Mathematical Modeling of FIRES

J. R. Mehaffey
editor

Mathematical Modeling of Fires

J. R. Mehaffey, editor

Peer Review Policy

Each paper published in this volume was evaluated by three peer reviewers. The authors addressed all of the reviewers' comments to the satisfaction of both the technical editor(s) and the ASTM Committee on Publications.

The quality of the papers in this publication reflects not only the obvious efforts of the authors and the technical editor(s), but also the work of these peer reviewers. The ASTM Committee on Publications acknowledges with appreciation their dedication and contribution of time and effort on behalf of ASTM.

Foreword

This symposium on Mathematical Modeling of Fires and Related Fire Test Methods was presented at New Orleans, Louisiana, 3 December 1986. It was sponsored by ASTM Committee E 5 on Fire Standards. J. F. Mehaffey, Institute for Research in Construction, National Research Council of Canada, Ottawa, Ontario, Canada, served as chairman of the symposium and as the editor of this publication.

Contents

Overview

Advances in fire science and engineering coupled with ever improving computer technology are spawning the development of sophisticated mathematical models. The last decade has witnessed the introduction of several computer fire models which purport to predict the course of a fire in a room from ignition through to extinguishment. Other models have been developed to predict the spread of smoke and fire from the room of origin throughout a building. Fire modeling offers the promise of providing a methodology for predicting for the first time whether the active and passive fire protection measures employed in a building perform their intended function (for example, permit for sufficient time for occupants to escape). As models are continuously refined, it can be expected that they will begin to play a more central role for providing fire safety in buildings.

Traditionally, the minimum levels of life safety considered acceptable to society have been spelled out in building codes. Requirements within such codes have been based on fire experience, research, and a great deal of engineering judgement. Fire test standards, called up in building codes, are relied upon to establish acceptable levels of fire performance for building materials.

ASTM Committee E 5 on Fire Standards has played a pivotal role in the development and maintenance of fire test standards. In view of the recent advances in fire modeling and their impact on the provision of fire safety, Committee E 5 established a Subcommittee on Fire Modeling and sponsored a symposium on the subject. It was felt that E 5 may be the appropriate Committee to develop test methods to provide input data needed to run the models.

The nine papers published herin were presented at the symposium on Mathematical Modeling of Fires and Related Fire Test Methods held in New Orleans, Louisiana on 3 December 1986. The symposium was sponsored by ASTM Committee E 5 on Fire Standards.

The paper by A. J. Fowell on page 1 reviews the background for forming the Fire Standards Subcommittee of ASTM Committee E 5 in 1985 and discusses the areas of principle interests to Subcommittee members. The Subcommittee's scope and principle tasks are defined in support of the needs for guidance on use and limitations, data, validations, and documentation.

The E. E. Smith and T. J. Green paper on page 7 describes how ASTM's E 906-83 Test Method is used to provide the basic reaction kinetic information for a mathematical model of a developing fire in a compartment. The model, which is a true predictive model, was designed to utilize experimental release rate data in a simple and straightforward manner without assumptions regarding the ideality of burning, the change in release rate with time, or heat flux to the solid surface or the plane of decomposition. The flux-time product concept, as defined and used in their model, has been tested experimentally and, for the materials checked, has shown to be a useful and reliable indicator for ignition.

H. Takeda's paper on page 21 presents a new simple model of fire growth in a compartment. The early stages in the compartment fires are modeled from the transient analysis of simple heat and mass transfer equations. Flame spread on the compartment floor, fire growth

in a compartment and flashover are analyzed. The purpose of his paper is to make a simple and reliable basis for fire modeling and to develop a user-friendly computer code.

In their paper on page 35, F. M. Galloway and M. M. Hirschler introduce a model on mass transfer and decay of hydrogen chloride. Their model has been formulated to be generic enough to be used for scenarios different from the one in which the experiments were carried out, and can be incorporated into more comprehensive fire hazard models. The significance of their model is that it can predict hydrogen chloride decay in a real fire scenario.

The paper by B. M. Cohn on page 58 details a fire loss modeling code for industrial facilities so that they can predict how far an accidental fire will spread in an industrial complex under the most probable adverse conditions and under the worst foreseeable conditions. The model he uses, called UNIFIRE, is site specific. It consists of numerous subroutines, each capable of analyzing the probable contribution of site-specific factors in a fire event, and of a main program that organizes all of the fire prediction data and develops a unified evaluation of the fire threat at that facility.

The P. J. Pagni, et al. paper on page 68 identifies several characteristic times for describing forced-ventilated enclosure fires. Using the initial properties of an enclosure and a prescribed fire heat release rate, a set of appropriate times for hazard evaluation can be calculated. Their paper proposes, defines and tests three times, characteristic of the histories of the mass of gas in the room, the energy in the room, and the response of the enclosure walls.

V. Babrauskas and G. Mulholland (on page 83) discuss the development of optical and gravimetric soot measuring techniques for the cone calorimeter. Smoke and soot production data have been obtained in the cone calorimeter for some reference materials and for actual furnishings. According to Babrauskas and Mulholland, these data are seen to be free of the difficulties present with the earlier methods. A small amount of full-scale data is also available; a comparison of the bench-scale data against the full-scale performance shows a promising correlation.

On page 105, W. J. Parker's paper summarizes a computer model for the heat release rate of wood and specifies its input data requirements. Some methods of obtaining these data are discussed. He describes an apparatus for measuring the heat of combustion of the volatiles and the kinetic parameters for the mass loss rate of the various chemical components of wood as a function of their degree of char. Also, the results of some of the measurements of cellulose made with this apparatus are presented.

The L. Y. Cooper et al. paper on page 116 describes a proposed benchmark compartment fire model computer code. It describes the model's characteristics and outlines the program that will lead to its development.

Dr. J. R. Mehaffey
National Research Council of Canada, Ottawa, Ontario, Canada K1A OR6; symposium chairman and editor