is it possible to develop models to describe this burning?

There is a need for active intervention to reduce the risk of flashover. The United Kingdom banned the use of polyurethane and this led to a decrease in fire deaths. We might look there and see why.

The single most important item responsible for flashover in homes is furniture. In general, if you tell me how big a chair is, I can tell you if it will generate a flashover. In the Gothenberg disco fire, two tons of furniture generated flammable gases that were responsible for the fire. Limiting the heat release rate of furniture would make a significant difference. When fires do occur, people must be able to escape.

Dr. Marc Janssens He agrees with Vyto's third point concerning the Fire Dynamics Simulator. Vyto's paper of three years ago said models weren't so helpful for real simulations, but now the situation is totally different. We have come a long way. If Vyto rewrote his paper today, it would likely reach a different conclusion. He thinks that we should continue along the same track. In order to determine priorities for our research, it is important to listen to the audience that Kevin has. They will tell us what is missing and what is needed to make the models more useful. With little effort the models can be expanded to make them more useful for variable fuels.

Dr. Mark A. Dietenberger Beware of wood. He feels that Kevin's assumption that 1/3 of the total energy released by a fire is loss by radiation is good estimate, but that it can be improved. Better estimates of soot yields would improve this estimation. Another area that needs attention is creeping flame spread.

Dr. Kevin B. McGrattan Even though we argue about the details, there is general agreement that six or so parameters are required to adequately model flame spread. Measuring these parameters for a wide range of fuels and making the data available to the community would help greatly. There is a critical need for experimental data.

Dr. Stephen Welch He is in general agreement with Kevin. He is encouraged that it will be possible to use material properties to develop models that are capable of predicting useful things.