Communications Between the Fire Research Community and the Owner-Operators of Buildings: Proceedings of a Conference (1984)

Pages
139

Size
8.5 x 10

ISBN
0309325498

Advisory Board on the Built Environment; Commission on Engineering and Technical Systems; National Research Council

Communications Between the Fire Research Community and the Owner-Operators of Buildings

Proceedings of a Conference

Advisory Board on the Built Environment
Commission on Engineering and Technical Systems
National Research Council

National Academy Press
Washington, D.C. 1984

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purpose of furthering knowledge and of advising the federal government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

This report was prepared as part of the technical program of the Federal Construction Council (FCC). The FCC is a continuing activity of the Advisory Board on the Built Environment, which is a unit of the Commission on Engineering and Technical Systems of the National Research Council. The purpose of the FCC is to promote cooperation among federal construction agencies and between such agencies and other elements of the building community in addressing technical issues of mutual concern. The FCC program is supported by 14 federal agencies: Department of the Air Force, Department of the Army, Department of Commerce, Department of Energy, Department of Health and Human Services, Department of the Navy, Department of State, Federal Emergency Management Agency, General Services Administration, National Aeronautics and Space Administration, National Endowment for the Arts, National Science Foundation, U.S. Postal Service, and the Veterans Administration.

Funding for the FCC program in 1983 was provided through the following agreements between the indicated federal agency and the National Academy of Sciences: Department of Commerce contract no. NB83SBCA2040; National Science Foundation Grant No. CEE-82-06605/R; National Endowment for the Arts grant no. 32-4253-60074/R; and Federal Emergency Management Agency contract no. EMW-83-C-1271/C.

For information regarding this document, write the Executive Director,
Advisory Board on the Built Environment, National Research Council,
2101 Constitution Avenue, Washington, D.C. 20418.

Printed in the United States of America

Communications Between the Fire Research Community and the Owner-Operators of Buildings: Proceedings of a Co
http://www.nap.edu/catalog.php?record_id=19427

ADVISORY BOARD ON THE BUILT ENVIRONMENT
1983-1984

Chairman

PHILIP G. HAMMER, Consultant to Industry and Governments, Edgewater, Maryland, and Tampa, Florida

Members

WERNER A. BAUM, Dean, College of Arts and Sciences, Florida State University, Tallahassee
ROBERT C. DOBAN, Senior Vice President, Science and Technology, Owens-Corning Fiberglas Corporation, Toledo, Ohio
EZRA D. EHRENKRANTZ, President, The Ehrenkrantz Group, New York, New York
HAROLD B. FINGER, President, The U.S. Committee for Energy Awareness, Washington, D.C.
DENOS C. GAZIS, Assistant Director, Semiconductor Science and Technology, IBM Research Center, Yorktown Heights, New York
GEORGE S. JENKINS, President, Consultation Networks, Inc., Washington, D.C.
JOHN T. JOYCE, President, International Union of Bricklayers and Allied Craftsmen, Washington, D.C.
JOYCE LASHOF, Dean, School of Public Health, University of California, Berkeley (member until February 1984)
WILLIAM LE MESSURIER, President, TSC Corporation, Cambridge, Massachusetts
ROBERT P. MARSHALL, Jr., Vice Chairman of the Board, Turner Construction Company (Ret.), New York, New York
MELVIN A. MISTER, Vice President, Citicorp, N.A., New York, New York
DOUGLAS C. MOORHOUSE, President, Woodward-Clyde Consultants, San Francisco, California
C. E. (TED) PECK, Chairman of the Board, The Ryland Group, Inc., Columbia, Maryland
LLOYD RODWIN, Professor, Urban Studies and Planning, Massachusetts Institute of Technology, Cambridge
LOUIS A. ROSSETTI, President, Rossetti Associates, Detroit, Michigan
GEORGE STERNLEIB, Director, Center for Urban Policy Research, Rutgers University, New Brunswick, New Jersey
RALPH WIDNER, Executive Director, Greater Philadelphia First, Philadelphia, Pennsylvania

Copyright © National Academy of Sciences. All rights reserved.

CONFERENCE STEERING COMMITTEE

Chairman

J. ARMAND BURGUN, Partner, Rogers, Brugun, Shahine, and Deschler, New York, New York

Members

HOWARD W. EMMONS, Professor, Mechanical Engineering, Harvard University, Cambridge, Massachusetts
GUNNAR HESKESTAD, Fire Research Scientist, Factory Mutual Engineering and Research Corporation, Norwood, Massachusetts
JOHN JABLONSKY, Vice President for Engineering, American Insurance Association, New York, New York
ROLF H. JENSEN, President, Rolf H. Jensen and Associates, Deerfield, Illinois
RICHARD P. KUCHNICKI, Executive Director, Council of American Building Officials, Falls Church, Virginia
VINCENT A. MEGNA, Head, Engineering Department, Lyles, Bissett, Carlisle, and Wolf, Falls Church, Virginia
ANTHONY R. O'NEILL, Vice President, National Fire Protection Association, Quincy, Massachusetts
J. KENNETH RICHARDSON, Codes and Standards Group, National Research Council of Canada, Ottawa, Ontario
JAMES D. STILLWELL, Manager, Design and Construction, United Technologies Corporation, Hartfor, Connecticut

Liaison Members from the Federal Construction Council

JONAS MOREHART, Senior Fire Safety Engineer, Department of Health and Human Services, Washington, D.C.
HAROLD E. NELSON, Group Leader, Center for Fire Research, National Bureau of Standards, Washington, D.C.
RICHARD RICE, Assistant Director for Fire Protection Engineering, Naval Facilities Engineering Command, Alexandria, Virginia
F. MARIO SABA, Senior Mechanical Engineer, U.S. Postal Service, Washington, D.C.
JACK E. SNELL, Director, Center for Fire Research, National Bureau of Standards, Washington, D.C.

Liaison Members from the State and Local Government Public Facilities Council

C. SUTTON MULLEN, Deputy Director for Building Regulation, Commonwealth of Virginia, Richmond
HOWARD H. SUMMERS, State Fire Marshall, Commonwealth of Virginia, Richmond

ABBE Staff

JOHN P. EBERHARD, Executive Director
HENRY A. BORGER, Program Manager
KATHLEEN ALMAND, Consultant
ROBERT BLAKE, Consultant
LENA B. GRAYSON, Secretary
DELPHINE D. GLAZE, Administrative Secretary

CONTENTS

PREFACE vii

CONFERENCE SUMMARY ix

FIRST SESSION: IDENTIFICATION OF THE COMMUNICATIONS AND INTERACTION GAP 1

The View of an Owner-Operator in the Public Sector
Chin Fun Kwok 1
The View of an Owner-Operator in the Private Sector
James D. Stillwell 7
The View of a Researcher
John L. Bryan 11
The View of a Designer
Ralph T. Rowland 19
The View of a Regulator
Charles M. Decker 25

SECOND SESSION: THE STATE OF FIRE RESEARCH 29

How Fire Research Programs Are Formulated
Jack E. Snell 31
Content, Availability, and Use of Fire Research at the State of the Art
Howard W. Emmons 45

THIRD SESSION: POSSIBLE WAYS OF BRIDGING THE COMMUNICATIONS GAP 49

Credible Engineering Methodologies
Harold E. Nelson 51
The Code Development and Writing Process
Lorne W. Gold and J. Kenneth Richardson 97
The Economics of Research and Funding as a Driving Force
Robert H. Barker 107
Organizations as a Communicating and Coordinating Mechanism to Bridge the Communications Gap and as a Means of Causing Direct Interaction
Jack C. Sanders 111
The Enhancement of the Professional Quality of People Involved in Building Fire Safety
David A. Lucht 121

PREFACE

The Conference on Communications Between the Fire Research Community and the Owner-Operators of Buildings was held on November 9-10, 1983, at the National Academy of Sciences, Washington, D.C. It was sponsored by the Advisory Board on the Built Environment (ABBE) and two of its councils, the Federal Construction Council and the State and Local Government Public Facilities Council, and was organized by a specially appointed steering committee. This publication includes the papers presented at the conference as well as a summary of the proceedings (which was delivered at the close of the conference but is presented first in this document as a service to the reader). The conference was attended by persons from a variety of public and private institutions.

The conference was designed to explore methods of improving the communication links between the fire researchers in public and private research organizations and the managers of organizations responsible for the design, production, and operation of public and private buildings. It was based on the hypothesis that a large communications gap presently exists between the fire research community (whose purpose is to produce new knowledge and improved techniques) and those who are responsible for creating and managing buildings, and that the existence of this gap is an impediment to the enhancement of fire safety in buildings.

The conference organizers recognized the contribution to improved fire safety that the building code community provides and the importance that owners place on getting fire safe designs from the fire safety engineer. They believed, however, that although codes are a method of institutionalizing safety research results, they are only an indirect link between the owner-operator and the research communities. Another indirect link is provided by the fire safety engineer who knows the work of the research community and reflects it in his advice to the owner. However, there is good reason to believe that everyone would benefit from more effective communications between the researchers and the owner-operators. The Steering Committee knows that there are barriers to producing effective linking mechanisms, but they also know that the incentive of improved conditions for all of the users of public and private buildings can help to stimulate an interest on both sides in finding better ways to share their knowledge and concerns.

CONFERENCE SUMMARY

John P. Eberhard
Executive Director
Advisory Board on the Built Environment
National Academy of Sciences, Washington, D.C.

J. Armand Burgun, Partner, Rogers, Burgun, Shahine, and Deschler, began the conference by restating the hypothesis that there is a communications gap between those who do research in the fire field and the owners and operators of buildings. He noted that in the past, buildings were made of local materials by local labor with a variety of skills but that today most buildings are the end product of a system that is more complex than the one used to build an aircraft carrier.

IDENTIFICATION OF THE COMMUNICATIONS AND INTERACTION GAP

Chin Fun Kwok, Associate Director for Engineering,, Veterans Administration (VA), indicated that the VA has a large, technical staff and an advisory committee with qualified fire engineers on both, which enables the VA to access research knowledge directly. He explained that the VA also supports research that can provide responses directly to the agency's unique fire research problems. James Stillwell, Manager of Design and Construction, United Technologies Corporation, said that private owner-operators vary in size but share concern for having safe buildings that preserve the regulations (and, thus, prevent litigation), maximize their return on investment, and help them to avoid adverse publicity associated with fire-related disasters. John Bryan, Chairman, Fire Protection Engineering, University of Maryland, pointed out that there needs to be effective transmitters and receivers operating at the same frequency if the results of researchers (who he characterized as "lone rangers" out to save lives) are going to effectively communicate with the owner-operators (who are out to maximize the effectiveness of their investments). Ralph Rowland, Director of Architectural Research, Fletcher-Thompson, Architects and Engineers, indicated that the professional design community, in the process of designing a building, establishes the design parameters of the building's performance which will, by intention or by default, affect fire safety. He explained that the design therefore tends to rely on building codes as reservoirs of human knowledge (as interpreted by code officials) that will assure his clients that they are obtaining safe buildings. Charles Decker, Chief, Bureau of Code Enforcement, State of New Jersey, pointed out that the regulatory process is changing along with the rapid technological changes in other sectors of society and that it now must be managed in a timely manner that provides predictable results. The courts, he stated, need to be assured that regulations are in the public interest, which means that they must be firmly based on knowledge (rather than opinion).

THE STATE OF FIRE RESEARCH

Jack Snell, Director, Center for Fire Research, National Bureau of Standards, made it clear that significant changes in the incidence of fire losses will not result from incremental (as contrasted to substantial) investments in fire research and that any significant increase in the knowledge base is likely to change the processes of design for fire safety, the education of professionals in the fire field, and the fire management system in general. Howard Emmons, Professor, Mechanical Engineering, Harvard University, provided a graphic example of how fundamental knowledge grows through the research process into a complex understanding of fire events. This understanding, he explained, can be communicated effectively only by being incorporated into computer programs able to handle the large data bases and calculations needed for good simulations of building safety performance.

POSSIBLE WAYS OF BRIDGING THE COMMUNICATIONS GAP

Harold Nelson, Group Leader, Center for Fire Research, National Bureau of Standards, said that "credible engineering methodologies," which are beginning to emerge from the fire research community (after a long history of pragmatic research of the "burn and learn" type), will provide a two-way bridge over the hypothetical gap as soon as verification efforts begin to make possible a detailed engineering model of building fires. Lorne Gold, Associate Director, Division of Building Research, National Research Council of Canada, in describing the relationship of building codes in Canada to fire research knowledge, noted that the owner-operator lacks a coherent community to serve as the focus for communication. He suggested than an institutional arrangement for that purpose needs to be created and that such an arrangement would facilitate the work of the fire engineering and code communities in creating a "knowledge system." Robert Barker, Professor, School of Textiles, Clemson University, poined out that fire research encompasses more than fire models and fire testing (e.g., it includes materials sciences) and that the policy decisions used for allocating research funds determine, in large measure, how the results of the research will be made available--either in the private sector or the public sector. Jack Sanders, Fire Marshall, State of Oklahoma, explained that attention should be given to institutions that can fill the "middleman" role between the researcher and the owner-operator. He noted that institutions such as the National Fire Protection Association, American Society for Testing and Materials, American National Standards Institute, National Safety Council, and National Academy of Sciences, which are interdisciplinary in nature, can serve in this way. David Lucht, Vice President, Firepro Inc., indicated that the new conceptual tools emerging from the fire research community dictate that educators reshape their programs to provide graduates with greater analytic skills. He noted, however, that the educators still lack the appropriate textbooks.

SYNOPSIS

A general consensus of how terms were to be understood seemed to emerge from the conference. It was generally believed that research produces knowledge and technology, some of which is fundamental and some ready for application by technically competent people and that specific problem-solving work should be called "consulting" or "management services," not research. Routine testing also was not considered to be research in the sense understood here. Thus, the basic goal is to provide mechanisms for communicating to the owner-operator the knowledge and technology emerging from research.

It also was accepted that owner-operators make private or public investments in facilities design and construction to house human activity, that they want these facilities to be both safe and good investments, that the public process of regulations requires owners to provide facilities that are safe, that the courts assure that the owners and their consultants act in a responsible manner, and that the press serves to publicize any dramatic failures. Therefore, there is enormous motivation for supporting the creation and extension of knowledge and technology related to fire safety--both publicly and privately--and that government should be made aware of these needs. Once this knowledge and technology are created, it can be communicated to the owner-operator community in the following ways:

1. By ensuring that there are knowledgeable people to serve on the owner-operator's staff and competent fire safety consultants.
2. By producing readable reports (probably not written by the researcher) for publication in journals read by the owner-operators and their staffs.
3. By having presentations made at professional society meetings.
4. By holding joint professional society meetings.
5. By incorporating fire research programs internally in the owner-operator's organization or by providing for direct support of research by others.
6. By incorporating research results into new products available for use by the owner-operator in their facilities (e.g., control devices).

FIRST SESSION

IDENTIFICATION OF THE COMMUNICATIONS AND INTERACTION GAP BETWEEN OWNER-OPERATORS AND THE FIRE RESEARCH COMMUNITY

THE VIEW OF THE OWNER-OPERATOR IN THE PUBLIC SECTOR

Chin Fun Kwok
Associate Director for Engineering
Veterans Adminstration, Washington, D.C.

I am here to present the view of an owner-operator. The Veterans Administration (VA) is unique in the sense that it is the owner, operator, designer, inspector, and researcher. It has a staff of 100 architects, 100 engineers, and 5 fire protection engineers concerned with the design and construction of VA facilities as well as a staff of 500 hospital engineers and 35 fire safety engineers involved in keeping VA facilities in operation. The VA also has a research staff consisting of five engineers who handle research projects that are awarded to private researchers and the National Bureau of Standards (NBS). In addition to these technical personnel, the law requires the Administrator of Veterans Affairs to appoint an Advisory Committee on Structural Safety on which serves at least one architect and one structural engineer who are experts in fire, earthquake, and other natural disaster resistance. The current committee includes such eminent people as Armand Burgun, Richard Stevens, Mete Sozen, and Roy Johnston.

As a hospital owner-operator the VA has an obligation to provide a fire safe environment for the patients who are in residence for various periods during their convalescence. The fire safety built into VA hospitals must be practical and proven. While pure research is of great importance to the scientific community, VA research projects serve only to test our fire safety designs and to demonstrate the practicality of these designs for use in the construction of VA facilities.

VA staff members serve on committees of such organizations as the National Fire Protection Association (NFPA), American Society for Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), and American National Standards Institute (ANSI). The VA has adopted various codes including the NFPA and the Uniform Building Codes, and it depends on public information as provided by Underwriters Laboratories (UL), ASTM (formerly the American Society for Testing and Materials), ANSI and others in the design of its facilities. When the information is not available, the VA funds a research project and gives it to the NBS or other researchers. Some typical research projects that the VA has been involved with that solved specific problems are as follows:

1. Around 1972--Fire-burn of San Antonio, White River Junction, type of suspended ceiling. The study indicated the heat sink/smoke capability of the large interstitial space and high ceiling.

2. 1973--First study on alternate ways of smoke control. Findings were that heating, ventilating and air-conditioning (HVAC) systems could control smoke.

3. 1978--VA, ASHRAE, and NBS development of a manual for the design of smoke control systems. This manual has just been published by ASHRAE.

4. 1980--VA and NBS study of pressurization of elevator shafts. The problem is greater than anticipated and the project is continuing.

5. 1980--NBS fire test to determine the hazard level and behavior characteristics that smoke (from a fire in patient bedroom) would have as it penetrates suspended lay-in acoustical tile ceilings. The test showed that suspended ceilings were not a significant problem and that smoke penetrating to space above the ceilings would significantly reduce the smoke concentration in occupied space below.

6. 1983--NBS fire tests of two types of walk-on platform assemblies of the VA building system to determine the fire rating characteristics of structural floor-ceiling assemblies and walk-on platforms. The findings will be available by December 1983.

7. 1983--Testing of engineered smoke control systems. It was found that duct smoke detectors are not reliable and the VA has since changed its design criteria to connect the fan operation to the sprinkler water flow switch.

All owner-operators including the VA are interested in cost savings. They are interested in saving dollars in the design, construction and operation costs of their facilities. These cost savings, however, are secondary to providing a fire safe facility as far as the VA is concerned. Research can provide cost savings, and when research does something in this area, the owner-operator listens very carefully to what the researchers have to say. There is no communication gap for this type of cost saving information. The owner-operator sees the carrot at the end of the stick as a major cost savings and develops an interest in the research work.

Major fires and large losses or multiple deaths also attract much attention to the fire safety field. Here the owner-operator seeks out the researcher to conduct tests to determine whether his building is in the same category as the one that just suffered a large loss. The sensationalism of the large loss gets the attention of all including the code committees who may have to change the codes to prevent a similar tragedy. When these large fires occur, laws are usually changed or new laws are passed that affect the owner-operator and require additional fire protection or life safety features in buildings.

We in the VA have been involved in one pure research project. We build fire resistive hospitals that have a light hazard occupancy and then we fill them with various combustible furnishings. These funishings include various plastic materials and upholstered furniture. Other government agencies were interested and a joint research project was launched to assess the hazard of these furnishings and to try to come up with standards on interior furnishings. This research project has been going on for several years and is not complete at this time. More questions were raised by this project than were answered. Important questions on toxicity and the method of measuring toxicity were raised. The NFPA has been pushing the problems relative to toxicity and used this subject as the theme of last year's annual meeting.

The results of fire research often are printed in publications that have limited audiences such as magazines on fire protection. This information should be published in magazines that owner-operators or management personnel normally read. Another suggestion is to present papers on fire research at meetings of such professional groups as ASHRAE or the American Society of Hospital Engineers. What I am really suggesting is that there is a need to widen the area to which fire research information is disseminated to close the gap in communications between the owner-operator and various research groups.

THE VIEW OF AN OWNER-OPERATOR IN THE PRIVATE SECTOR

James D. Stillwell
Manager of Design and Construction
United Technologies Corporation, Hartford, Connecticut

The hypothesis that a large gap exists between private owners and fire researchers requires a definition of the "private owner," an examination of the objectives of the owner, and a review of the legal and economic requirements imposed on the project process.

THE PRIVATE OWNER

Private owners range from individual persons who own a single building to the multinational corporations that own thousands of buildings and have "in-house" facility staffs that develop the design, build the project, and operate the facility. Private owners built over 685 million square feet of office, store, commercial, and manufacturing space in 1982 at a cost of $37 billion. Some companies such as Tishman Real Estate and Construction and Marriott Corporation have their own "in-house" research operations that provide both public and proprietary research.

Among the larger companies is United Technologies Corporation (UTC). It is the seventh largest manufacturing company in the United States and it consists of diverse operations such as Otis (elevators), Carrier (heating, ventilating, and air conditioning equipment), Sikorsky (helicopters), Pratt and Whitney (jet engines), Mostek (microelectronics), Essex (wire), Inmont (paint), Hamilton Standard (controls), and various smaller operations. The building activities of the company consist primarily of office, manufacturing, and warehouse facilities including over 2500 buildings and 80 million square feet.

UTC manages its fire protection through a central corporate coordinator who manages the process of providing the most cost effective, state-of-the-art fire protection system within each of the UTC operations. This activity includes review of all building designs, review and management of the insurance requirements (which are normally the first stringent requirement), and direction of the loss-prevention program for the corporation. UTC, unlike most companies, has its own fire deparptment at its major sites staffed with trained firefighters and fire prevention personnel.

Fire prevention for operations such as Sikorsky Helicopters requires close daily working relationships between the corporate insurance carrier and UTC's fire protection managers. The potential high risk of a fueled helicopter undergoing testing presents unique requirements not covered by codes and, therefore, requires a close relationship between UTC's fire protection personnel, insurance carriers, and researchers. However, this is a unique situation that does not represent the condition for an average owner-operator.

The private owner discussed in this paper is neither a single individual with one building nor a multinational corporation with thousands of buildings but an owner who is incorporated and owns approximately 10 buildings with a total square footage of 500,000. They do not have a comprehensive in-house staff but secure the necessary services for design, construction, and operation of buildings from outside consultants or companies.

OWNER FIRE PROTECTION OBJECTIVES

The owner's typical objectives are important to review since they influence the relationship of the owner to his building team and to society, which imposes legal controls on his projects.

First, they do want to provide safe facilities--real and perceived. Second, preservation of the real estate and equipment asset is extremely important. It generally represents an income producing system and, therefore, must be kept in operation to produce the required income to meet mortgage and operational costs and profit objectives. Third, they do want to meet building codes and other legal requirements imposed on their operations. Fourth, maximization of their return on investment is extremely important. This means lower building costs, reduced operating costs, reduced insurance costs, and increased potential to be more competitive in the market place as well as increased profit potential. Fifth, adverse publicity affects the value of the company's stock and may reduce sales, shorten the life of a product, and reduce profits. Avoiding adverse publicity may be more important than constructing buildings to meet specific code requirements (which may be out dated).

HOW DOES THE SYSTEM WORK FOR THE AVERAGE OWNER?

The fire protection project flow chart presented in Figure 1 shows the normal activity relationships for a project. Note that the work tasks are delegated by the owner to consultants for several reasons:

1. Technical expertise availability elsewhere--normally not "in-house."
2. In-house staffing is not economical due to varying work volumes.
3. Legal requirements for building design certification requires consultants.
4. Construction tradition.

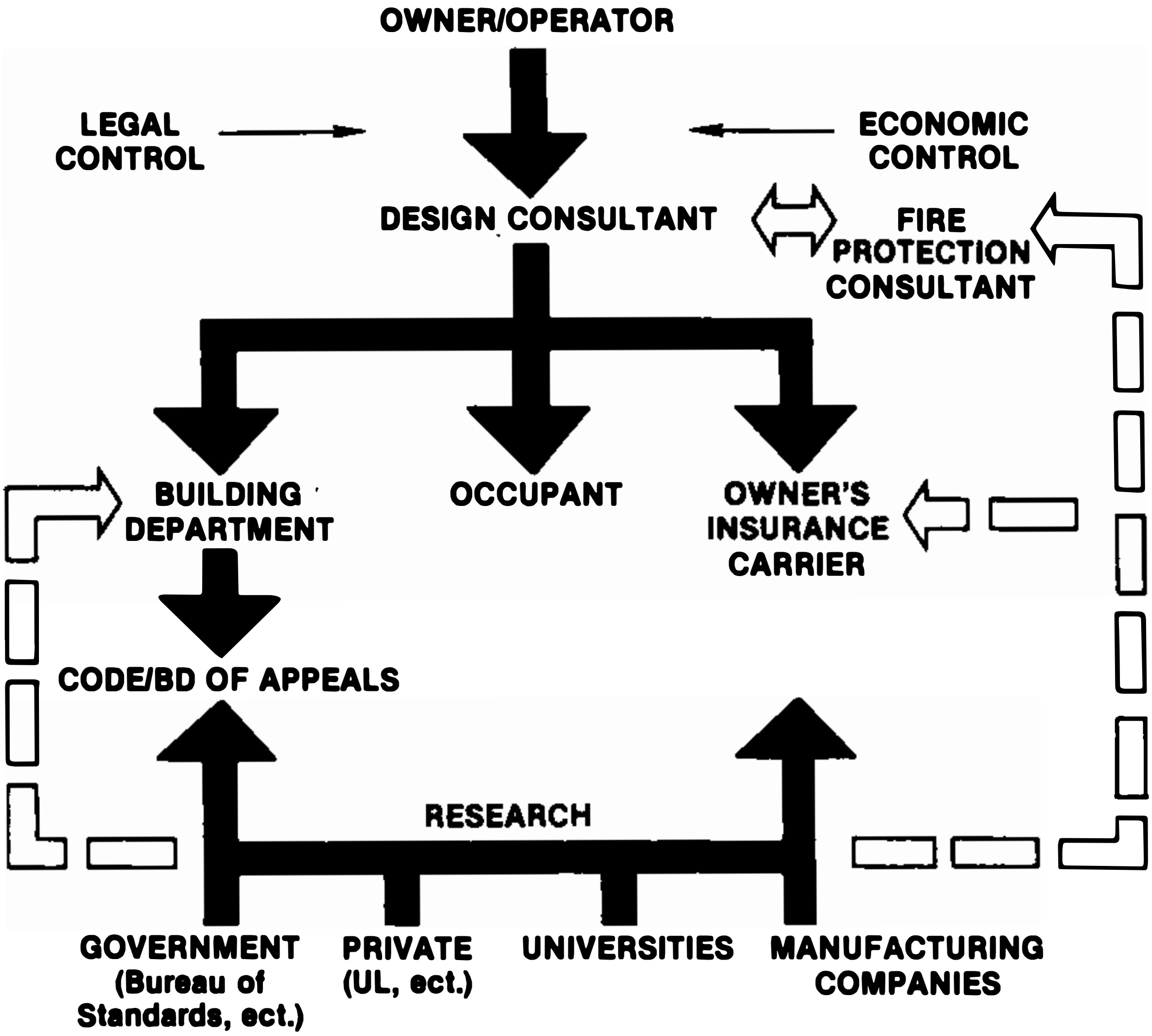


FIGURE 1 UTC fire projection flow chart.

Direct contact between the owner and the insurance carrier occurs due primarily to economic considerations. Some direct contact also occurs between the owner and the product manufacturer's research arm, again for economic reasons. For example, such companies as Owens-Corning Fiberglas Corporation with its large corporate research center can provide structural, fire, energy, and constructability research results directly to the owner. This link benefits Owens-Corning in increased sales and the owner in securing cost-effective systems.

However, direct links between the owner and government or institutional researchers do not exist. This is primarily due to the lack of direct economic contact between the parties and the traditional gap between private enterprise and government agencies.

PRIVATE OWNERS NEED DIRECT CONTACT

In reviewing the original five owner objectives, it becomes apparent that a closer relationship with researchers would be beneficial. First, safer buildings would be created by linking owner needs directly to research activities. For example, existing requirements in open, closed, and multistory office buildings might be modified by direct owner involvement. Other areas of concern include toxicity, compartmentalization, smoke control and management and communications. Second, any research that would improve the preservation of a corporate asset would be beneficial. Third, building code and legal requirements can be influenced by direct involvement of the owner in such matters as innovative configurations and new materials. Fourth, maximization of the return on investment certainly could be enhanced by development of more economical and cost-effective products and systems and elimination of antiquated requirements. Fifth, direct research that would eliminate adverse publicity caused by disastrous incidents would be welcome particularly when projects constructed to meet codes experience a disaster due to use of out-dated technology or improper operation.

CONCLUSION

A direct relationship does not now exist between the owner and the research community. Bridging the gap would be helpful to the owner financially. However, the method of bringing the owner and his needs in direct contact with the researcher and his expertise is not simple and, in many cases, is not financially feasible. The owners also do not know who the researchers are or what activities are planned or under way.

One method of linking the two groups together would be the pooling of financial resources by several owners in order to establish sufficient funding for use by both private and institutional researchers. A good example of this technique is the office productivity research program developed by the Buffalo Organization for Social and Technological Innovation (BOSTI) and funded by several corporations and the federal government. Of particular interest is the role that BOSTI played in creating the project as a "developer," marketing the potential benefits of the research, and soliciting corporate financial support--a role that could also be played by the fire research community.

THE VIEW OF A RESEARCHER

John L. Bryan
Chairman, Fire Protection Engineering
University of Maryland, College Park

The program for this conference program contains the following statement: "However, there is good reason to believe that everyone would benefit from more effective communications directly between the researchers and the owner-operators." Obviously, effective communications are the means for the sharing of information, concerns, concepts, ideas, and opinions. We should not forget that this conference is essentially a communication means and, hopefully, an effective means; however, that judgment will be an individual one determined at the time of adjournment. I would therefore like to modify the title of this presentation from: "The View of The Researcher" to "The View of A Researcher." The opinions to be expressed here are entirely personal and should not be attributed to any other members of the research, fire research, or academic communities.

COMMUNICATION

Obviously, for communication to be effective there must be both a transmitter of the message and a receiver of the message. These components must be connected into the same system or interconnected between systems and, if involving a wireless type of communication, they must be on the proper frequency. It appears that the lack of communication between the researcher and the building owner-operator may be due to the researchers and the owner-operators not being involved on the same frequency or not even connected into the same system. We have all had the experience of attempting to convey information, and although we believe we are effectively transmitting the message, it does not appear to be received or even perceived by the intended receivers. We may be observing an example of this phenomenon at this very moment in this auditorium.

The concept that may be most important is the following: For communication to be effective, there must be a receptive attitude and a perceived need to receive the content of the message. I am not convinced that owner-operators of buildings have an attitude that would be receptive to most of the reports presented at the 1983 Annual Conference on Fire Research at the Center for Fire Research at the

National Bureau of Standards. As an example, examine a typical report, "Effects of Material Properties on Burning and Extinction-Fires on Vertical Fuel Surfaces (National Bureau of Standards, 1983, p. 44). It is apparent that building owner-operators would not perceive this report as pertinent to their building problems.

FIRE RESEARCH REPORTS

A fire research report usually is a detailed, specific description of the hypothesis of the study, the study procedure, and the research results with an identification of the preceding research leading to the study and the hypotheses for additional research. Thus, fire research reports like most research reports are primarily prepared for the research community and research funding agencies. It should be apparent that the most effective means for continuing the communication gap would be to take fire research reports prepared for the research community and distribute them to building owner-operators or their organizations.

Fire research reports need to be interpreted and, in a sense, translated into a form that is compatible with the attitudes and interests of building owner-operators. According to the type of fire research study involved, such an interpretation may be a relatively uncomplicated process. The Ft. Lauderdale evaluations of polybutalene plastic pipe sprinkler systems with quick response residential sprinkler heads were effectively reported by Cote (1983). However, it should be noted that this research project was designed for effective communication of the research results to the sponsors of the project, which included building owner-operators.

Another approach is to analyze an engineering evaluation report of a fire incident and explain the fire dynamics involved in the fire incident in relation to the established principles and parameters found in fire and combustion research studies. Emmons (1982) used this technique most effectively with his analysis of the fire and smoke spread in the Beverley Hills Supper Club fire.

The medium of the communication is an important consideration and one should not expect building owner-operators to have access to the fire research literature or periodicals including the Sixth Annual Conference on Fire Research (Cherry, 1982), The Journal of Heat Transfer, Combustion Science and Technology, Combustion and Flame, Fire Technology, or even the Fire Journal.

The provision of translated and interpreted fire research results can be more effectively communicated when they are presented in periodicals oriented to the attitudes and interests of building owner-operators. As an example, the article by Morehart (1983) entitled "Fire Research Can Lower Health Care Costs" appeals to the interests and attitudes of health care administrators. More important, however, this information was accessible to them since the article appeared in the American Health Care Association Journal.

Obviously fire researchers are going to continue to prepare their reports for the research community and the research funding agencies.

In recognition of the need for an interpreter and translator of fire research results into engineering practice, in 1980 Harold Nelson, with the Society of Fire Protection Engineers, conducted a conference at the Center for Fire Research of the National Bureau of Standards (NBS) designed to provide practicing fire protection engineers with results of fire research in a form that could be applied to empirical building fire protection problems (Nelson, 1980). This type of educational and communicative conference would appear to be one means of providing effective communications between fire researchers and building owner-operators.

To enable a better understanding of the problem of attempting to identify the communications gap between these two rather diverse populations, fire researchers and building owner-operators, it is helpful to consider some fundamental questions. Some of the most important questions are: Do building owner-operators want to communicate with fire researchers? Do building owner-operators want the fire research results interpreted for them? Does their interest in fire research correlate with their moral and legal compliance with the building and fire prevention codes through their representative design engineers and architects? In other words, do owner-operators interpret the occurrence of a fire in their building to be a financial, professional, legal, or moral threat to them as individuals and professionals?

There are, in all probability, as many various answers to these questions as there are different building owner-operators. However, my limited experience with owner-operators leads me to believe that like the accountant and the purchasing agent, the owner-operator is concerned with the financial aspects of the building. Obviously, without adequate financing to construct and maintain a building and an adequate financial return, there is no building. In other words, <u>cost</u> may be the critical variable rather than the <u>value</u> of the building or the occupants in the building.

Feller (1982), in his article on the cost-benefit effect of codes and standards, has attempted to clarify this issue. However, here we are only attempting to indicate a possible difference in professional attitude between the researchers and the building owner-operators. The attitude divergences between building owner-operators and fire researchers relative to the effective application of the fire researchers' efforts may be critical in achieving effective communications.

THE FIRE RECORD

Consider the total fire effect on society in the United States of a total 1982 property fire loss from building fires of $5.7 billion which was approximately 89 percent of the total direct fire loss of $6.4 billion (Karter, 1983). In addition, the civilian fire fatalities in 1982 consisted of a total of 6020 individuals (Karter, 1983) with 1083 of these fatalities occurring in multiple death fires in which three or more persons died (Jones, 1983). The application of effective techniques, procedures, and data, whether generated by fire research, empirical experience or communicative discussion, that would achieve a significant reduction would be valuable.

A comparison of the building fire record in relation to both the frequency of building fires, the building fire loss per capita, and the fire fatalities per 1 million persons for 1979-80 was computed by Banks (1983) for the United States and 16 other countries. The United States was second worst in terms of the frequency of building fires with a rate of 4.6 fires per 1,000 persons. First place was achieved by Ireland and the lowest rate by Japan with 0.3 fires per 1,000 persons. In relation to the direct building fire loss per capita, the United States improved in rank order to seventh among the twelve countries reporting this data. In relation to the number of fire deaths per million persons, the United States was tied for first place with Canada with a rate of 29.4.

Schaenman (1983) has indicated that he believes the enviable fire record of the European countries in relation to building fires has been achieved due to their emphasis on strict fire prevention and building code regulation. Schaenman reports that he observed more stringent codes and code enforcement than is typical in most United States cities. He also indicated the greater emphasis on enforcement of the building and fire prevention codes in the following manner (Schaenman, 1983):

> In France, builders of large, new structures pay a private company to inspect the building for code compliance. This inspection is required in order to receive a license to open. If there is a fire due to a code violation, both the builder and the inspection company are held liable.
>
> In general, European fire officers are very fire prevention oriented, and fire chiefs can function as fire protection engineers, capable of reviewing building plans and advising on safety features.

The concept explained by Schaenman relative to the utilization of a private inspection company for the occupancy inspection of the building is similar to the self-certification concept being considered currently by some U.S. cities. This concept involves the self-certification of the building plans for compliance with the building code by the architectural and design firm that originates the plans. Levy (1983) has indicated that self-certification by the design firm responsible for the building plans has certain inherent problem areas in relation to insuring the public safety. However, he does indicate that use by the building official of a third-party design firm with oversight responsibility may be an effective procedure for building departments to use to reduce the workload while not abdicating their public safety responsibilities.

Now, how does this discussion of the fire loss record of the United States, the fire loss relationship of other countries, and the role of the building official relate to our concern of improving communication between the fire researcher and the building owner-operator? The previous discussion has been an attempt to provide a possible perspective on the perceived difference in attitude between the building owner-operator, the building enforcement official, and the fire researcher.

PROFESSIONAL ATTITUDES

The fire researcher usually prefers to consider his profession as involving the study of fire phenomenon and the development of knowledge that may have an impact on the overall improvement of the understanding of the problems of fire propagation, fire ignition, smoke propagation, or even human behavior in fire incidents. Any of these may be a factor in the reduction of the acknowledged unsatisfactory record of the United States in relation to fire fatalities.

This professional attitude and concept of fire research efforts in the United States has been stated in relation to the NBS Center for Fire Research by Cohn (1982) as follows:

> For eight years, NBS Center for Fire Research has sought to expand the knowledge of the physics and chemistry of fire and to provide the technical basis for scientists, engineers, manufacturers, U.S. government agencies, and state and local fire and building code officials to improve public safety.

In a similar manner, the building owner-operator's concern with the fire problem in the United States, like that of most citizens, tends to be a reflection of his professional interests--the design, construction, and occupancy of a building. They are concerned with what fire safety is required in the building according to the legal requirements of the building and fire prevention codes and the cost of these requirements in relation to the total cost of the building. The building owner-operator rightfully expects the architect and engineering design firm to develop a building design that meets the legal fire safety requirements of the governmental jurisdiction in which the building is to be located.

CODES

What then is the role of the fire researcher and of fire research results in the development of the fire prevention codes that regulate the design of the building? Generally, it would appear that in most cases there is little input from fire research studies or fire researchers in the building or fire prevention code development process.

This lack of fire research input is sometimes due to the fact that most of the fire research results are not perceived as being directly applicable or are not developed and presented in a form that appears to be applicable. It also should be recognized that the building code development organizations are very homogeneous organizations and that unless one is a building official and a member of the code organization, there are insufficient mechanisms to provide for the introduction and acceptance of fire research results. The National Fire Protection Association (NFPA) has a standards development procedure that currently allows for the maximum public, private, and diverse input to its standards. However, this organization is currently involved with only three codes utilized in the building design process, a fire prevention code, the National Electrical Code, and the Life Safety Code (1981). Due to the concurrent individual professional interests of some of those involved, some research relative to the human behavior of individuals in fire incidents has been introduced and utilized in the development of the proposed 1984 edition of the Life Safety Code (Bryan, 1983).

The communication of fire research reports and results through the existing and proposed building and fire prevention codes appears to be a limited and inefficient means through which the building owner-operator can become familiar with fire research. However, it should be noted that code items and provisions developed from fire research would gain the attention of the building owner-operator if utilized in the code compliance design approval process. The problem of the application of fire research results to the government-developed building regulations in England has been discussed by Butcher (1983). This research involved the application of a formula for the prediction of building compartment fire resistance and the relationship of building areas and fuel load to the effectiveness of automatic sprinkler systems. Thus, it would appear that the problem of the utilization and application of fire research results into the codes is not unique to the United States.

Swersey and Ignall (1980) in an assessment of fire research in the United States from the viewpoint of public fire protection policy, have indicated that experimental research fire studies may provide information useful to public officials concerned with codes and standards as follows:

> Knowledge of how fast fires spread is the foundation for reducing fire losses through better design, detection, and suppression. Research on basic combustion phenomena, standard flammability tests, and the behavior of real fires is relevant here. The literature on the physics and chemistry of combustion does not quite provide information that is useful to policy-makers. Flammability tests are more relevant to policy questions, but it is well known that the behavior of specific materials in real fires often does not correspond to test results.
>
> The research on the behavior of real fires seems of most use to policy. In it, we have found two approaches to the behavior of real fires. The first consists of heavily instrumented burning of real and scale-model rooms and structures. The second uses data collected at real (non-experimental) fires. It attempts to overcome the large number of uncontrolled and unmeasured quantities by studying a large number of fires (usually in the thousands.)

Swersey and Ignall also have provided their assessment of published fire research based on a study of 1200 fire research reports and articles published prior to 1976. They evaluated the research relative to quantity, quality, and priority for future research. It should be recognized that this National Research Council funded study was an attempt to evaluate the research from the viewpoint of the public policy-maker concerned with the total effectiveness of fire protection for a community, not from the viewpoint of the fire researcher or the building owner-operator.

SUMMARY

This presentation has attempted to provide an opinion on the varying interests and attitudes relative to the communication of building fire protection concerns between the fire researcher and the building owner-operator. Due to the inherent and professional differences in the attitudes and interests of these two populations and the existing means of presenting fire research results, it would appear that interpreters and translators of the fire research reports are needed. Such interpretations are needed for the building owner-operator and, in addition, for the building design professionals, primarily the architects and the design engineers. A fire protection engineer with a graduate degree who has been intimately involved and immersed in both the fire research literature and a fire research study could be an optimum interpreter.

It must be recognized that the building owner-operator is the key individual for the provision of fire protection and fire safety features within the structure beyond the necessary, mandated requirements of the building and fire prevention codes. Thus, effective communication with the building owner-operator, in spite of the difficulties involved, is essential.

The successful approach utilized by Nelson (1980) in organizing with the fire researchers a dedicated conference to present significant results in uncomplicated terminology with illustrations of the practical applications or possible applications of the research results in buildings should be pursued.

The national professional organizations for the design professionals, including the American Institute of Architects, the National Fire Protection Association and the Society of Fire Protection Engineers, could follow the example of Morehart (1983) by encouraging the presentation of articles and reports that interpret and apply the fire research results to specific building occupancy and professional design situations.

In conclusion, the initiation of effective communications relative to fire research results between fire researchers and building owner-operators will require diplomatic interpreters and skillful individuals, not unlike this conference audience.

REFERENCES

Banks, Jerry. 1983. Selected international comparisons of fire loss, 1979-1980. Fire Journal 77, 1: 36-41, 61-65.

Bryan, John L. 1983. An Examination and Analvsis of the Dynamics of the Human Behavior in the MGM Grand Hotel Fire, Clark County, Nevada, November 21, 1980, Rev. Ed. Quincy, Mass.: National Fire Protection Association.

Butcher, Gordon. 1983. Expensive research results are being withheld while bureaucracy dithers. Fire 76, 936: 597.

Sonya M. 1982. Sixth Annual Conference on Fire Research, NBSIR 82-2612. Washington, D.C.: Center for Fire Research, National Bureau of Standards.

Cohn, Jeff. 1982. Firesafety research at NBS. Fire Journal 76, 6:75-79.

Cote, Arthur E. 1983. Highlight of a field test of a retrofit sprinkler system. Fire Journal 77, 3:93-103.

Emmons, Howard W. 1982. The analysis of a tragedy. Fire Technology 19, 2:115-124.

Feller, Irwin. 1982. A benefit/cost framework for assessing the impact of codes and standards on technology. Fire Journal 85. 1:63-65, 73.

Fox, Bernard H. 1964. Classes of risk. In Accident Research, Methods and Approaches. Edited by W. Haddon, William, E.A. Suchman and D. Klein. New York: Harper and Row.

Jones, Jon C. 1983. 1982 multiple-death fires in the United States. Fire Journal 77, 4:10-25.

Karter, Michael J. 1983. Fire loss in the United States during 1982. Fire Journal 5:44-60.

Levy, Robert. 1983. Self-certification of plans. AEBCO Newsletter 83-1:6-10.

Morehart, Jonas L. 1983. Fire research can lower health care costs. American Health Care Association Journal 9, 5:20-30.

National Bureau of Standards. 1983. 1983 Center for Fire Research Annual Conference on Fire Research. Washington, D.C.: Center for Fire Research, National Bureau of Standards.

National Fire Protection Association. 1981. Code for Safety to Life from Fire in Buildings and Structures. Quincy, Mass.: 101.

Nelson, Harold E., Ed. 1980. Proceedings, Engineering Applications of Fire Technology Workshop. Boston: Society of Fire Protection Engineers.

Schaenman, Philip S. 1983. International concepts in fire protection. Fire Engineering 136, 8:67-68.

Swersey, Arthur J., and Edward Ignall. 1980. What does fire research have to do with fire protection? Fire Journal 74, 1:63-74.

THE VIEW OF A DESIGNER

Ralph T. Rowland, FAIA
Director of Architectural Research
Fletcher-Thompson, Architects and Engineers, Bridgeport, Connecticut

DESIGN PROFESSIONALS AND RESEARCH

There is very little direct communication between fire researchers and design professionals. For purposes of this discussion, the term "design professionals" is defined as the great majority of architects and planners in general and specialized practice and the structural, mechanical, electrical and civil engineers who work with those architects in the design of buildings. Fire protection engineers, who are more likely to have direct contact with fire research activities, are not included in this broad definition because most buildings are designed without the specific input of their discipline.

It is important to note, however, that a significant amount of general research is related to building design and some of that is conducted by design professionals. In recent years, the subject of energy conservation has been studied intensively by architects and engineers. Firms specializing in the design of specific building types, such as schools or hospitals, have made the study of building function, occupant behavior, and social effect very much a part of their practices. But the study of fire phenomena and countermeasures has traditionally been conducted outside the design community. The results of fire research are incorporated by designers after being used as the basis for building and fire code requirements or for the testing of building components. Design professionals tend to accept such codes and tests as authoritative even though they have not participated in their development.

I believe this condition is changing or about to change. At the Architectural Research Roundtable held at the American Institute of Architects (AIA) in September 1975, fire safety was not even mentioned as a subject in need of research (AIA Research Corp., 1975). This year, however, the Architectural Research Council has listed 6 building code, fire code, and life safety topics among the 25 subjects most in need of research (Architectural Research Council, 1983).

DESIGN DECISIONS VS. FIRE SAFETY

Design professionals, usually architects, make most of the initial design decisions that affect the fire safety of buildings. Their decisions may be based on specific program requirements of building owners and operators and may be influenced substantially by the advice of consultants, but these early design choices often establish the relative safety of the resulting building under fire conditions.

Examples of such design decisions are those concerning the building's mass, configuration, height, location, structural materials, structural system, compartmentation, floor construction, heating and air conditioning systems, stairway and elevator locations, fire suppression equipment, occupancy relationships, and access roads. None of these design choices stands alone in the fire safety context, but each combines with the others to form a complex relationship that comprises the unique fire safety (or fire hazard) character of each building.

How are these decisions made? What does the designer take into account before deciding? What kind of research, if any, is involved?

It should be pointed out that architects and engineers are licensed to practice their professions by state governments primarily to safeguard life, health, and property. Each design professional, therefore, has a statutory as well as a professional responsibility to consider life safety as an element of every design decision. This consideration must be coordinated with the satisfaction of many other very important (but perhaps less profoundly critical) requirements (e.g., efficient function, occupant comfort and convenience, accessibility for the disabled, conservation of energy, durability, ease of maintenance, cost effectiveness, esthetic objectives).

Building design is a complex activity. In the real world of limited fees and compressed time schedules, most design professionals have little opportunity for research, so any efforts in that direction tend to be concentrated on the specific needs of the project at hand. These are much more likely to relate to the "state of the art" of the occupancy type or the environmental comfort system than to fire safety.

SOURCES OF FIRE SAFETY INFORMATION

Design decisions are obviously the application of the knowledge and preferences of the designer to the program of a projected building. For our present purpose, let us disregard the preference element and concentrate on the sources of the designer's knowledge, limiting our consideration to his or her knowledge of fire safety. Where does that come from?

Each design discipline learns about fire and fire safety from a different viewpoint, not unlike the classic story of blind men studying an elephant. Structural engineers learn the fire resistance of concrete, the heat absorption of steel, the weights of fireproofing materials and the fire durability of timber. Ventilation engineers study smoke and fire movement through ducts and air handling equipment. Electrical engineers are concerned about the many possibilities for ignition that may be caused by faulty design or installation.

Architects, having the prime responsibility to coordinate all design disciplines for most buildings, consider all of the engineers' concerns plus such other elements as the flammability of furniture and finishes, but they realize that their most important fire safety objective must be to provide the opportunity for a building's occupants to move quickly to safety in the event of fire. To satisfy this primary life safety objective, most architects rely heavily on applicable building and fire safety codes as interpreted by the enforcing officials who have jurisdiction in the place where the building is constructed.

Architects learn very little about fire in their professional education. In most architectural schools, even the study of codes is very limited. It seems to be widely accepted that certain elements of professional training must be deferred to the apprenticeship period between graduation and licensing because the academic period is barely long enough to learn basic professional skills. Code theory and practice, although touched on briefly in the academic years, are usually among the deferred elements.

For practical purposes, fire safety requirements are learned by the design professional in the early years of employment by applying building and fire safety codes to specific design problems. By the time he or she takes the professional licensing examination it is probable, though not necesarily certain, that the candidate has had sufficient exposure to code practice to undertake independent practice. The likelihood of direct communication with the fire research community in the apprenticeship period is very remote.

The next factor contributing to the absence of direct communication is the way building design is practiced, at least by architects. Of the members of the American Institute of Architects, for example, 60 percent work as independent single practitioners and another 24 percent work in offices with three or fewer professionals. Although some of the other 16 percent practice in much larger organizations, it is obvious that a substantial majority of practicing architects are not in a position to commission or conduct fire research, even if they were able to define specific research needs.

THE CODE COMMUNITY

Between the designers and the researchers is the code community. Anyone who attends public hearings of the model code organizations soon becomes aware that the results of fire research are sometimes used to support proposed code changes. The effect, however, is uneven; most code provisions have evolved from a nonscientific base and reflect opinions based on necessarily limited samples or models. These widely accepted building regulations may someday complete the transition from an empirical to a scientific basis, but there is little reason to believe that it will happen very soon. Meanwhile, the designers, the code community, and, in fact, the entire building industry must expect to cope with hybrid rules.

The code community is the principal intermediary between designers and researchers. A few design professionals participate directly in the code process as building officials or code specialists, but most designers interface with the fire research community through local building and fire officials who are presumed to be sufficiently informed of the rationale for code requirements to transmit that information to the user.

POTENTIAL FOR THE FUTURE?

The system works--but not as well as it should. Architects and engineers who read of the work of the fire research community in reports of the National Bureau of Standards Center for Fire Research, for example, wonder how and when it will be possible to use in their own designs the methods being developed for computer modeling of safe egress plans or other technically sophisticated fire safety systems. Such methods seem light-years away from today's experience, which often consists of time-consuming arguments with code officials over the true meaning of building regulations.

Many opportunities are already in existence, I believe, to bring design professionals and the fire research community closer together. And there is good reason to achieve this. Design professionals should be able to identify the elements of design where research is needed so that research resources may be used to greatest potential benefit. With better communication, valuable exchanges may take place while specific research programs are in progress. In some cases, early but incomplete results may warn the design professional against erroneous assumptions.

Before offering some suggestions for closing the communications gap between design professionals and the research community, I believe it appropriate to comment on the position of the design professional in the entire chain of contact between the researchers and the owners and managers of buildings. Recognizing that there is a great range in fire safety sophistication from the owner of a small apartment house to the operator of a large teaching hospital or major industrial complex, just as there is a great range in fire safety understanding among design professionals, I believe, for purposes of this discussion, that the typical owner-operator who is the client of a design professional expects the design professional to be the nearest link in the communication chain leading to the fire research community.

RECOMMENDATIONS

With that premise in mind, and as an architect--a design professional--who happens to have developed a special interest in building safety and the regulatory process I suggest the following methods by which design professionals may become more effective links in the chain:

1. Architects and engineers must take a more active part in the code development process. This is in their own interest because building and fire safety codes are the major regulations that apply to

their life's work. Such participation will inevitably bring them into direct contact with researchers.

2. Architects and engineers must give more thought to research needs. As creative individuals, they should question any long-accepted standard that is not scientifically supported and ask for better rationale.

3. Architects and engineers must become aware of the research that has been completed or is in progress and support public funding for those programs that seem likely to benefit the quality of future building. A review of National Technical Information Service bulletins, for example, and selected reports is a practical way to accomplish this.

4. All members of the building industry must become more concerned with the quality of code enforcement. Inadequate staffing of local building and fire departments, political interference in code administration, use of building permit fees for other public expenditures, and the absence of prompt appeals processes allow misapplication of regulations, increase building costs, and violate the concept of a scientific basis for building safety.

5. Researchers should use the architectural and engineering press to inform the design professions of work in progress and conclusions reached. Most design professionals read the journals of their disciplines regularly and their attention may be attracted this way.

6. Fire reporting, wherever possible, should identify the building code (and edition) that was in effect at the time of the fire-damaged building's construction. Although this will not be practicable (nor very meaningful) for buildings more than 30 or 40 years old, it could be quite informative for more recent structures.

CONCLUSION

From the designer's viewpoint, existence of the communications gap, which is the subject of this conference, must be acknowledged. In this time of rapidly advancing building and fire technology, it would be irresponsible to allow the chasm to remain unbridged. I believe that the design professionals' consciousness of fire research is being raised. I believe the gap can be closed, and I trust that this conference will help to accomplish that objective.

REFERENCES

The Architectural Research Roundtable. A Report. Washington, D.C.: AIA Research Corporation.

Architectural Research Council. 1983. Architectural Research Priorities 1983. Washington, D.C.: The American Institute of Architects Foundation.

THE VIEW OF THE REGULATOR

Charles M. Decker
Chief, Bureau of Code Enforcement
State of New Jersey, Trenton

The central hypothesis of this conference, that there presently exists a gap between the fire research community and those who design, build, and manage buildings, is undoubtedly true on the face of it. At least we can accept this thesis as a truism for the purpose of this conference. But like all truisms, it requires some examination to determine the reasons, and some careful reasoning to decide whether there is any point to attempting to change this status. What follows is one regulator's perspective on this subject, viewed in these terms.

Regulators are often depicted as somewhat less than directly involved in "the real world." Quite frequently one of the members of the design team, the construction team, or ownership will express just such a thought, usually connected with a plea for a waiver or variation from the literal requirements of the code being applied at the time.

Although it should not be so, since the great majority of regulators have experience that is directly rooted in that "real world" (most having years of experience as contractors, architects, or engineers), there has been some truth to the charge. Notice I use the phrase "has been some truth" for the regulatory world has changed greatly in the past few years, and further change is occurring all the time.

Today, we are beginning to see regulatory systems evolve that operate on two principles: <u>timeliness</u> and <u>predictability</u>. By the first of these we mean that the users of the system should be able to depend upon it to operate in a timely manner--to produce decisions within realistic and "real world" time frames. By the second we mean that the users should expect to know in advance what is expected of them--what the code requires and how to demonstrate compliance with those requirements.

The first principle, that of timeliness, is not at issue today, depending as it does on factors such as staffing levels, staff training, and enhancement of the administration of the code enforcement system itself. The second principal, predictability, is very much connected to our topic. The concept of predictability, knowing what you have to do and how to do it, requires that the codes contain clear, comprehensible provisions which leave no doubt in either the designer's or the regulator's mind as to their meaning.

Obviously, the quality of the technical provisions of the code is dependent quite directly on the efforts of researchers. Thus if we can improve the efforts of the research community in a way that will result in higher quality code provisions, then regulators are indeed interested. The central question for regulators then is whether the topic addressed here will contribute to improving the quality of code provisions. In order to answer that question, we need to look at the history of code development.

Traditionally, regulatory codes responded to tragedies. We fixed the latch after (sometimes long after) the horse had left the barn. We relied on "body count," judgments were formed about the causes of disasters by reviewing the actual results of the incidents, and solutions were devised to (hopefully) prevent that particular disaster from recurring. Indeed, this methodology is still widely used (and useful) today, and we are continuing to look for ways to improve our ability to gather and evaluate incident data. There will always be a real need to utilize this system for some issues.

However, this system of code development is dependent on three conditions:

1. Design technique and technology development moved rather more slowly in the past than today; therefore, those solutions lasted longer and they covered a wider range of problems.
2. The news media was somewhat less given to sensationalizing disasters--and especially less given to pointing fingers (particularly at government officials).
3. Public policies were less progressive than those of today in that barrier-free access, energy conservation, and other policy concerns had not yet entered and inevitably complicated the regulatory world.

These conditions are quite obviously no longer entirely valid. The prevalence of new design techniques (e.g., the widespread use of atriums in all kinds of buildings) and the mushrooming incidence of new technologies (e.g., the use of plastic in buildings) inevitably put increasing stress on regulators to respond to the problems created by these movements.

Similarly, the tendency of the news media to sensationalize disasters and the resultant public and political responses to disasters necessitates, in most cases, that regulators be responsive to problems more quickly than was formerly expected. Thus, the regulator increasingly needs to respond to problems caused by either new design techniques or new technologies before the full range of incident investigation and documentation can take place.

The adversarial nature of the building process in this country also puts considerable strain on the regulator. It is quite often necessary for the regulator to be able to demonstrate that the code provisions which are relied upon are justified. It is necessary to assume that ultimately one will have to defend a particular provision in a court of law, or at the least, in an informal conference with one of the affected parties (designer, contractor, owner-operator). There is nothing wrong with this aspect, but it does become a factor when considering specific code provisions.

Finally, the relatively recent development of regulatory documents based on public policy decisions further strains the traditional code development process. The real need to involve all our citizens in the life of the community means, for example, that buildings must be made accessible to the disabled.

This movement, valid on its own terms, has placed additional strain on the code development process. Some would argue that life safety issues for such structures as high-rise buildings should be re-evaluated. Previous assumptions about exit flow, the need for areas of refuge, and the design of elevators and elevator shafts, among others, may need to be altered in order to provide a reasonable degree of life safety for all occupants of our buildings.

Similarly, the need for energy conservation, which arise as a policy issue, places traditional code development methodology at risk. With the development of code provisions that require greater thermal and equipment efficiency, certain fire safety provisions of the existing codes are affected.

Few would argue with the need for energy conservation, but even fewer would wish to be placed at risk by smoke, toxicity, or flame spread problems created or enhanced by the use of, for example, plastic materials. When the technological response to code provisions requiring greater thermal insulation involved increased use of plastics, the fire resistance provisions of the code were affected, and the need for research in these areas became apparent.

This review of the changing code development system allows us to identify at least one of the causes of the gap between the fire research community and owner-operators of buildings: the code development system itself. It has always proven more efficient for owner-operators to participate (when they chose to participate at all) in the code-writing process than in the research process. They are often more interested in the shape of the regulation than in the basis for the regulation.

In addition, the changing code development system also allows us to rephrase more succinctly the question this conference raises for regulators: Will providing for more direct contact between owner-operators and the fire research community result in better code provisions? Or, at the very least, can we be sure it will not place additional strain on the process?

At first glance, it appears that there would be no significant drawback to increased contact and that there would be several distinct advantages, not the least of which would be the prospect of increased funding for fire safety research. On the need for this, virtually everyone would agree.

However, there is a troubling side issue that must be addressed. Most knowledgeable observers would not argue with the need to act swiftly in certain critical, life safety areas, sometimes even before we have sufficient fire incidents to use to develop code provisions the traditional way. Indeed, it would, in some instances, be irresponsible to fail to act swiftly because large numbers of people can be placed at risk. Yet, most regulators believe it equally irresponsible to develop completely pro-active code provisions without valid substantiation of the need. And, regulators above all are acutely aware of the legal and policy reasons for this position.

The courts have (rightly) shown little patience with code provisions that cannot be demonstrated to fill a real need and that have little technical merit. Similarly, it may not be possible politically to sustain a code document that moves in too cavalier or sweeping a fashion. In short, there is a need to be convinced of the need for, and the technical basis of, any specific code provision before it can be fully supported.

Here then is the issue for the regulator: Assuming more direct contact between owner-operators and the research community, will the research agenda thus generated improve or degrade the quality of the codes?

To the extent that a fuller participation by owner-operators in the research system generates increased funding, it will surely have a salutory effect. Similarly, to the extent increased contact results in a better understanding by owner-operators of the technical basis of specific code issues, it certainly will be welcome. But if it results in a diversion from critically needed research we will all suffer.

We stand in real need of research in several important areas at this point. Most of us would agree we need more information on atriums, smoke handling, smoke barriers, methods of construction, methods of testing, indoor air quality, means of egress computation, and furnishings/finishes. Each of us could add to this list, no doubt.

If the enhanced contact between the fire research community and owner-operators of buildings, which is sought by this conference, does not divert us from our task of developing more soundly based code documents and does not prove to be an expensive quest for substitute methodologies that add to confusion rather than reduce it, then the support of regulators can be expected.

The regulatory system can always stand closer scrutiny and adding reasonable voices to the debate should be welcomed. It is my hope that the participants at this conference can and will do much to ensure that these voices add to the harmony.

SECOND SESSION

THE STATE OF FIRE RESEARCH

HOW FIRE RESEARCH PROGRAMS ARE FORMULATED

Jack E. Snell
Director, Center for Fire Research
National Bureau of Standards, Washington, D.C.

INTRODUCTION

In 1974, the U.S. Congress passed legislation creating a Center for Fire Research (CFR) at the National Bureau of Standards. This represented the culmination of developments over nearly 30 years to bring about intensified research attention to the nation's fire problem. In fact, in 1956 Hoyt Hottel of the Massachusetts Institute of Technology addressed the need for basic research on destructive fire (as distinct from combustion research) at the National Academy of Sciences first Fire Research Conference (National Academy of Sciences, 1956).

In short, the programs of the CFR are formulated in response to this legislation, upon analysis of fire incident statistics, following extensive consultations with many others in both the private and public sectors and careful review of our capabilities and those of others in this field.

Several points underlie much of what I have to say. First, the role of the Center for Fire Research is primarily one of conducting fundamental research in fire. Thus, not only is CFR just one of many organizations with a commitment to improving our country's very poor fire safety record but also the scope of our activity is limited very narrowly and precludes a direct role in fire loss reduction.

Second, substantial reductions in U.S. fire losses and, particularly, in the costs of fire protection will not follow simply from a continued succession of small incremental refinements in traditional fire safety practice. Rather, new understanding is needed to establish the technical and scientific basis for vastly more effective fire protection practices.

My academic roots are in aeronautical engineering. Also for most of the past decade I was directly involved in research to develop and deliver energy management programs and energy conservation measures for buildings, industry and communities. I see exciting parallels between these fields and fire protection engineering. Specifically, fire protection practice is now where aeronautical engineering was in the mid-1940s and the type of technical basis that enabled the energy conservation measures of the 1970s is only now being developed in the fire field.

Third, the timing of this conference is crucial. In 1974 our government made a commitment to a national program of fundamental research in fire as one of several essential measures in addressing the nation's fire problem. It is now over 10 years since America Burning (National Commission on Fire Prevention and Control, 1973) was published and nearly 9 years since passage of the Federal Fire Prevention and Control Act (Public Law 93-498, October 29, 1974). The Administration is committed to a federal role in fundamental research. At the same time, it is seeking to identify those programs in the federal government that should be the responsibility of the private sector or of state or local governments and to implement appropriate changes. In programs involving applied research or technical change, joint efforts or collaborations may be most effective. Therefore, it is highly appropriate to examine now, from the viewpoint of an important set of users and beneficiaries of our work, what additional efforts in behalf of building owner-operators may be needed and appropriate means for getting them done.

By way of overview, I will first say a few words about the Center for Fire Research and then elaborate on how our research programs are formulated, Finally, I will suggest four issues for further consideration in this forum on the effective direction and use of fire research in meeting the needs of building designers, builders, and operators.

CENTER FOR FIRE RESEARCH

The creation of the Center for Fire Research at the National Bureau of Standards (NBS) in 1974 following passage of the Fire Prevention and Control Act marked a major turning point in the course of fire research at the Bureau. Up to that time, most of the Bureau's fire-related effort had been directed to problem solving, that is, addressing major fire problems of the day through the application of state-of-the-art scientific knowledge and technology. These efforts were undertaken typically in collaboration with organizations such as the Underwriters Laboratories, state and local governments, the National Fire Protection Association, and Factory Mutual Research Corporation. The Fire Prevention and Control Act of 1974 authorized NBS to pull together a highly specialized team of scientists and engineers to establish a new basis of understanding of fire-related phenomena.

The Center for Fire Research operates on roughly $9 to $10 million of annual funding. About $6 million of this is directly appropriated through the National Bureau of Standards. The remaining $3 to $4 million is provided by other agencies of the federal government. Figure 1 depicts the basic pattern of funding sources and expenditures for the Center. Note that one-third of directly appropriated funds are dedicated to the Grants Program (Table 1). This activity supports nearly all fundamental fire research at U.S. universities and other basic research laboratories in this country. It also provides the principal source of support for the nation's future fire scientists and indirectly supports academic fire protection engineering programs.

The research conducted by CFR for other agencies of the federal government typically extends the more fundamental research CFR funds

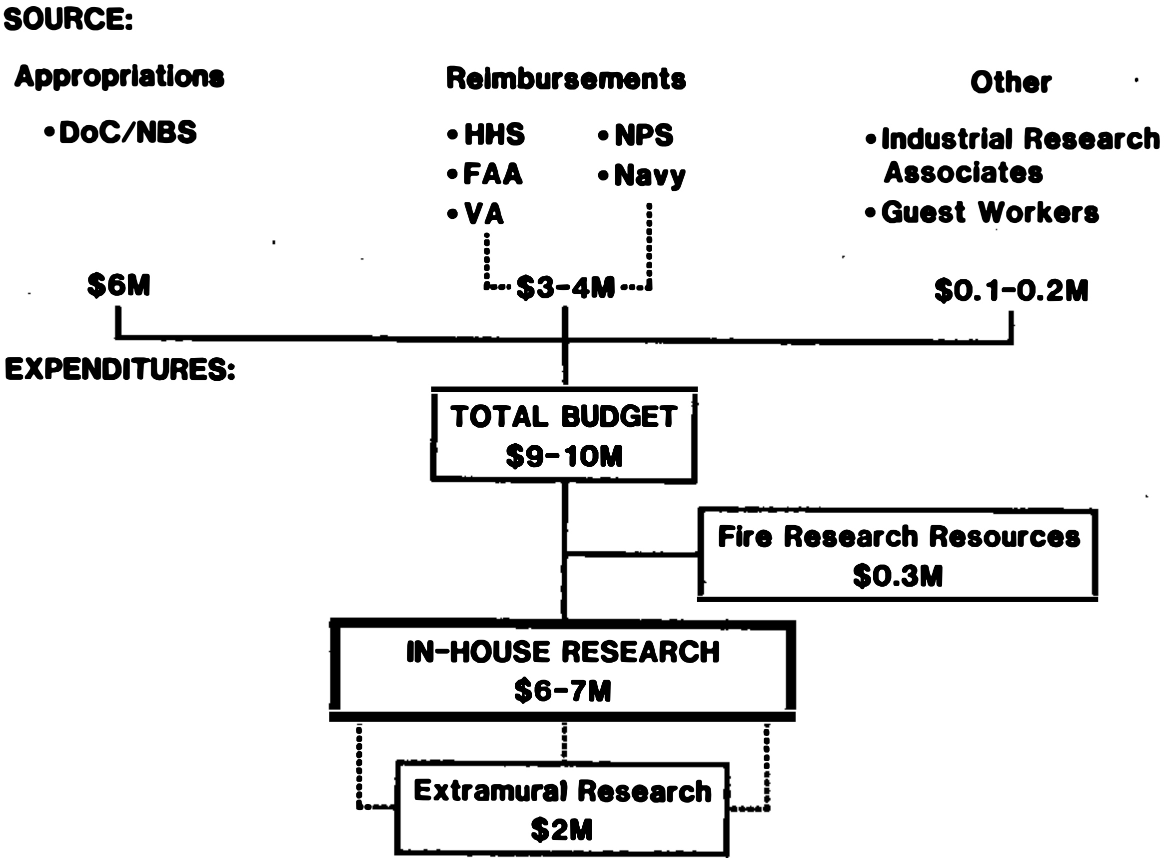


FIGURE 1 CFR funding overview.

to address the specific fire research needs of other agencies. Table 2 lists examples of CFR work in support of other federal agencies. Note that a number of these agencies design, produce, and operate public buildings. The balance have other fire safety problems (e.g., transport vehicles, ships).

Table 3 summarizes the disciplines or academic backgrounds of CFR's professional staff. This capability is unique worldwide. Diverse as this listing of disciplines and expertise is, it represents a minimal critical mass of the capabilities needed to carry out the Center's charge. NBS is predominantly a physical science and engineering research laboratory. Thus, NBS is an ideal setting for fundamental research into the chemistry and physics of thermal decomposition of materials and basic fire processes such as ignition; flame spread; fire growth, suppression, and extinguishent; and smoke generation and movement. However, this necessitates reaching out, principally through the Grants Program, to obtain expertise in the many disciplines CFR does not have. These include life and behavioral sciences and some engineering disciplines as well as engineering science.

TABLE 1 CFR Grants Program

Recipient	Project Title
American Institute of Architects Foundation	Fire Safety Evaluation System for Board and Care Homes
Brown University	Effects of Material Properties on Burning and Extinction-Fires on Vertical Fuel Surfaces
California Institute of Technology	Experimental Study of Environment and Heat Transfer in a Room Fire
Case Western Reserve University	Experimental and Analytical Study of Fire Sprinkler Scaling Laws
Case Western Reserve University	Flame Spread and Spread Limits
Clemson University	Ternary Reactions Among Polymer Substrate-Organohalogen-Antimony Oxides in the Condensed Phase Under Pyrolytic, Oxidative and Flaming Conditions
Colorado School of Mines	Characterization of Aerosols from Fires
Factory Mutual Research Corporation	Computer Modeling of Aircraft Cabin Fire Phenomena
Factory Mutual Research Corporation	Determination of Fuel Parameters for Fire Modeling
Factory Mutual Research Corporation (Joint Program with Harvard University)	Prediction of Fire Dynamics
Harvard University	The Prediction of Fire Dynamics
National Fire Protection Association	Investigation and Analysis of Major Fires
Pennsylvania State University	An Investigation of Turbulent Fires on Vertical and Inclined Walls
Princeton University	Flow Field Effects on the Sooting Structure of Diffusion Flames
SRI International	Continued Development of Residential Fire Decision Analysis Model
SRI International	Polymer Degradation During Combustion
TRW	Modeling of Wind-Aided Flame Spread
University of California, Berkeley	Dynamics of Smoke and Inert Tracers Produced in Porous Fuels
University of California, Berkeley	Fire Propagation in Concurrent Flows
University of California, Berkeley	Intralaboratory Evaluation of a Standard Room Fire Test
University of California, Lawrence Berkeley Laboratory	Fire Modeling
University of California, Lawrence Berkeley Laboratory	Flame Radiation
University of Florida	Network Models of Building Evacuation: Development of Software System--Year Two
University of Maryland	The Determination of Behavior response Patterns in Fire Situations, Project People II
University of Michigan	Degradation of Mechanical Properties of Wood During Fire
University of Montana	Chemistry of Smoldering Combustion and its Control
University of Notre Dame	Computer Modeling of Aircraft Cabin Fire Phenomena
University of Notre Dame	Scaling Correlations of Flashover Experiments
University of Pittsburgh	Toxicity of Plastic Combustion Products

TABLE 2 Examples of CFR Projects Supported by Federal Agencies

Agency	CFR Contribution	Agency "Product"
Health and Human Services	Facility fire safety performance model.	Fire safety requirements.
Veterans Administration	Fire resistance evaluation of interstitial walk-on platforms	Improved medical facility design feature
Federal Emergency Management Agency/U.S. Fire Administration	Field performance measurement systems for residential	Promotion of new fast-acting residential sprinklers
Interior/National Park Service	Fire risk management model and procedure	Improved facility fire safety
Energy and Consumer Product Safety Commission	Heat transfer from solid fuel stoves	Installation of fire safety giode;omes
Navy	Fire growth and smoke movement models	Improved ship fire safety
Transportation/Federal Aviation Administration	Flame spread measurement	Material performance requirements

TABLE 3 Disciplines of CFR Professional Staff

Discipline	No. of Staff Members
Physics	7
Chemistry	11
Microbiology	1
Psychology	1
Mathematics	3
Mechanics	2
Aerospace Engineering	3
Mechanical Engineering	7
Chemical Engineering	2
Civil Engineering	2
Industrial Engineering	3
Electrical Engineering	2
Fire Protection Engineering	5

The Center's staff is further augmented by industrial research experts through the Research Associates Program. Past (since 1975) and current sponsors of research associates at CFR are:

1. American Apparel Manufacturers Association
2. American Iron and Steel Institute
3. Armstrong Industries
4. Consumers Union
5. Dow Chemical
6. Foundation for Cotton Research and Education (The Cotton Foundation)
7. Gypsum Association
8. Man-Made Fiber Producers Association
9. National Forest Products Association
10. PPG Industries
11. Rhone-Poulenc Industries
12. Society of the Plastics Industry--Amoco Chemical, BASF-Wyandotte, Celanese Corporation, DuPont, Hooker Chemical Company, Monsanto, PPG Industries, Union Carbide Corporation
13. Underwriters Laboratories
14. U.S. Department of Agriculture/Southern Regional Research Center

Also, active collaboration is maintained with our international counterparts (i.e., the French, Canadian, English, and Japanese fire research organizations).

CFR laboratories are a valuable national resource. These laboratory facilities include the following:

1. General Purpose Laboratories (one-third of Building 224 adapted with smoke control and abatement equipment and other safety features for fire research). Activities relate to basic fire research, fire modeling, fire risk analysis, fire toxicology, building fire safety performance, material fire property, fire suppression, and smoke.
2. Fire Test Facility (Building 205, specially constructed with instrumented gas removal hood systems for experiments and model validation studies). Activities relate to room-corridor burn, large fire endurance furnace, rate of heat release, flame spread, room fire test, and toxicity test.
3. NBS Annex (nearby former Nike missile site which serves as field station for experiments that cannot be accommodated readily in main laboratories). Typical activities include: fire tests of mobile homes, studies of smoke and gas movement in buildings, smoke control system studies, tests of sprinkler activation and effectiveness, fire detector siting and performance studies, and fire spread studies.
4. Other NBS Center Facilities utilized relate to applied mathematics, building technology, chemical engineering, analytical chemistry, material research, and instrument shops.

Importantly, these facilities and equipment represent scientific research tools rather than burn halls or standard test devices. Such capabilities exist elsewhere and need not be replicated at NBS.

As a focal point for basic research in fire, both nationally and internationally, CFR provides a number of important additional services. The Fire Research Information Service (FRIS) provides an important communication link for fire researchers throughout the world. CFR sponsors and participates actively in conferences, symposia, and workshops devoted to important topics in fire research and its staff participates intensively in the technical and standards committees of organizations such as the National Fire Protection Association (NFPA), American Society for Testing and Materials, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., American Society of Mechanical Engineers, and International Standards Organization. CFR also is a contributing sponsor to the NFPA fire investigation reports.

This briefly summarizes the resources of the Center for Fire Research at NBS. The National Bureau of Standards is a scientific research laboratory. It is dedicated to the development of new knowledge and to the provision of reliable and accurate scientific and technical data, measurement methods, and practices. Its leading strength is its technical credibility.

HOW CFR's PROGRAM IS FORMULATED

Three important sets of factors are considered in the formation of CFR's research program. These, as depicted in Figure 2, include assessment of the Center's capabilities, understanding the external environment, and development of sharply focused objectives in view of our expanding knowledge of the fire problem and the state-of-the-art

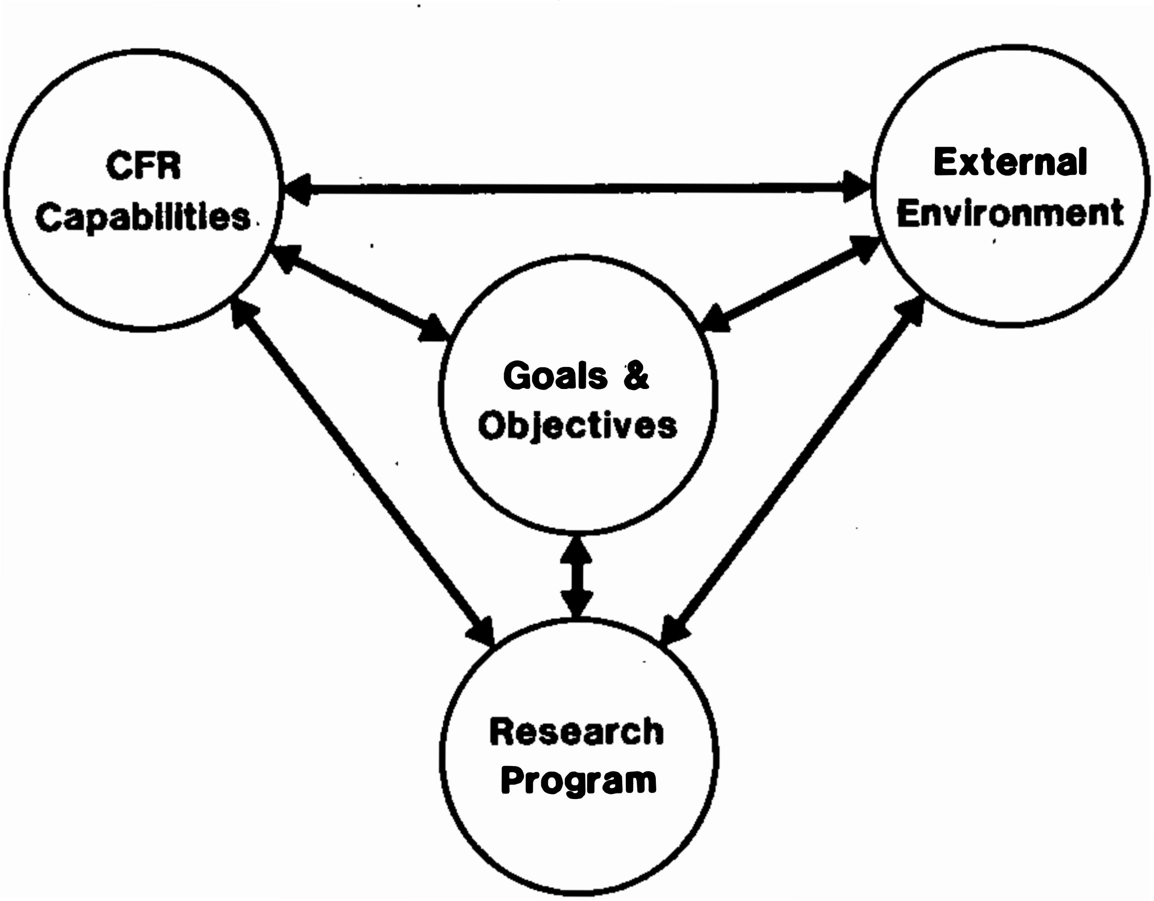


FIGURE 2 CFR program formulation.

in fire science. The previous section summarized the first of these (i.e., CFR capabilities). CFR's research program is formulated in a synthesis of these three elements.

The external environment is comprised of those outside of CFR who influence the shape and content of our program (Figure 3). It includes, for example, the Fire Act and the Congress, which oversees the fire problem and the actions of others as well as our plans and progress. It includes the Administration and its policies. It includes the many organizations, both private and public, that deliver improved fire protection or safety services, products, materials, or designs and many of those for whom such are intended. From the perspective of CFR, the organizations in this external environment function in one or more of the categories depicted in Table 4 (i.e., research peers, intermediary organizations, or end users-beneficiaries of our research results). The lists shown are clearly representative and not exhaustive. Note that many of these organizations address the fire safety concerns of building designers, builders, owners, and occupants.

TABLE 4 Representative Organizations in CFR's External Environment

Research Peers	Intermediary Organizations	End Users-Beneficiaries
Universities	U.S. Fire Administration/National Fire Administration	Public Fire services
Factory Mutual Research	National Fire Protection Association International Association of Fire Chiefs	Fire and code officials designers-engineers
Private and industry labs	American Society for Testing and Materials American Society of Mechanical Engineers	Product manufacturers
International Counterparts--National Research Council of Canada, Building Research Institute of Japan, Fire Research Station of England, Centre Scientifique et Technique du Batiment	Society of Fire Protection Engineers American Institute of Architects Underwriters Laboratories Testing Labs Industry Associations--American Iron and Steel Institute, American Textile Manufacturers Institute, Upholstered Furniture Action Council, Society of the Plastic Industries, Carpet and Rug Institute, Man-Made Fiber Producers Association, Forest Products Association Advisory Board on the Built Environment National Institute of Building Sciences National Conference of States on Building Codes and Standards National Association of Home Builders	

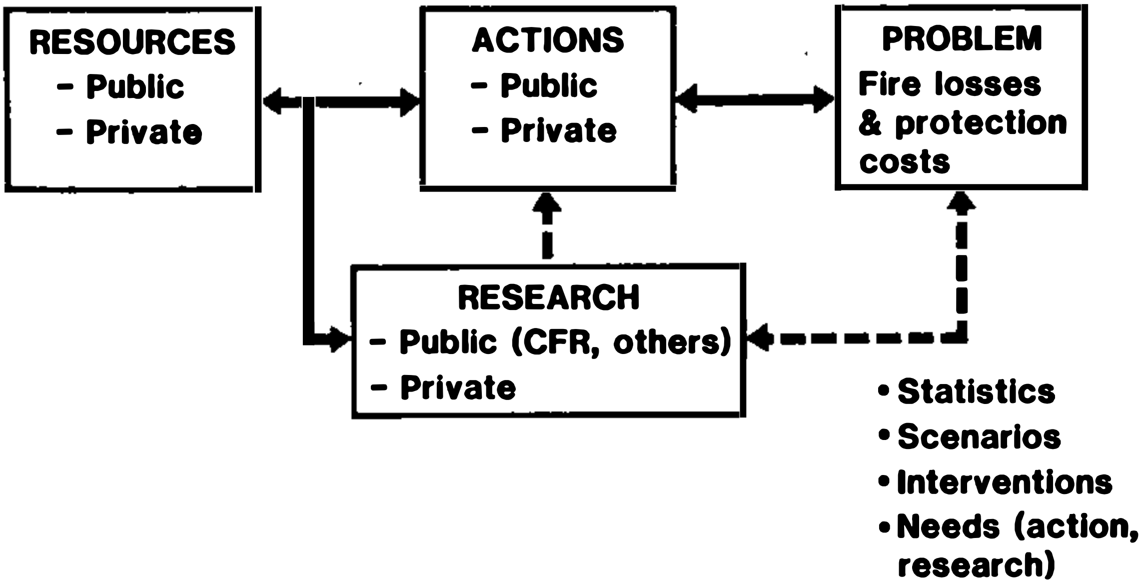


FIGURE 3 External environment influencing CFR programs.

This external environment influences the CFR program in many ways. I have already mentioned congressional review and oversight, administration policy, and private sector interests. Obviously, many of the needs and questions that arise in this realm are readily answered. Clearly it makes little sense for CFR to undertake activities best performed by others or in any way needlessly duplicative of work ongoing elsewhere.

Finally, and importantly, it is within this realm that the fire problem itself is characterized; fire incident reports are abstracted and statistics compiled; apprehensions and concerns are raised; and public pressures arise for answers, action, or retribution. This aspect of the CFR program formulation effort tries our ability to listen and question patiently, intelligently, and persistently.

This brings me to the next element in the program formulation triad--that of setting our corporate goal and objectives. Most of what I have said up to this point reflects an analysis of what is and a careful listening to the hopes, plans, and prognostications of others. However, a really good research program embodies a great deal more. It reflects vision and will and a commitment to its relative merit and practicability. We have tried to pack some of all of this into the CFR plan.

THE CFR RESEARCH PROGRAM

The goal of the CFR program is to provide the scientific and technical basis for reducing fire losses and the costs of fire protection by at least half by the end of this century. This necessitates the following strategy for the Center's technical program:

1. Promote the continued advance of fire science,
2. Promote the development and widespread use of scientifically based fire protection engineering practices, and
3. Provide technical support for the timely resolution of major fire safety issues or problems.

This strategy reflects a desired balance between the ideal and longer-term and the pragmatic and near-term perspectives. It reflects, we believe, an understanding of current and future dimensions of the fire problem, practical interventions, and the lessons provided by earlier developments in other areas of engineering and building practice. In its simplest terms, the CFR program is designed to provide a scientific and technical basis for practical predictive tools for cost-effective fire protection. This concept is elaborated somewhat in the following elemental objectives of CFR:

1. Fire risk measurement methods
2. Engineering prediction of facility fire performance
3. Scientific basis for fire suppression technologies
4. Smoke hazard assessment methods
5. Predictive formulae for elemental fire processes--ignition, flame spread, growth extinction
6. Measurements for material fire performance and fire model data
7. Knowledge of smoke toxicity and effects
8. Proof and validation testing at reduced and full scale
9. Fundamental studies of smoldering, soot formation, radiant ignition, polymer decomposition

Mr. Nelson's conference paper addresses the second objective, which represents one of the more applied research efforts.

ISSUES RAISED BY CFR RESEARCH PROGRAM

The CFR research program promises a great deal of ultimate benefit to the building designer, owner, and occupant. How soon and how effectively these tools are developed and delivered depends on a number of factors in addition to CFR's research skill, few of which we control.

The premise of the CFR program is that an improved scientific and technical basis is necessary for major reductions in costs and losses of fire in the United States. Experience to date bears out this premise. Recent reviewers concur. These include Congressional and Administration oversight and technical review by the National Academy's Evaluation Panel (National Academy of Sciences, 1983). However, the continued vitality of the program depends in large measure on sustaining a viable community of leading researchers in the academic and industrial basic research communities. This means removing the limitations of arbitrary test methods and dubious rank orderings of materials and developing scientifically valid computer-based models of fire processes and new measurement methods for the data they require. Many important technical questions remain before essential calculations or predictions can be made.

This powerful new technical base will differ significantly from traditional practices and codes. Think, for example, of the many developments in the field of energy conservation in buildings over the past decade--in particular: the development of practical tools for energy efficiency evaluation of buildings, equipment, and designs; and the institutional adjustments required to develop and train architects and engineers to use these tools to make "energy-conscious design" a practical reality and to establish widespread use of effective energy management practices. Similar changes can be anticipated in the fire field. This will necessitate new approaches and programs for the education and training of designers, architects and engineers, code officials, fire safety officials, and those who provide technical assistance to building owners and operators.

Important new functions need to be provided by the institutions that many of you represent. Scientifically valid measurement methods and computer-based models will need to be adapted and adopted to meet your varied needs efficiently. Institutional mechanisms for the review, approval, and acceptance of such tools will need to be established. Data bases including the requisite data on building materials, designs, and commonly used building contents must be compiled and made available. Further, tests, demonstrations, and reference analyses must be developed and conducted to affirm and communicate the practicability of these powerful new tools for various classes of designs, buildings, owners, and occupants.

In fire safety, as in energy conservation, our priorities should reflect a frontal assault on the toughest, most important elements of the fire problem. These are in priority order the following:

1. Existing one and two family residences,
2. Other existing residential occupancies,
3. New one and two family residences, and
4. New other residential occupancies.

These priorities reflect the realities of fire incident statistics. This prioritization clearly weighs need ahead of ease. Fire safety inevitably involves trade-offs between function, cost, and safety. Providing the basis for cost-effective fire protection in existing residential occupancies is an extremely tough challenge.

SUMMARY AND CONCLUSIONS

The CFR research program is designed to provide powerful new capabilities for reducing fire losses and the costs of fire protection. It is based on an analysis of CFR's capabilities and a complex array of factors in the environment external to the Center. It represents a significant departure from the more conservative course of incremental improvement in those traditional practices for fire protection that have no basis in scientific fact. This course raises a number of issues. Four have been singled out: the need for a viable community of private and public sector researchers; departure from dependence on traditional practices; the need for new institutional mechanisms; and a directed assault on the toughest area of fire loss, in particular, existing residential occupancies. This is clearly not the most expedient or the easiest course for CFR to follow. However, it is the one the Congress assigned to the Center nearly a decade ago. Experience to date affirms that it remains the right one.

REFERENCES

National Academy of Sciences. 1983. An Evaluative Report on the National Engineering Laboratory, National Bureau of Standards, Fiscal Year 1983. Washington, D.C.: National Academy of Sciences.

__________. 1956. Proceedings of the First Fire Research Correlation Conference, Washington, D.C. National Academy of Sciences.

National Commission on Fire Prevention and Control. 1973. America Burning. Washington, D.C.: U.S. Government Printing Office.

CONTENT, AVAILABILITY AND USE OF FIRE RESEARCH AT THE STATE OF THE ART

Howard W. Emmons
Professor, Mechanical Engineering
Harvard University, Cambridge, Masssachusetts

Researchers need the input of owner-operators to understand what the owner feels his fire problems are. In research, one finds that what the practitioner feels his problem is, is indeed his problem from his point of view but may not be quite the right expression of the question from the point of view of selecting a research program to answer that question.

In this conference we have talked about basic research and applied research. Industry generally does practical research because it has to see potential return of its research dollars, particularly if they are big dollars. The total solution to the difficult fire problem will take big dollars. Thus, basic fire research is generally not supported by industry; there is no mechanism now in place.

Fire research spans many areas including soot formation processes, actuation of sprinkler heads, and safety of wood burning stoves. All these areas appear to be applied research and of interest to the owner-operator. However, a publication in the first area is entitled "Observations of Laser-Induced Visible Fluorescence in Sooting Diffusion Flames." Communicating this basic research result to an owner-operator would be of no value; in fact, it may do harm if it is unintelligible to the average public. However, if money had been put into that kind of fire research 40 years ago, we would be in a lot better position today than we are. Sooting does damage and it is unhealthy, but it is also the major source of radiation from fire, the mechanism by which fire spreads. If we could understand and control sooting, we would be closer to understanding and controlling fires. Thus, long-range basic research, although not easily communicable, is essential. Not all research should be of this type. Many problems for which we need immediate answers can be solved by a small- or large-scale fire test right now. Thus, a balance between these two types of research should exist.

I would like to describe the limitations of standard fire testing in answering fire problems. Flammability testing of a given set of materials carried out in six different countries with six different test methods yields results that scatter almost as much as random numbers. Each test was designed and carried out by competent professionals and each suits a specific fire system perfectly. In fact, however, the tests are measuring something that does not exist: inherent flammability. This property is dependent on the test system, and since we do not live inside a piece of test apparatus, this type of test is of value to us only as a screening of particularly dangerous materials.

The accumulation of knowledge gained from tests such as these is presently in our building codes. Since the code essentially contains our experience, it contains things that are and are not relevant and important to controlling fire. The codes could be improved by incorporating information that is already available; incorporation is a slow process. The ultimate goal of fire research should not be to add to prescriptive codes, but to provide long-term basic answers so fire protection can be put on the same engineering basis as other fields of engineering. For example, because we understand the laws of mechanics, there is no question that a structure designed by a competent civil engineer will stand up. Fire is more difficult; there is no hope of designing with a slide rule, for instance because the computer is needed to deal with the complexity of the problem. Our first step is to stop trying to use the head as a computer to predict fire spread. The fire triangle may be the basis upon which we think qualitatively about fire, but it is of little value for quantitative design. Eventually we must be able to predict the process of burning in an entire high-rise building. First though, our computer predictive models must be validated.

I would like to illustrate why fundamental research is important and may change our approach to the fire problem in the not too distant future. We cannot have the total answer to our problem today, so building a background is important.

What does a fire really consist of? When a scientist looks at a fire he sees a lot of phenomena. To understand fire we must understand each piece of the puzzle and how they interrelate. In Harvard's work, sponsored by the National Bureau of Standard's Center for Fire Research, we are looking at individual scientific questions. In order to be sure that the questions we were examining were the right ones, we ran full-scale bedroom fire tests, heavily instrumented with the help of Factory Mutual Research Corporation. Three tests were run to check on reproducibility. The purpose of the tests was to study fire development and to verify computer model predictions such as fire growth rate, burning rate, ceiling layer development rate, temperature history, gas composition, and air entrainment. Things we learned from the tests included the time of ignition of the "second object," the role of radiative feedback from the hot ceiling layer in fire development, and ventilation effects on fire period and growth rate in addition to the minute-by-minute development of the fire.

In our work, we compared test results and computer results to determine which piece of information we need to measure to characterize the fire and add to our understanding. I would like to comment that interpretation of test results is sometimes difficult, even in our full scale room burn studies because our measurement techniques are just not good enough. One of the areas which we do not understand well is the toxicity of products of combustion and their spread. This is important because, in order to ensure the safety of the building occupants, we need to predict the time at which the fire alarm systems will warn them of danger and the time at which the escape routes are no longer tenable because of high temperatures or toxic gases. All this information will make it possible for design engineers to generate alternate fire safety designs for buildings with computer verification of the feasibility of these designs. Incidentally, through this process, existing buildings can also be dealt with.

In summary, there is a communications gap between fire researchers and building owner-operators. In solving this problem we must not disregard the small owners who collectively own most buildings but whose interest in fire is on an ad hoc basis at best. We also must not disregard the researcher who feels that communication is a waste of time; his greatest value to us is his research abilities, and his funding should not be tied to communicating ability. We need intermediaries between these two groups: communicators.

Today and tomorrow, all our fire research answers will have to come from building codes and fire specialists such as fire protection engineers. When will our computer code be ready? My prediction is that in 10 years we will be able to answer some design problems with the computer; it will be 20 years before we can satisfy a performance code. To speed up the process, national priorities must be changed and funds reallocated to give the fire problem the attention and the solution it requires.

THIRD SESSION

POSSIBLE WAYS OF BRIDGING THE COMMUNICATIONS GAP

CREDIBLE ENGINEERING METHODOLOGIES

Harold E. Nelson
Group Leader, Center for Fire Research
National Bureau of Standards, Washington, D.C.

This presentation is based on the premise that the communications gap between the science community and the owner-operator community is technical and semantic. The science community deals with the partitioning of problems into smaller and smaller increments to determine the nature of the phenomena involved and to quantify that involvement. The owner-operator community (e.g., building operators, maintenance managers, and planners) deals with the dimensions and material specifications of real buildings. Neither community group can adopt the other's mode without significant diversion from its purpose and dilution of its capabilities and credibilities.

Historically, at least until the past decade, fire research was largely empirical. While empirical research has resulted in some major impacts on the methods of application of fire safety, these impacts have been sporatic. Three or four decades ago this empirical approach was sufficient. Most buildings were inherently massive and highly compartmented. Wood and paper were the prime combustibles of concern. The rate of change in building technology was slow and the cumulative history of how buildings reacted when exposed to fire or other stress was a good prediction of future expectations. In that atmosphere a system of consensus codes (criteria, standards, etc.) arose covering the full scope of building health and safety.

The code system was designed to address the total charge of public health and safety. Whenever creditable technology existed, it was incorporated, but when it was not available, committee consensus judgment was used. In the case of fire safety, technology input has been minor and judgment has been dominant. Unfortunately, the result is a rigid set of requirements. The objectives and expectations of the consensus body in setting a requirement are infrequently recorded. Consequently, the value and intent of the requirements are seldom apparent.

Virtually every code has an equivalency clause that permits alternative approaches provided equal performance can be achieved. It is, however, difficult to demonstrate the required equivalency when the factors that need to be considered were established by consensus. As a result, the code document rather than its original purpose becomes the objective. Expertise becomes entombed in relating fixed requirements to building materials and systems. Innovation, rational design, and cost control are constrained and frustrated.

As the title of this presentation indicates, this paper proposes that a better approach rests in the development and accreditation of the underlying fire protection engineering technology. The remainder of this paper covers: the state of fire science that now makes such an approach possible and a proposed organization for such an approach, case study examples of two different ways to apply the approach to the problem of management and control of fire safety in buildings, and directions and conclusions.

THE STATE OF FIRE SCIENCE

Over the past several decades a relatively small but fortunately persistent group of research scientists and engineers have labored in laboratories and universities around the world. They have dedicated their efforts to determining the basic principles of unwanted fire; measuring the variables involved; and (in recent years) developing coordinated engineering approaches to predicting the course of fire, the response of fire safety features, and the resulting impact on the people, property, and productive missions involved. As a result, there is a progressively emerging fire protection engineering technology that can potentially evaluate the fire safety performance of a building that may differ widely from the current prescriptions of the code. It can also provide an assessment of the impact of a code requirement as it applies to a specific building or set of circumstances. It is now possible to make at least a primitive analytical evaluation of fire development and impact from the moment of ignition to the final determination of the results of the fire.

The use of the engineering approach presented herein is viable for either individual building analysis or generalized requirements for codes. In the first case, the actual building conditions and arrangements are used. In the second case, it is necessary to establish the characteristic allowable fuel condition for the occupancy under consideration and apply this to a series of test cases representing an array of building arrangements for that occupancy. For consistency and simplicity of presentation, this paper initially addresses the concept in terms of evaluating a specific building design. The example concentrates on a single situation. In application, as with any engineering design, it is necessary to make a sufficient number of analyses to determine the response of the building to all of the potentially important fire scenarios for the facility.

Figure 1, an overview of the key areas to be addressed in the engineering method, outlines the logical progression of an engineering design. The design process starts with the given building conditions. In fire safety design the necessary details include:

1. The building, its layout or shape, materials of construction, subsystems (utilities, electrical, fire alarm, sprinklers, etc.);

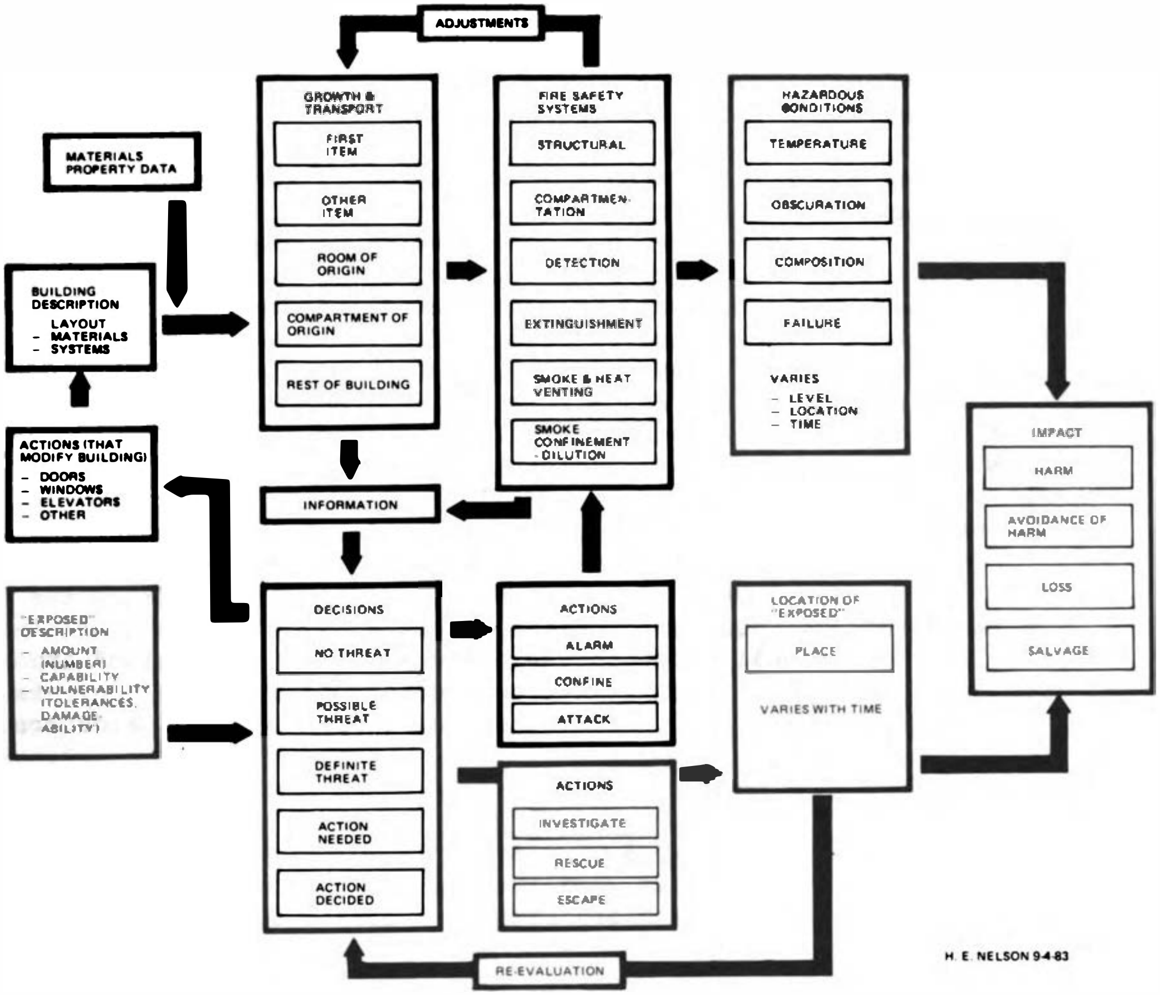


FIGURE 1 Elements of an engineering methodology.

2. The intended use of the building, particularly in terms of the collection of combustible materials as fuel packages; and
3. The people in the building in terms of their location within the building and any special physical impairments or other characteristics.

As a practical design problem, some of these qualities are reasonably fixed in any building and some are variables that may change from time to time. Many of these variables can affect the course or the level of danger presented in a fire. To attempt to analyze every conceivable variable and all the permutations or combinations of variables is irrational. The evaluation of design cases that reasonably represent the fire-induced stress that the building is expected to endure is practical. Normally this design fire stress would encompass the expected fire load conditions either typical in the occupancy class to be housed or specific to a known case of concern. Similarly, the position of doors (i.e, open or closed) and the location and disposition of the people in the building can be evaluated on the basis of the most vulnerable situation, a selected situation of particular interest, or a series of selected design cases to determine the impact of one design case versus another.

The engineering method views fire as an energy-driven stress on a building and its internal environment. The building reacts to this stress by absorbing it, removing it, or undergoing some type of change in response to the stress.

In recent years the fire research community has made significant progress in fire modeling, and as more information on material properties becomes available, it will be possible to analyze the ignition and growth of fire through its entire course of development. This presentation illustrates the use of currently available capabilities. It includes critical use of empirical results derived through experiments and tests. The type of empirical results involved are engineering data expressed in term of rates and quantities compatible with the available formula.

Currently there are sufficient data and calculating capability to work the elements in Figure 1 and to produce a cautious appraisal of building fire safety. Exceptions to this generalization include the effectiveness of extinguishing agents and the prediction of the decisions made by individuals upon receiving an alarm. The level of capability, however, varies from primitive calculations for some elements to advanced models with a significant degree of confidence for others.

EXAMPLE OF THE APPLICATION OF ENGINEERING METHODOLOGIES TO THE ANALYSIS OF A SPECIFIC BUILDING

The proposed method analyzes the risk in a specific building through the following steps:

1. Empirically obtain the rate of release of energy and other products of combustion in the free-burning mode for typical fuel packages.
2. Calculate potential involvement of additional fuel packages. Develop the resultant rates of energy and product release.
3. Calculate hazard development in the room or space of origin.
4. Calculate hazard development in corridors or other spaces exposed to the room of origin.
5. Calculate the development of hazardous conditions through the rest of the building.
6. Appraise the structural (fire resisting) response of the building frame and other structural elements.
7. Estimate the response of smoke detectors, heat detectors, and sprinklers and the impact of any activated extinguishing system.
8. Appraise heat and smoke venting potentials.
9. Appraise smoke control system potentials.
10. Estimate the amount of time required for the evacuation of occupants from danger.
11. Develop emergency movement plans to accomplish safe evacuation within available time.

12. Appraise the impact of the resulting interaction of hazardous environments and those persons and property exposed to these conditions.

To demonstrate the approach, consider an example involving the guest rooms in a 25-story hotel. The bedrooms are approximately 12 ft by 18 ft* and contain two double beds with inner spring mattresses and wooden headboards. There are two bedside tables, two overstuffed chairs, and one or more waste baskets. The layout is as appears in Figure 2. The interior finish in most rooms is gypsum board decorated with paint or wall paper, but some rooms have 1/2-inch-thick hardwood plywood finish. The plywood is not fire-retardant treated but has a glue that is not subject to delamination under fire conditions. The layout of rooms on a single floor is shown in Figure 3. The above choices were made because there is a limited catalog of good empirical test data on all of the items concerned as a result of projects at the National Bureau of Standards (NBS) for the Department of Health and Human Services and the National Park Service.

The object is to determine if any occupant will be exposed to hazardous conditions assuming a reasonable response at the time of fire. For this example, a hazardous condition is considered to occur when the fire generated smoke and gas layer envelopes the building occupants or subjects them to radiation higher than approximately 0.25 W/cm^2.

The calculations used in this example can be applied to questions such as:

1. How fast can fire make the room of origin intolerable?
2. At what stage would a smoke detector operate, and how much escape time would this give the room occupant?
3. How does the escape time provided by a smoke detector compare with that of a low heat sink, fast response heat detector?
4. When would standard and fast response sprinkler heads actuate?
5. If the room door were open, how fast would hazardous conditions develop in the corridor, and what would be the characteristics of these conditions?
6. What would be the effect of providing a smoke barrier across the corridor?
7. How much smoke would flow into the stairs?
8. How much fire proofing of the structure would be necessary for these fuel conditions?
9. Once people started to move, how fast would they clear an area exposed to a developing fire?
10. How fast would the building be cleared, and would there be congestion in the stairwell?

---

*Since this paper is for an audience involving many building owner-operators as well as researchers, those dimensions commonly used by owners (length, width, area) are given in the English system.

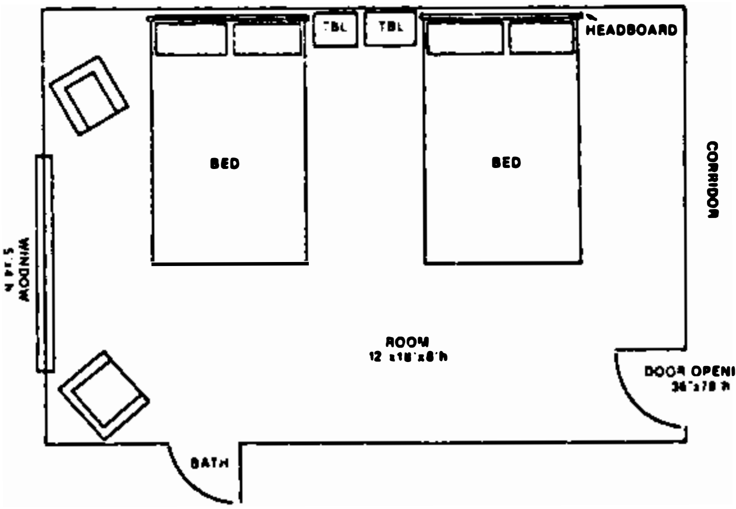


FIGURE 2 Layout of Example Room.

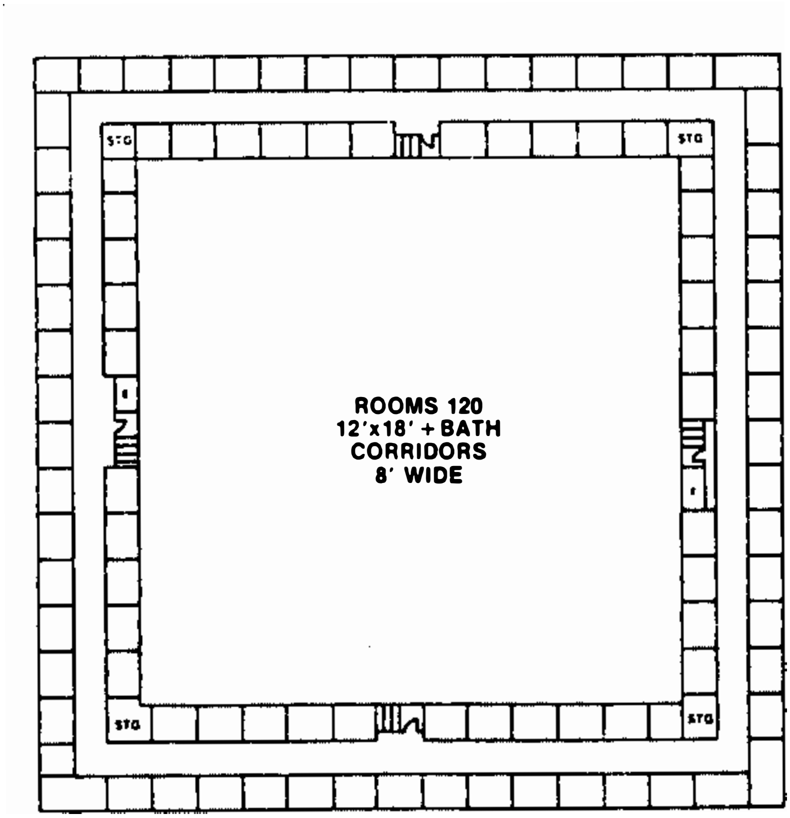


FIGURE 3 Floor plan for example problem.

11. Could the smoke be managed, either by keeping it above the head height of the evacuees or by preventing it from penetrating other floors, stairwells, or elevators?

In this example, the reference data and calculation approaches used are currently accessible by practicing engineers. Other methods that promise to produce more exact results are in various stages of development.

FIRE GROWTH AND TRANSPORT

The procedures in this example follow the organization in Figure 1. The analytical calculations begin with the procedures listed in the box in Figure 1 labeled "Growth and Transport." At this stage calculations are concerned with the growth and spread of fire and fire effects wthout any fire safety system intervention.

First Item (Initial Fuel Package)

Most fire research laboratories have enhanced their ability to determine the rate of energy release, combustion efficiency, and carbon monoxide production by the use of methods referred to as oxygen depletion calorimetry. This approach is akin to measuring stack gases in an industrial furnace or tuning an automobile engine by examining the chemical composition of its exhaust gases. A readily understood discussion is presented by Huggett (1980).

The so called calorimeters involved are large hoods that collect all of the gases from the burning item and analyze the composition as the gases pass through the hood exhaust stack. At the National Bureau of Standards these types of calorific studies have been made on items ranging from waste baskets and small chairs to simulated hotel rooms and jail cells. The tests produce time plots of the rate of energy release and the rate of production of carbon monoxide or any other combustion products for which continuous measurement instrumentation is available. One use of oxygen depletion calorimetry is to measure the products produced by a fuel package burning in a location having no restriction on air supply from the sides and no ceiling. The results are termed the free burn characteristics of the fuel package.

Figure 4 shows a stylized representation of the rates of energy production by burning a common hotel bed standing against a gypsum board wall. Figure 4 also shows the same results when the gypsum board wall is replaced with a plywood panel wall. In this test, the effect of the wall occurred relatively late in the fire. Finally, Figure 4 illustrates similar results from the test of a small free standing upholstered chair. The three curves represent the furniture in the example problem. They are the starting data for the calculations.

Involvement of Other Items

Fire can propagate across the space between separated fuel packages by direct radiation from the flame plume or from general room radiation

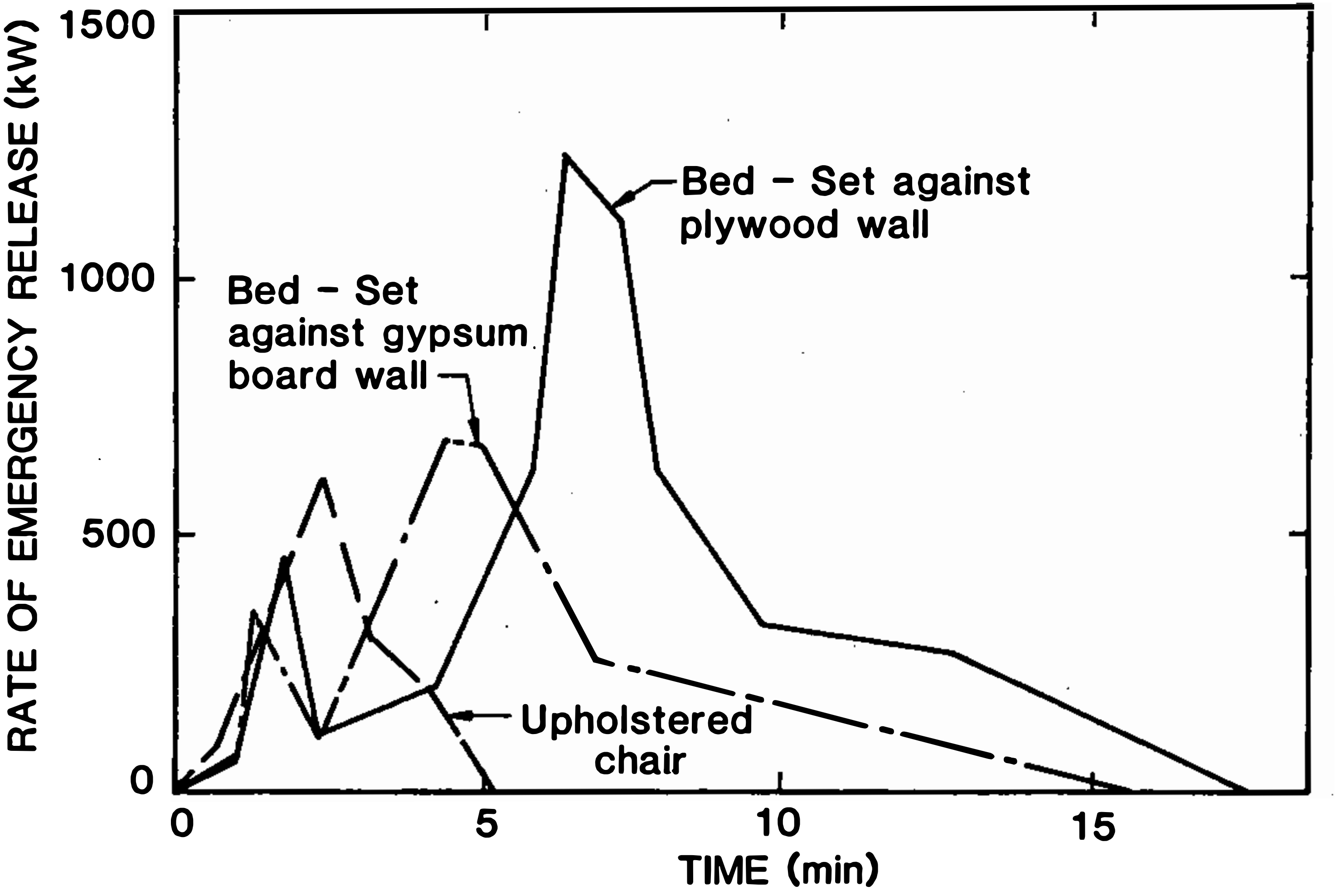


FIGURE 4 Free burn energy release rates.

during or after the transition to a flashed over space. In the early (pre-flashover) stages of burning, the concern is radiation from the flame plume produced by the initially involved item. Ignition transfer must be expected if the radiant impact on the exposed material is sufficient to bring it up to its ignition condition. This problem has been examined and quantified by Babrauskas (1981). Figure 5 is an adaptation of a graph from his paper. Babrauskas divided material ignition susceptibility into three categories of materials: those that are especially easy to ignite, those in the normal ignition range, and those that are difficult to ignite.

The "especially easy to ignite" materials include very thin combustible materials such as curtains or drapes or very low density combustible materials such as low density foam plastics. Ignition can occur with radiation levels as low as 10 kW/m^2. The "normal ignition range" category includes those materials for which the imposition of 20 kW/m^2 or more is required for ignition. This category includes most common upholstered furniture. In the example both the beds and the upholstered chairs are considered to be in this category. The "difficult to ignite" category includes wood, particularly if it is 1/2 inch or greater in thickness, and other high density non-melting materials. These items have an inherent ability to absorb and disperse a reasonable proportion of the energy received.

The example assumes that fire starts in a waste basket at the side of the bed near the window and that the chair is approximately 10 inches away from the bed. Figure 5 indicates that a fire of about 300 kW will produce enough radiation to involve the chair. At this time the chair is assumed to ignite and burn at the free burn rate. Since energy is cumulative, it is reasonable and conservative to add the energy plot from the chair to the energy release rate plots for the bed (Figure 4). The addition is started when the exposing fire first produces the critical ignition energy (300 kW). The resulting combined energy release rate curves are shown in Figure 6. These two curves are the input to the design calculation process.

Room of Origin (Early Course of Fire Hazard Development)

A number of researchers have produced early stage fire growth models using a concept known as zone modeling. Figure 7 taken from the work of Quintiere (Jones and Quintiere, 1983), is an idealization of this approach in which a burning fuel releases combustion products into a fire plume where they mix with air entrained in the rising plume. The thermal effects and fluid dynamics of the plume are major elements in zone modeling of fire development and smoke movement. An excellent introduction to the fire protection engineering aspects of the fire plume is provided by Heskestad (1982). The gases produced fill the upper part of the room and flow out of any openings. During this process some of the heat produced is radiated from the rising flame and associated products contained in the plume, and some is transferred to the wall and ceiling surfaces in contact with the hot gases. As the fire progresses, the gaseous products in the upper layer become black and hot and radiate energy to the burning material and any other combustible or noncombustible surface in the room.

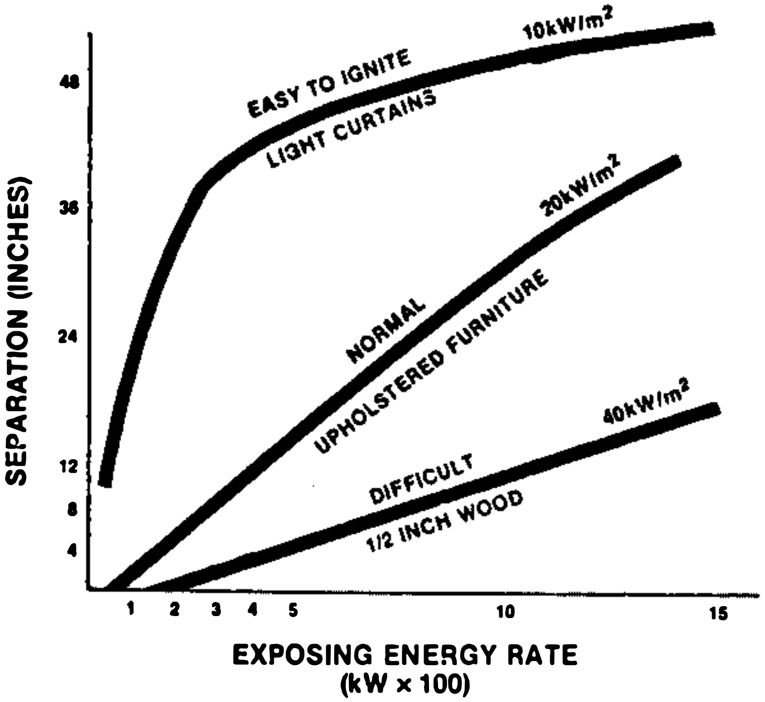


FIGURE 5 Ignitability of exposed items.

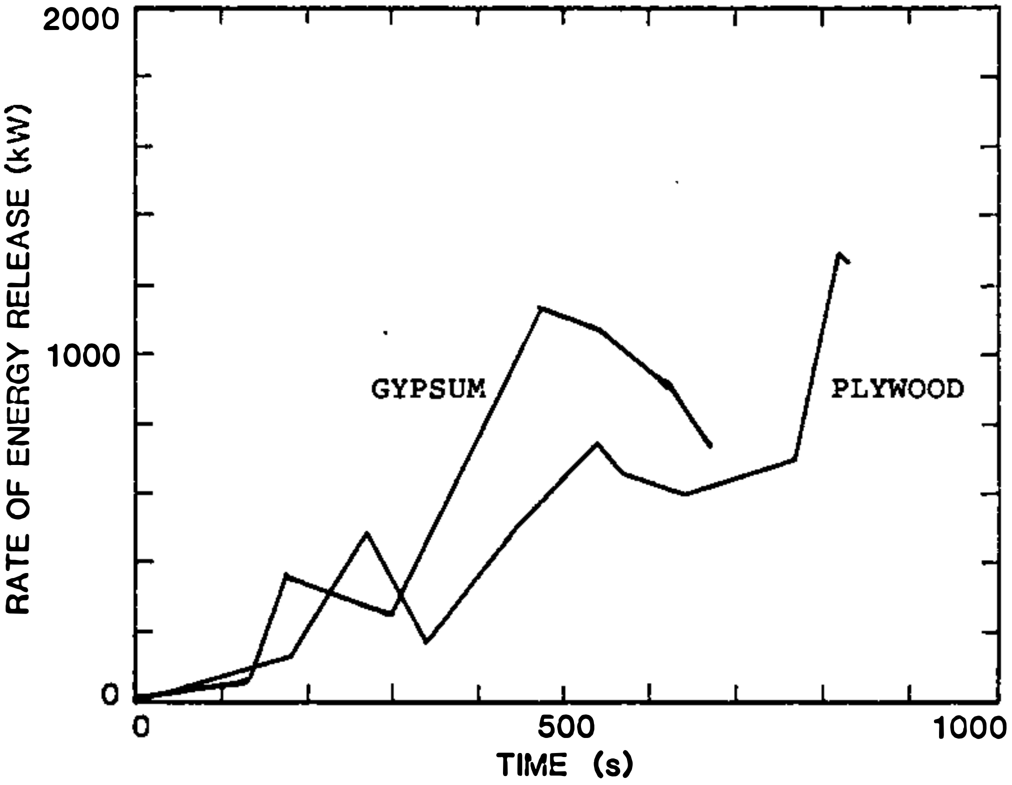


FIGURE 6 Cumulative energy release rate (bed plus chair).

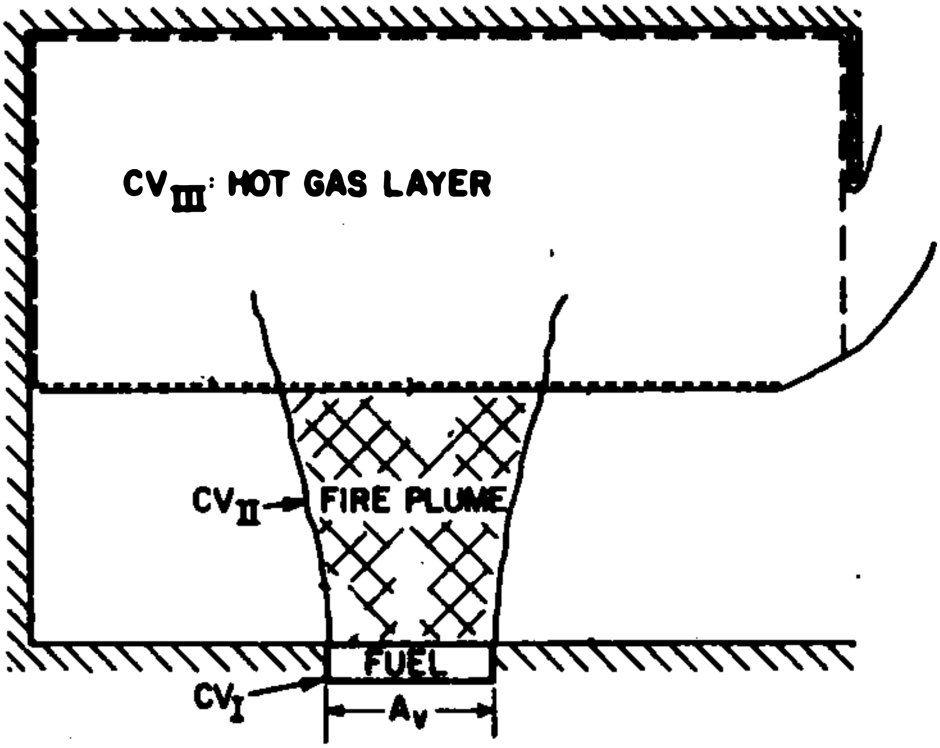


FIGURE 7 Control volumes (CV) used in zone models of fire growth.

Elaborate models using this principle now are in varying degrees of development. This presentation, however, uses a somewhat less sophisticated and more useable model developed by Cooper. Cooper's work has been further developed into a user friendly computer model that can be run on a minicomputer (Cooper, 1982). In the near future it probably will be possible to run a version on some of the microcomputers now being used in many engineering offices. Cooper's computer program, ASET (which stands for Available Safe Egress Time), is available to anyone.

ASET calculates the development of a variety of the hazardous conditions that accumulate in a space when there is sufficient air for combustion reaching the fire and none of the smoke or other gases are escaping from the space. This represents the conditions in a closed portion of a building and is an appropriate "worst" case condition for conservative design. To operate the ASET model, the height and floor area of the space involved is entered. Also entered are the previously developed energy release rate curves (Figure 4) for the combination burning of a bed and chair and two energy transfer constants.

The introduction of energy transfer constants constitutes a major simplification in ASET but reduces the accuracy of the results. The model is purposely conservative to accommodate this. The first energy transfer constant represents the proportion of the energy transferred by radiation from the flame and therefore not retained in the fire plume. For common materials where there is a reasonable amount of soot and other material in the flame, a value of approximately 30 to 35 percent is considered appropriate for the first constant. The second energy transfer constant represents that amount of heat not available for heating upper layer gases. The range usually considered for this is wider, ranging from about 60 to over 90 percent of the energy released by the fire. Unless experiments indicate a specific value, the conservative position for considering the development of hazardous conditions is to use a lower value, which assumes that more energy stays in the smoke cloud. Tests at NBS suggest that 80 percent is a conservative value appropriate for rooms like those in the case study (Jones and Quintiere, 1983).

For the example calculation, a flame radiant energy transfer constant of 35 percent and a total energy loss constant of 80 percent is used. The ASET model contains an instruction to cease calculations at any time the ceiling gas temperature exceeds 750°F (400° C). By that time, the energy feedback from the hot gas zone is approaching the point where any material not already burning will be raised to its ignition temperature.

Even before this, when the ceiling temperatures are around 450°F (232°C) the radiation from the hot gases is assumed to exceed human tolerances (Cooper, 1982). ASET calculates that the temperature in a closed gypsum board lined room of origin will rise to the 450°F (232°C) level in 20 seconds after open flaming ignition of the bed and that the smoke cloud in the room will descend to four feet above the floor in 90 seconds. Further, the model indicates that the temperature will climb to 750°F (400°C) by 320 seconds (Figure 8).

For the room lined with wood paneling, the temperature rises to 450°F (232 °C) in 245 seconds (Figure 9). The smoke layer descends to 4 feet above the floor in 90 seconds and the temperature prediction of 750°F (400°C) is reached in 330 seconds. There is little variation between the two conditions because there is very little involvement of the wood paneling in the early stages of fire development.

Important limitations on the ASET-produced data are contained in Figures 8 and 9. First, ASET depends on preset energy release data. The empirically derived data used is useful only to the time in the fire development when the upper room temperature (i.e., smoke zone) reaches a level that will affect the rate of burning of the fuel package being modeled. This is expected to occur by the time ASET indicates temperatures around 750°F (400°C). At this point the user should assume that flashover has occurred and ASET is no longer useful. Also, ASET assumes the presence of sufficient oxygen for continued free (fuel controlled) combustion. Once the smoke zone has descended to near the level of the fire, the oxygen supply will be limited. ASET will overestimate the burning and filling rates. For these reasons, Figures 8 and 9 and all subsequent plots of ASET-developed data do not show data indicating temperatures of greater than 750°F (400°C) and show dashed lines for parts of time-temperature curves that occur after the smoke level drops below the level of the fire. Dashed lines also are used to show ASET-indicated smoke levels after ASET predicts smoke zone temperatures of 750°F (400°C).

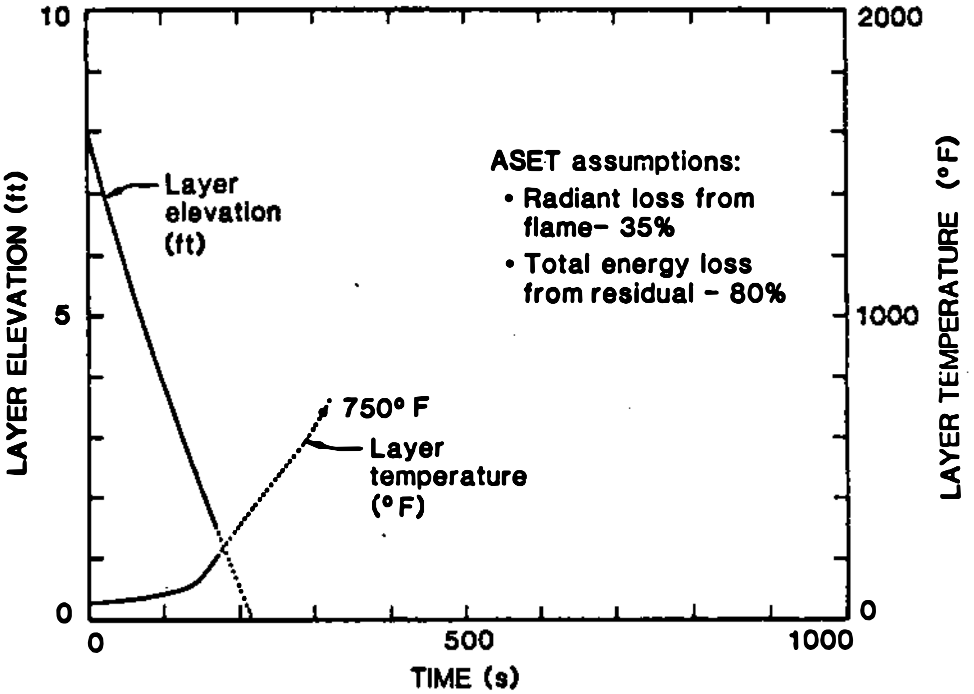


FIGURE 8 ASET results for closed room, gypsum board walls.

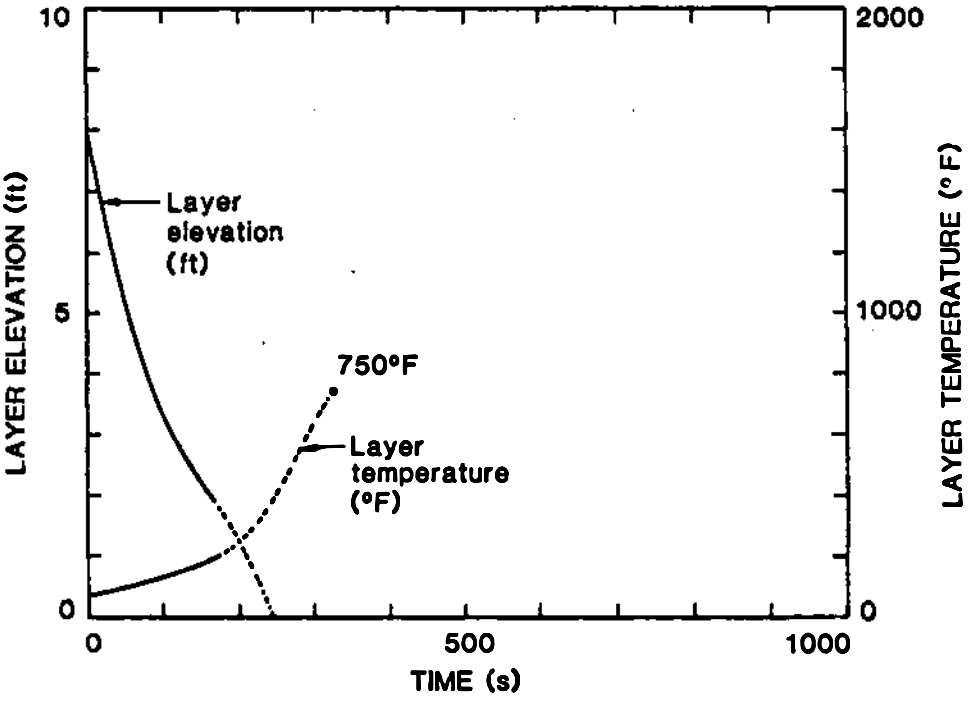


FIGURE 9 ASET results for closed room, plywood walls.

Prediction of Flashover

Flashover is a phenomenum resulting primarily from energy feedback from the smoke layer. As flashover occurs, fire transforms from a relatively modest energy condition of individual item burning to a ventilation controlled condition where generally all combustible exposed surfaces become involved. There are calculation models that attempt, with varying degrees of success, to plot the actual course of room temperature and energy release through this process. For this paper, however, once conditions approach those that can induce flashover, the impact of flashover is considered in the hazard evaluation. On this basis the calculations assume that flashover is certain if the ASET model shows a temperature in excess of 600°F (315°C) and that it occurs when the temperature reaches 750°F (400°C). This represents a conservative but not unlikely situation. In most fire tests the transition through the 600°F (315°C) to 1000°F+ (538°C) range is quite rapid. Actually, not every fire that reaches a temperature of 600°F (315°C) will pass through flashover, however, the probability of flashover is high in any such case and is assumed when using ASET.

Compartment of Origin (Post-Flashover Conditions)

At this point ASET can be again used to address the conditions in a corridor abutting and open to the room of origin. Some limited verification tests addressing pre-flashover hazard development in an exposed corridor were well predicted by ASET (Jones and Quintiere, 1983). More advanced models that will improve the accuracy of the calculations are in development.

Recently, the full-size room burn facilities at NBS and the associated smoke pollution control vent system have been used as a large-scale oxygen depletion calorimeter. Using this arrangement, a flashed-over room can be treated as the fuel package. The energy and fire products emitted from the door are determined by measurements of oxygen depletion and heat capacity as the products are caught and measured in the hood. Tests (Lee, in press) have been made on a bedroom set-up approximately half the size of the hotel room in the example case. In one test, the bedroom contained a bed, end table, and headboard fuel package with gypsum board lining. In the other test, the room had the same fuel package with plywood panel lining. These room tests and similar room tests of prison cells (Lee, 1982) are the only post-flashover measurement of this type made by NBS.

The design room in the example is twice the size of the test rooms and contains two bed arrays and two chairs. The door opening to the corridor is the same size. Prior to flashover, the rate of burning will reflect only those items involved by progressive spread of fire across or between items. After flashover, however, everything in the room will be involved. Again, energy release rates are cumulative.

Since the amount of surface area is approximately double that of the tests, and the second bed array is likely to be involved, every point on the energy release curve is doubled from the moment of flashover. This result again is probably conservative (i.e., overestimates the energy release rate) because the excess pyrolysis products being released in the room might actually dampen the burning rate and have some effect on reducing temperatures and the resulting radiation on the combustible surfaces. The doubling assumption, however, gives a modest but reasonable margin of safety. Also, since the two chairs will be involved in the post-flashover fire, the energy available from these items is added to the curve.

With these assumptions, new curves are developed for both the gypsum board and plywood lined rooms. In each case the curve from the moment of ignition to the moment of flashover is the same rate of energy release obtained from the pre-flashover plots shown in Figure 6. From the moment of flashover, however, the post-flashover energy release rates were used. The combined curve for fire in the example rooms is shown in Figure 10.

ASET is used to estimate the smoke filling and temperature rise in combined room and corridor arrangements. Based on limited data from a series of full-scale corridor filling tests (Jones and Quintiere, 1983), it is assumed that the energy lost by the upper layer for the combination of the room of origin and adjacent corridor is 90 percent. Three different combinations of the room of origin and adjacent corridor are assumed to be the smoke compartment size. These total areas considered are 10,000 ft^2, 5,000 ft^2, and 1,000 ft^2, representing corridor lengths of approximately 1,200 ft, 600 ft, and 100 ft. Figures 11 and 12 show the smoke filling and temperature rise data developed for the 10,000 ft^2 and 5,000 ft^2 conditions, respectively. Important values are also listed in the Table 1.

Rest of Building (Migration of Smoke and Other Fire Products)

The previous calculations trace the changing conditions in the compartment of fire origin. The next question addressed is: What products will migrate through the cracks and other openings into other portions of the building. A technical reference containing the formula used to calculate such migration is "Design of Smoke Control Systems for Buildings" by Klote and Fothergill (1983). The formula used herein are either contained in or derived from the information in Chapter 2 of that document.

The problem is one of fluid flow. The fluid movement forces are the combination of those produced by the fire and those resulting from ventilation, wind, and stack effects.

For the example problem, the fire room is considered to be on the second floor of the 25-story building. The selected design condition is based on an outside temperature of $5^{o}F$ ($-15^{o}C$) with an inside temperature of $70^{o}F$ ($22^{o}C$), a wind of 20 mph, and a possible location of the neutral plane as high as the fifteenth floor. It is conservatively assumed that all of the pressures are additive or cumulative. The pressure potential of the fire plume is conservatively estimated to be 0.08 inches of water (20 pa), produces a stack effect of 0.26 inches of water, (65 pa) and the wind produces a head of 0.10 inches of water (25 pa) for a total pressure of 0.44 inches of water (110 pa).

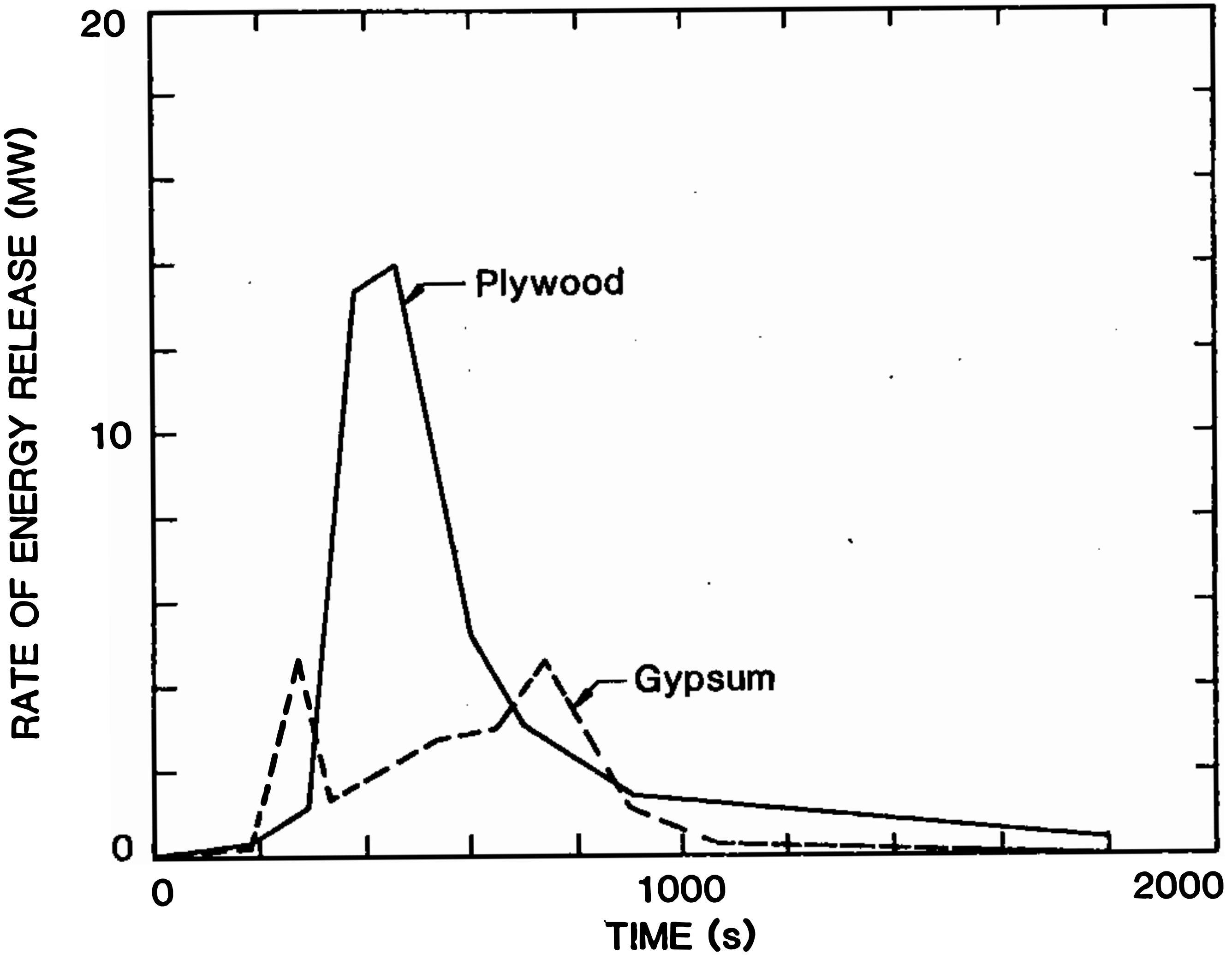


FIGURE 10 Cumulative rates of energy release (for post-flashover situations).

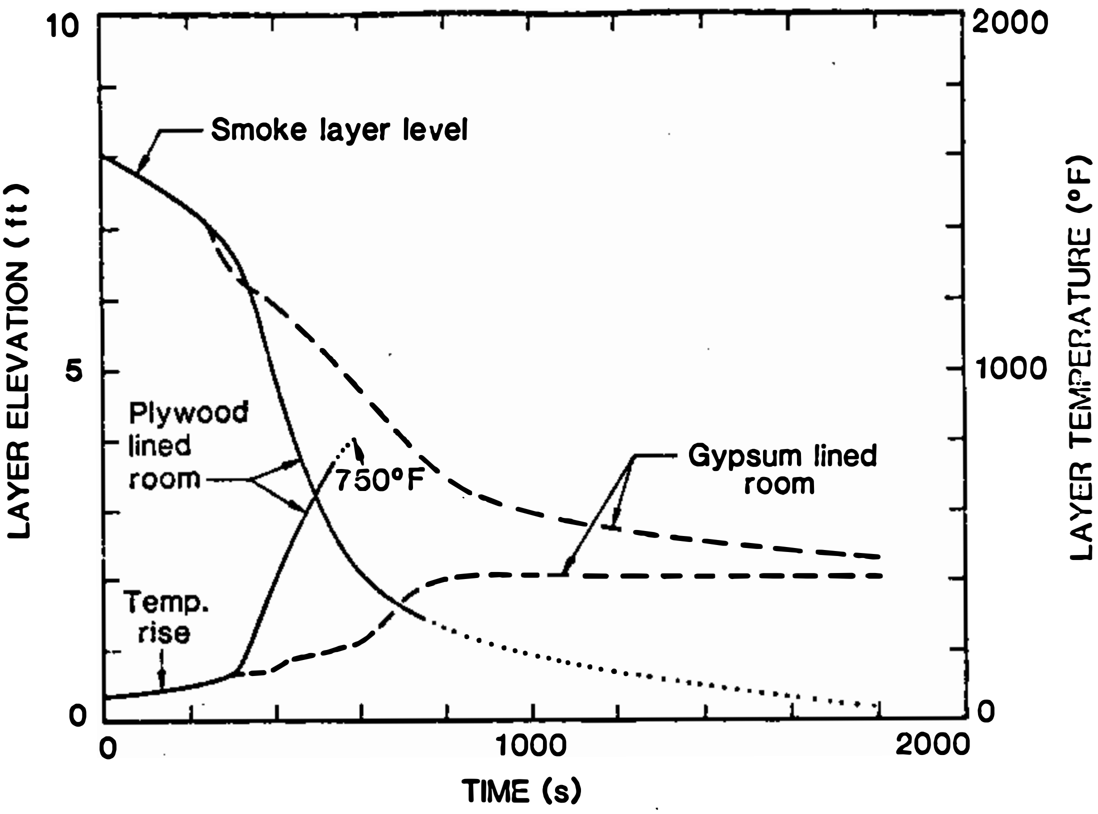


FIGURE 11 ASET-derived results, 10,000 ft^2 area.

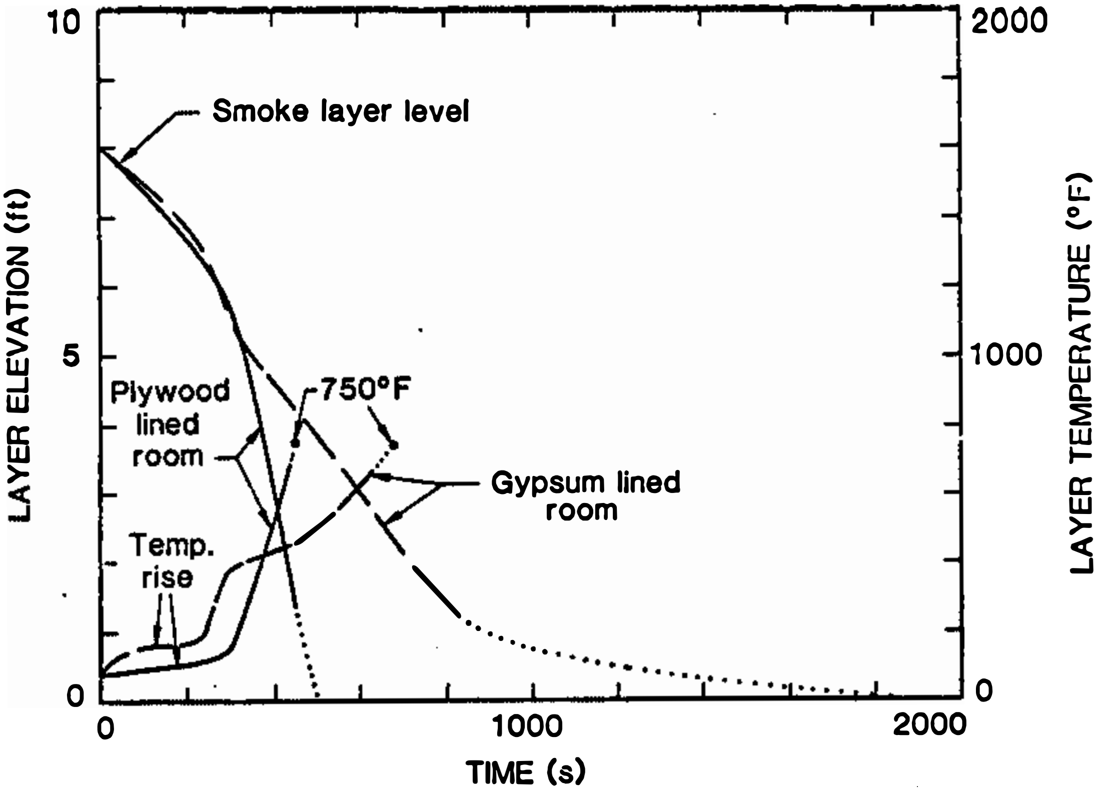


FIGURE 12 ASET-derived results, 5,000 ft^2 area.

TABLE 1 ASET-Derived Times to Reach Individual Conditions

Fire Scenario (Room Lining and Total Area)	Time and Smoke Layer Temperature at Various Smoke Layer Elevations			Time to Smoke Layer Temperature	
	5 ft	3 ft	1.5 ft	450°	750°F
Gypsum Lined					
1,000 ft^2	170 sec, 100°F	260 sec, 700°F	280 sec, 700°F	[a]	[a]
5,000 ft^2	370 sec, 210°F	610 sec, 310°F	780 sec, 486°F	750 sec	[a]
10,000 ft^2	570 sec, 230°F	1,000 sec, 370°F	< 2000 sec, 400°F	< 2000 sec	< 2000 sec
Plywood Lined					
1,000 ft^2	140 sec, 100°F	245 sec, 170°F	320 sec, 220°F	[a]	[a]
5,000 ft^2	350 sec, 200°F	400 sec, 500°F	440 sec, 675°F	400 sec	[a]
10,000 ft^2	400 sec, 370°F	510 sec, 660°F	720 sec, 900°F	440 sec	560 sec

[a] Indicated temperature not reached prior to descent of smoke layer below level of fire.

The calculation of smoke transfer through any specific part of the smoke compartment enclosure requires determinations of:

1. The cumulative fluid flow from the fire compartment.
2. The portion of that flow passing through any given component (e.g., smoke barrier, stair opening).
3. The portion of the flow that contains fire products.
4. The concentration of contamination in the smoke flow (carbon monoxide for this example).

The expression of Bernoulli's theory for flow through cracks and small openings is:

$$Q_a = KA\ (\Delta P)^{1/2}, \qquad (1)$$

where Q_a = flow (cfm), $A = A_e$ effective leakage area (ft^2), ΔP = pressure differential (inches of H_2O), and K = constant (2610 for dimensions shown). All of the variables in the above formula are either determined or measurable except for the effective area (A_e). A_e is derived from the measured leakage areas and the relationship of those areas of the inflow (suction) openings into the compartment to those of the outflow (discharge) openings from the compartment. The relationship of actual leakage area to effective leakage area can be expressed as:

$$A_e = \frac{A_i A_o}{(A_i^2 + A_o^2)^{1/2}}, \qquad (2)$$

where, A_i= total area of all leakage opening on the intake (suction) side and A_o= total area of all leakage openings on the outflow (discharge) side.

In the example problem, however, the interest is in the leakage through a specific hardware arrangement such as a door. Also, until the smoke layer reaches the floor, only a portion of the leakage will be smoke laden. The smoke leakage (Q_s) through any particular hardware element can be expressed as a proportional relationship as follows:

$$Q_s = Q\ \frac{(A_h)\ (A_s)\ (T_s)^{1/2}}{a(A_t)\ (A_h)\ (T_a)^{1/2}} \qquad (3)$$

where, Q_a = total fluid flow from Eq. 1, A_h = Total leakage area of hardware component, A_t = Total leakage area of all elements in compartment that are involved in the same flow (i.e., inflow or outflow), A_s = Leakage area of hardware component above smoke layer, T_s = absolute temperature of smoke layer, and T_a = absolute ambient temperature.

In the example problem, the following situations involving three example fire conditions are considered:

1. Smoke leakage from the floor of origin into open or closed stair or elevator shafts when the floor is undivided.
2. Smoke leakage through smoke barrier doors from the fire side to the safe side of the floor is divided into two equal sections by smoke barrier doors on opposite sides of the building.
3. The expected redistribution of smoke leakage from fire floor to floors in higher portions of the building.

For the example problem the leakage areas involved are estimated as follows:

1. The exterior walls on each floor are approximately 25,000 square feet. Using the data of Klote and Fothergill (1983, Appendix C), a wall of average tightness with the windows closed would be expected to have a leakage rate of approximately 0.21 square feet per 1,000 square feet of wall area. Since the design case is based on extreme winter conditions, it is expected that the windows would be closed. The outside wall leakage area for the entire building is therefore approximately 10 square feet. Correspondingly, the outside leakage area for each of the two sections in the case where the building is subdivided by smoke barriers would be 5 square feet in each zone.
2. The floor has four stairwells (two in each smoke zone in the divided case); each door is 36 inches wide by 78 inches high. The gap on each side and over the top of the door is 1/8 inch. There is a 1/2-inch undercut.
3. There are six elevators (two banks of three doors each). The elevator doors are each 60 inches wide (two 30-inch leafs) by 78 inches high. There is a 1/4-inch gap around the door and a 1/4-inch gap at the overlap of the two leaves. When the doors are fully open there is a 1-inch gap all around the car between the car and the face of the shaft.
4. Each of the two smoke barrier doors assumed in the case where the floor is divided into two smoke zones consists of a pair of doors each 36 inches wide and 78 inches tall. These doors have a crack 1/4 inch wide at the top, down each side, and at the edge where the leaves meet.

To calculate cumulative flow (Q_a) from the fire compartment using Eq. 1, it is necessary to determine the effective leakage area (A_e) using Eq. 2. Figure 13 contains detailed calculations of A_e for three different door arrangements. In each case the floor is undivided and all windows are closed, but the 4 feet by 5 feet window in the fire room is broken out. The effect of opening or closing stairwell or elevator doors is demonstrated by the differences in effective area.

Figure 14 makes similar calculations to determine the effective area except that smoke barriers reduce the size of the smoke zone to half the floor. Leakage from the fire zone is both into the stairs and

$$Ae = \frac{Ai\ Ao}{\sqrt{A_i^2 + A_o^2}}$$

Case 1: No Smoke Barriers

(a) All doors closed, window in fire room broken.

Ai = (given) wall leakage area + window area
= 10 + 20
= 30 ft^2

A_o = 4 stair + 6 elevators (all closed)
= 1.16 + 3.66
= 4.8 ft^2

$$Ae = \frac{(30)\ (4.8)}{\sqrt{(30)^2 + (4.8)^2}} = 4.7\ ft^2$$

(b) Same as (a) except 1 stair open on fire floor and at least 3 other doors in same stairs open on floors 15th floor or above.

A_i = 30 ft^2 (see (a) above)
A_o = Open door + 3 closed doors + 6 closed elevators
= 19.5 + 0.88 + 3.66
= 24.04 ft^2
A_e = 18.8 ft^2

(c) Same as (a), except 1 elevator open on fire floor.

A_i = 30 ft^2 (see (a) above)
A_o = opening between cab and shaft + closed doors + 5 elevators
A_o = 1.92 + 1.16 + 3.05
= 6.13 ft^2

Ae = 6.0 ft^2

FIGURE 13 Calculation of effective leakage areas (Ae)--full corridor exposure.

elevators on the fire side of the floor or through the smoke barriers. In five of the six cases in Figures 13 and 14, the leakage from the fire zone to the other portions of the building is significantly smaller than the total inflow leakage through the broken window and infiltration around closed windows. In these cases the effective area (A_e) is controlled by the size of the cracks and other openings from the fire zone into the rest of the building. Additional openings from the fire zone would increase A_e and thereby increase flow. In the third situation where both a smoke barrier and the stairwell doors on the "safe side" are open, the outflow leakage area is significantly larger than the total area of the opening through the broken window and around the window cracks. In this case, the leakage rate is primarily controlled by the restriction of the inflow air, and opening more doors

Case 2: Floor Divided in Half by Smoke Barriers

(d) All doors and elevators closed.

A_i = wall leakage on fireside of smoke barrier plus window area

$A_i = 5 + 20$
$= 25\ ft^2$

A_o = 2 stairs + 3 elevators + 2 smoke barriers
$= 0.584 + 1.83 + 1.56$
$= 3.970$

$A_e = 3.9\ ft^2$

(e) One pair of smoke barrier doors open, all other doors closed.

Note: While area of open pair of barrier doors is 39 ft^2, the leakage area through the "fire" side is determined by the leakage into the elevator shafts and stairs on the now open floor.

$A_o = (0.584 + 1.83)\ 2$
$= 4.83$

$A_e = 4.7\ ft^2$

(f) One pair of smoke barrier doors and 2 stairwell doors open on "safe side." (Also at least 2 doors above 15th floor open on each stair.)

Note: Leakage area from "safe" side now exceeds leakage area of open pair of doors. In this case, leakage through the fire side is determined by the leakage area of the smoke doors and the other leakage areas on the "fire side".

$A_o = 0.584 + 1.83 + 39$
$= 41.4\ ft^2$

$A_e = 21.4\ ft^2$

FIGURE 14 Calculation of effective leakage areas (Ae)--half corridor exposure.

and shafts on the outflow side would have little effect on the total flow through the fire zone. Conversely, breaking or otherwise opening another window in the fire zone could increase the rate of flow from the smoke zone into other areas.

Once the effective area has been established, the traditional fluid flow relationships in Eq. 1 can be applied. The results are shown in Figure 15 for all six cases. Note that the effective areas range from a minimum of 4 ft^2 to a maximum of 21 ft^2. The corresponding total pressure induced flow from the smoke compartment ranges between 7,000 and 36,000 cfm.

$$Q_a = KA\,(\Delta P)^{1/2}$$

where: $K = 2610$

$A = A_e\,(ft^2)$

$\Delta P = 0.44$ in. H_2O (given)

Case 1: Full Corridor Exposed

(a) $A_e = 4.7\ ft^2$

$Q_a = 8137$ cfm

(b) $A_e = 18.8\ ft^2$

$Q_a = 32548$

(c) $A_e = 6.0\ ft^2$

$Q_a = 10{,}387$ cfm

Case 2: Floor Divided in Half by Smoke Barriers

(d) $A_e = 3.9\ ft^2$

$Q_a = 6752$ cfm

(e) $A_e = 4.7\ ft^2$

$Q_a = 8137$ cfm

(f) $A_e = 21.4\ ft^2$

$Q_a = 37{,}049$ cfm

FIGURE 15 Calculation of total mass flow.

The flows developed are constant through the course of the fire so long as the pressure and the openings remain the same. The portion of the flow that is actually smoke laden, however, will vary according to the position of the smoke layer predicted in the previous analysis of conditions inside the smoke zone. When the smoke layer is above the soffit height of the doors, all of the flow out of the smoke compartment will be essentially clean air. The clean air may carry some odor or light haze developed from eddies and other turbulences that cause a small portion of the smoke to drop below the predicted smoke layer. If the smoke layer drops to the floor, then all of the flow from the fire zone will be smoke laden.

Where the outflow from the smoke compartment is distributed among a number of cracks or openings, the amount of the flow passing through any single opening is only a proportion of the total flow. Flow through specific openings also will be affected by density differences resulting from temperature differences between the smoke layer and the lower layer. The effect will be proportional to the square root of the ratio of the absolute temperatures of the two gases. In the cases evaluated in this example, the temperature differentials have not been considered. Eq. 3 shows this relationship.

Figure 16 is a plot of the rate of leakage at a stairwell door, both open and closed. The plot also shows the difference in leakage between the smoke conditions generated from the gypsum board lined room and the plywood lined room. The different leakage rates for gypsum board and plywood lined rooms reflects the difference in the speed of descent of the smoke layer. Figure 17 is a similar plot showing the leakage into an elevator shaft through closed and open elevator doors. In the case of the open elevator door the leakage area is not the full area of the door opening but the area of the crack between car and the shaft.

Figure 18 shows the movement of smoke through a smoke barrier for three different situations, namely, when the doors are all in the closed position, when one of the smoke barrier doors is open while all of the other doors stay in the closed position, and when stairwell doors on the "safe side" are open into stairways that have significant venting capabilities of their own (into upper floors and out through the windows of those floors). The significant differences between the two cases of open smoke barrier doors reflects the impact of effective leakage area as expressed in the Eq. 3. In the former case, the flow is constrained by the relatively small amount of outflow area available to it in the "safe zone." In the latter case, the flow, while much greater, is throttled by the limited area for intake into the fire zone. It is important to note that in both cases where a smoke barrier door is open between the fire zone and safe area, the calculations are based on the door being open for only a brief period of time. If the door were to remain open for any extended period of time long enough to establish a hot layer on the safe side, the value of the smoke barrier would be lost and the entire floor would operate as a smoke zone filling approximately as described in the previous section covering the compartment of origin.

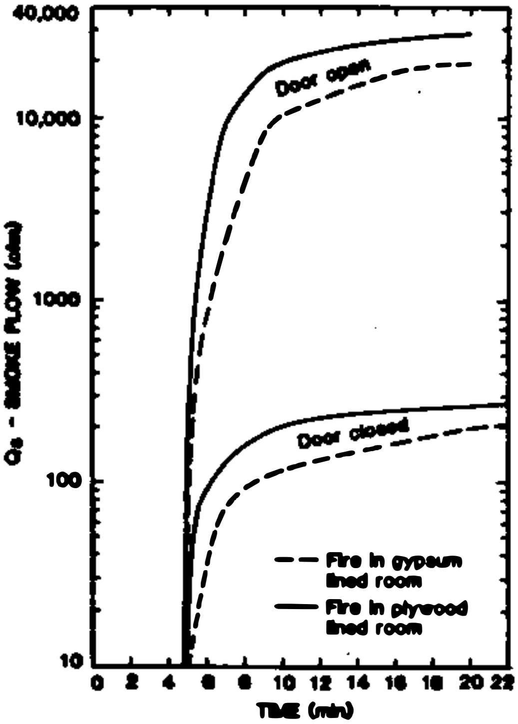


FIGURE 16 Smoke leakage (Q_s) through a stairwell door.

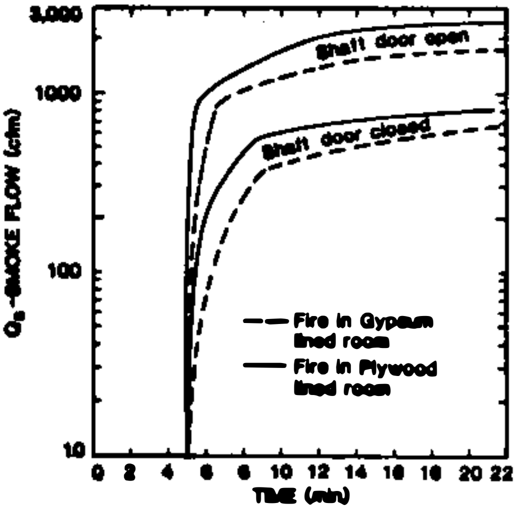


FIGURE 17 Smoke leakage (Q_s) through an elevator door.

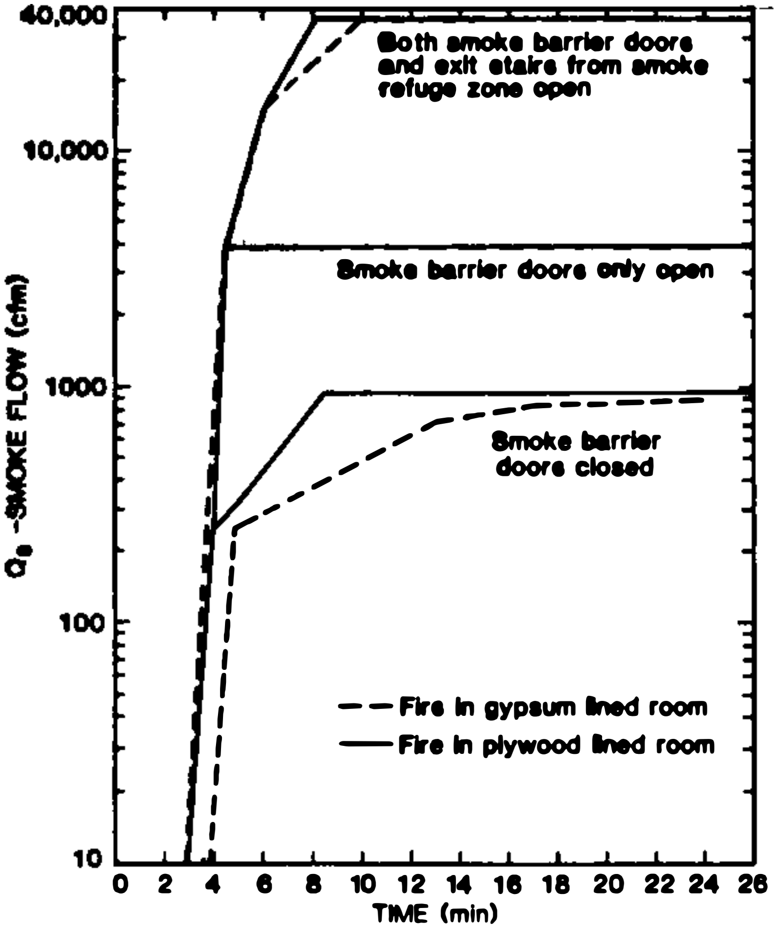


FIGURE 18 Smoke leakage (Q_s) through a set of smoke doors.

Since the ASET model also calculates carbon monoxide concentration, it is possible to give the rate of increase of carbon monoxide by transfer from the fire zone. Tables 2 and 3 give values associated with the leakage rates shown in Figures 16, 17, and 18.

Having determined the rate of passage of smoke into a stairway or elevator, it is often desirable to estimate the redistribution of smoke to other floors throughout the building. For the 25-story building in the example problem the smoke will be discharged through the shafts to floors above the neutral plane. The same equations used to determine the passage of smoke from the fire zone apply. For example, consider that the leakage areas from the stairwell are the same on each floor (i.e., all the stairwell doors above the neutral plane are closed or all are open). The stack effect in the stairwell generates a different pressure for each floor. The stack effect formula is detailed by Klote and Fothergill (1983, Chapter 2).

For the conditions of the example case, the outflow pressure from the stairwell into the rest of the building will range from zero at the

TABLE 2 Carbon Monoxide in Outflow Smoke--No Smoke Barrier

Time (min.)	CO Conc. (ppm)	Smoke Outflow (Qs) (cfm)			
		Thru Closed Stairwell Door	Thru Open Stairwell Door	Thru Closed Elevator	Thru Open Elevator
		Fire in Gypsum Board Lined Room			
6.5	565	69	2476	225	866
9.0	2459	104	6908	329	1108
12.0	3479	139	12932	450	1437
16.5	4936	173	18126	554	1731
20.0	5075	190	19476	589	1801
		Fire in Plywood Lined Room			
6.5	388	103	6908	329	1108
9.0	5423	190	20152	606	1835
12.0	6941	225	25865	710	2147
16.5	7895	252	28618	779	2320
20.0	8384	260	30072	814	2389

TABLE 3 Carbon Monoxide in Outflow Smoke--Base Floor Divided by Smoke Barriers

Time (min.)	CO Conc. (ppm)	Smoke Outflow (Qs) (cfm)			
		All Doors Closed	Barrier Doors Open		
			Other Doors Closed		Stair Doors Open
		Fire in Gypsum Lined Room			
4.5	3163	277	4069[a]		6129
6.0	6297	381	"		16100
8.5	11380	502	"		28046
10.5	21220	623	"		37049[a]
12.5	44330	727	"		"
20.0	104100	866	"		"
		Fire in Plywood Lined Room			
4.5	439	242	1662		1662
6.0	1851	364	4069[b]	606	23268
8.5	7877	918	"	710	37049

[a] Maximum flow through opening has been reached.

[b] Smoke layer has reached floor level.

neutral plane on the fifteenth floor to 0.2 inches of water (50 pa) at the twenty-fifth floor with a linear distribution across the intervening floors. The flow is proportional to the square root of the pressure differential (Eq. 3). Smoke leakage is calculated to range from 4 percent to the eleventh floor to 14 percent to the twenty-fifth floor. In a more complex situation where both the pressure and the effective area vary, the problem is more complex and tedious but solvable.

FIRE SAFETY SYSTEMS

Previous considerations have related to the growth and transport of fire and fire products without consideration of the impact of any fire safety system. In any building, however, there are systems designed to resist, extinguish, or otherwise impact upon the fire. The following portion of the example problem considers several of these fire safety systems.

Structural

The principal structural consideration is the building frame (i.e., the columns, beams, and other primary and secondary members that actually bear the live and dead loads of the structure). For example, consider the effect of a fire on the temperature of an 8-inch-wide flange beam in the room of fire origin. The expected time-temperature history in both the gypsum lined and plywood lined rooms is calculated using COMP/F2, a program for calculating post-flashover fire temperature developed by Babrauskas (1979). This model was chosen over several others because of its completeness, public availability, and ability to use rate of energy release inputs as developed in the example problem. The energy release curves shown in Figure 10 and used to predict the growth of fire products and spread of smoke in the compartment of fire origin also are used in the COMP/F2 calculations. To maintain the concept of worst case, the environmental conditions are based on the room door being closed and the window to the room being broken early in the fire. The COMP/F2 model also requires knowledge of the effective heat of combustion, which is the ratio of energy release rate to mass burning rate and is derived from the free burn tests (Figure 4).

The temperature rise in the flange of the beam is then predicted for several different thicknesses of fire proofing using the calculation system developed by Iding, Nizamuddin, and Bresler (1977). This model is a finite element model that has demonstrated reliability in a number of large scale experiments. The model traces the migration and dispersion of energy from a fire through the insulating material and the exposed structural member. The predicted temperature rises in the bottom flange of the 8-inch beam are shown in Figures 19 and 20.

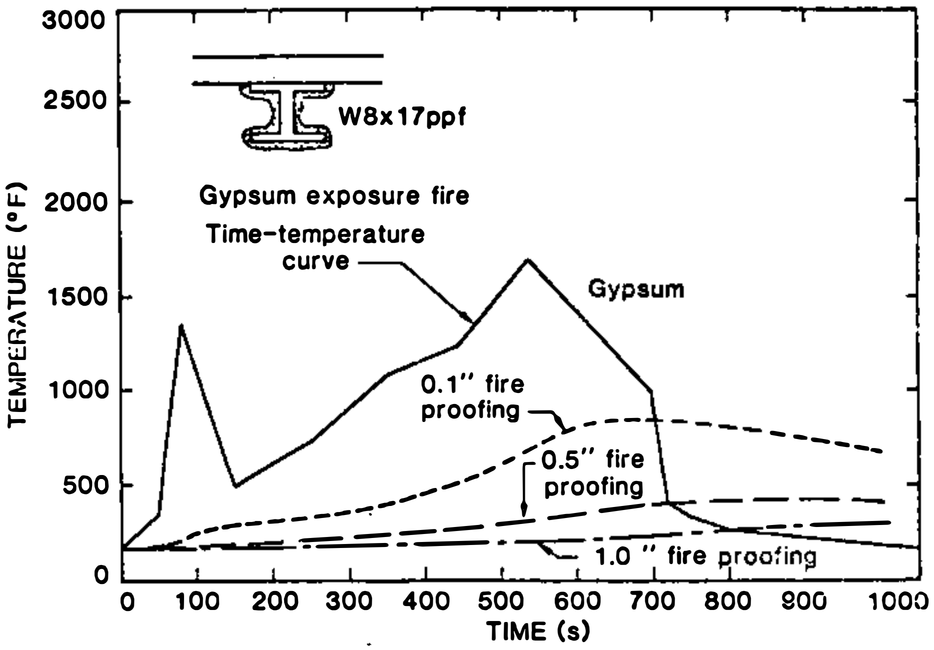


FIGURE 19 Predicted temperature of beam flange exposed to fire in gypsum lined room.

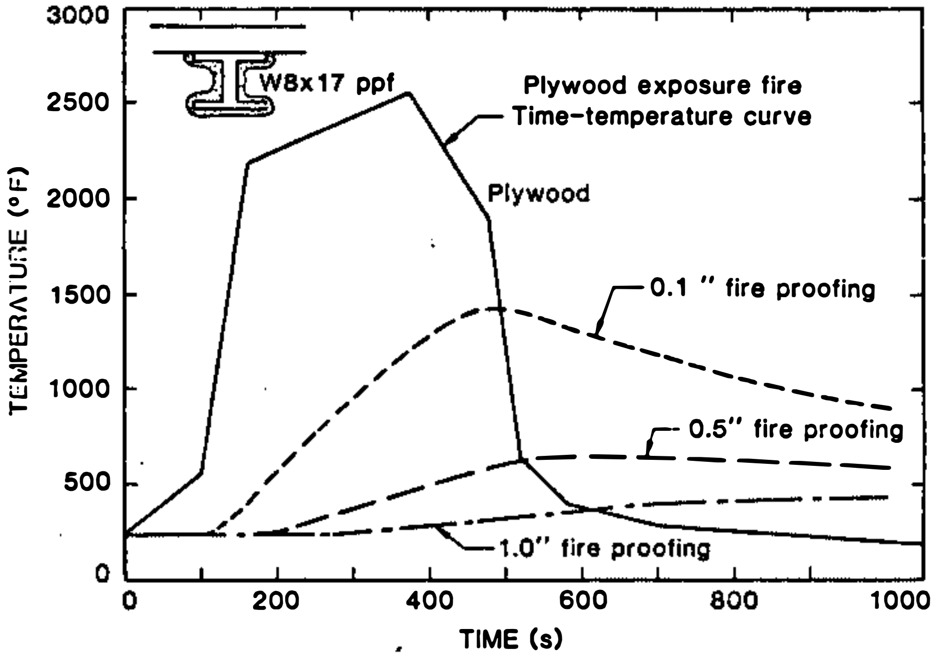


FIGURE 20 Predicted temperature of beam flange exposed to fire in plywood line room.

Compartmentation

Compartmentation is the design of enclosing boundaries that will remain intact during a fire and prevent the passage of smoke and heat. Smoke control systems, which will be discussed later in the paper, can also serve this function by countering the driving pressure. The structural integrity of compartment boundaries is important but no calculations are included in this example.

Detection and Extinguishment

Detection and extinguishment are considered together for purposes of this example. No mathematical models for the calculation of the suppression capabilities of extinguishment systems such as sprinklers are known to the author. There is, however, a broadly accepted qualitative understanding of the effectiveness of sprinklers, particularly where the fuel loading is moderate as in the example case.

This discussion therefore considers the prediction of the fire condition at the time of actuation of a detection device or sprinkler head. The basic research underlying the prediction of the operation of detection devices has been done by Alpert (1972) Heskestad and Delichatsios (1977, 1978), Benjamin (1980) and Evans (1981). Recently the National Fire Protection Association (NFPA) Committee on Signaling Systems formally proposed a new Appendix C for NFPA Standard 72E-M, Guide for Automatic Fire Detector Spacing (National Fire Protection Association, 1983b). This guide provides the basic information for determining the expected speed of operation of heat response devices including both sprinklers and heat detectors and, to a reasonable first approximation, smoke detectors. Since the NFPA draft standard is generally available, it has been extensively used in this example.

The response of heat reactive detectors (generally presuming a smooth ceiling) can be expressed as a relationship of six factors are:

1. The device temperature response setting in terms of the difference between the response setting and the ambient (prefire) temperature in the space.
2. The response time index, the thermal lag built into the mass of the detector.
3. The rate of fire growth in terms of change of rate of energy release.
4. The rate of energy release specific at the moment of consideration.
5. The height of the ceiling over the fire.
6. The lateral distance of the device from the fire.

For the example problem, the height of the ceiling is 8 ft. (The height of the ceiling over the fire is 6-1/2 ft.) The rate of fire growth is shown in Figures 8 and 9. For approximately 1 minute both fires (gypsum and plywood lined rooms) grow at a relatively slow rate (a rate that would require aproximately 600 seconds to double the rate of energy release) and then change quickly to very fast fires that would double their energy approximately every 100 to 150 seconds.

The expected level of energy at the time of response and the time from response to flashover can be predicted for devices having different device time constants and different locations (9 ft. center of the room, and 15 ft., and 18 ft. from the source of the fire). The response time of a smoke detector located in approximately the same position can so be predicted.

The response time index is a measure the thermal lag of the heat actuated element, which may be a fusible link, a liquid filled glass bulb, a chemical cartridge, or other arrangements.

Within the past decade a new family of sprinkler heads with device time constants that are an order of magnitude faster than traditional sprinkler heads has been developed. Heskesad and Delichatsios (1977 and 1978) has measured and reported on the response time indices of many sprinkler heads. The newest fast response heads have indices of 20 seconds whereas traditional sprinkler heads have indices ranging from approximately 100 seconds to slightly over 300 seconds. Of the standard heads, the fusible link type heads are generally faster than liquid filled glass bulb heads.

Figure 21 shows the energy release rate at the time of operation of different sprinklers at the three locations. The example shown is based on an initial room temperature of 65°F and sprinkler set at 135°F.

The curves in Figure 21, predict the detector response in a space with enough volume to absorb all the energy of the fire without flashover. In the example problem, the relatively small size of the bedroom results in a prediction of flashover when the fire is approximately 600 kW. Therefore, for the example problem, only those devices calculated to respond at an energy level below 600 kW are of interest.

The proposed guide for fire detector spacing in the report of the NFPA Technical Committee on Detection Devices (1983b) provides a series of graphs and calculations to estimate the response of smoke detectors. The guide is intended for large commercial or industrial applications and is consequently conservative for small spaces such as those in the example problem. For this reason, Figures 22 and 23 are adaptations of the pertinent graphs from the Technical Committee's report and depict the ceiling height and potential spacing in the example problem. Figure 22 is based on a fire time constant of 150 seconds (amount of time required to double the rate of energy release if that rate were to continue indefinitely). Figure 23 shows the rate for a time constant of 600 seconds. A fire time constant of 600 is appropriate for the rate of burning during the first minute of the example case since this low rate of burning only reaches about 70 kW before the mattress and bedding become sufficiently involved to cause a much more rapid rate of heat release. Figure 23 indicates that a ceiling-mounted smoke detector 9 ft from the fire source operates when the fire is approximately 70 kW in size.

Figure 22 is based on the faster fire time constant of 150 seconds to represent the fire after the first minute. At this rate the detectors at the 15 ft and 18 ft spacing are predicted to respond when the fire reaches approximately 250 and 350 kW respectively. This approach however ignores the smoke that had started to rise during the first minute at the lower energy release rate. It is expected that

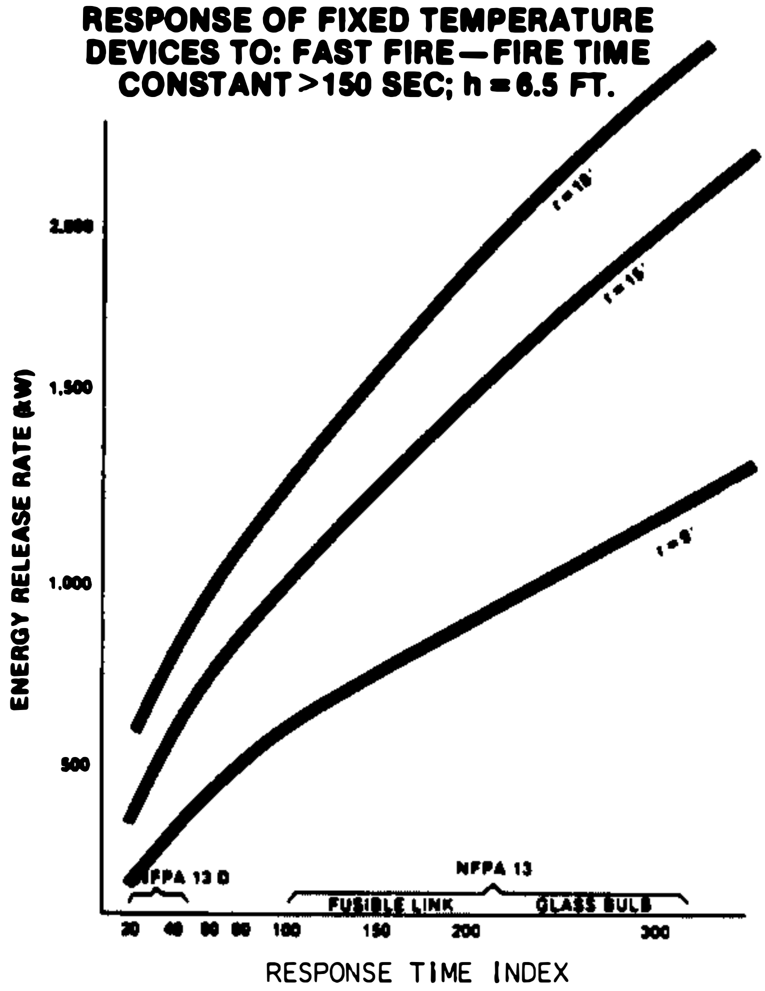


FIGURE 21 Predicted response of sprinkler heads as a function of device response time constant.

this smoke would have some effect. Comparing the indicated response of a detector at 9 ft. in this fire situation to the response of the same detector exposed to the slower (600 seconds fire time constant) fire growth, there is approximately a 53 kW increase in the size of the fire at the time of the detector response. This increase suggests that smoke transport occurring in the initial minute reduces the energy level necessary to cause response of ceiling mounted detectors 15 ft. and 18 ft. from the fire source by 50 kW. These values are then 200 and 300 kW respectively.

By comparing the rates of energy release at the time of activation with the initial rate of heat release in the example problem (Figure 6), the time of activation of smoke detectors and the heat response element (of heat detectors and sprinklers) can be predicted. Table 4 presents typical predictions for the example cases.

Since ASET was used to calculate conditions through the compartment of origin, the capability of ASET to predict carbon

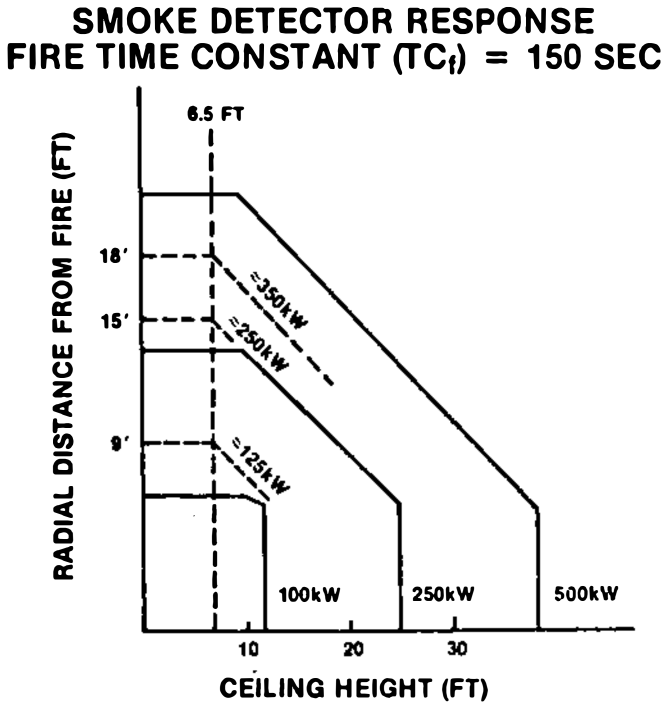


FIGURE 22 Predicted response of smoke detectors exposed to a fire with a 150-sec time constant.

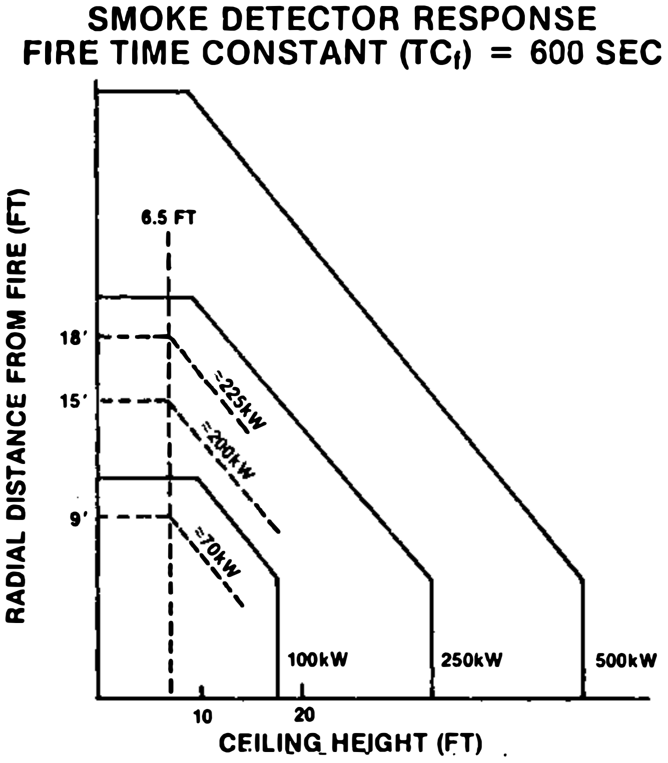


FIGURE 23 Predicted response of smoke detectors exposed to a fire with a 600-sec time constant.

TABLE 4 Selected Predicted Response Times for Detectors and Sprinkler Heads

	Gypsum Board Lined Room			Plywood Lined Room		
	r=9 ft	r=15 ft	r=18 ft	r=9ft	r=15 ft	r=18 ft
Smoke detector	60 sec	125 sec	150 sec	60 sec	150 sec	175 sec
Heat devices						
Tc_D = 20	100 sec	150 sec	F/O	120 sec	130 sec	F/O
40	150 sec	F/O	F/O	150 sec	F/O	F/O
80	180 sec	F/O	F/O	180 sec	F/O	F/O
80	F/O	F/O	F/O	F/O	F/O	F/O

NOTE: F/O = Activation during flashover transition, r = lateral distance of device from source, and TC_D = device time constant.

monoxide concentrations can be combined with other data to predict overall environmental conditions at the time of operation of any device or at any other time of interest. Table 5 makes a number of such comparisons.

Smoke and Heat Venting

Under certain conditions it may be desirable to use either gravity or mechanical means to vent a sufficient amount of the hot smoke and gases from the compartment of origin to maintain the smoke level at some minimum distance above the floor. To do this, it is necessary that the capacity of the smoke withdrawal system at least match the smoke production at the maximum burning rate.

The venting requirements of the fully involved room can be calculated from the energy release rate curves (Figure 10) and the analysis provided by ASET. For example, assume that an opportunity exists to use a freight elevator shaft as an emergency smoke vent shaft. The system must be able to transport the cab to a location below the fire point and there must be an emergency louver providing an opening above the 5-ft level into the elevator shaft at each floor. At the top of the shaft, there should be another opening and possibly an emergency fan to exhaust smoke from the shaft. For this calculation, we will assume that there is no wind and no stack effect and the smoke is relatively cool. The maximum imposed pressure assisting the movement of the smoke is therefore 0.02 inches of water (5 pa). Figure 24 demonstrates the calculation of the opening size that would be needed to maintain the smoke level above 5 ft.

TABLE 5 Selected Examples of Calculated Environmental Conditions at the Time of Various Events

Time		Smoke Layer Evaluation (ft) For Floor Areas in Sq. Ft.			CO(ppm) For Floor Areas in Sq. Ft.			Smoke Volume (ft^3 · 1000) For Floor Areas in Sq. Ft.		
(sec)	Event	1000	5000	10,000	1000	5000	10,000	1000	5000	10,000
60	Smoke detector (gia)	6.8	7.8	7.9	180	160	155	1.2	1.0	1.0
60	Smoke detector (plywd)	6.7	7.7	7.8	120	106	104	1.3	1.5	2.0
100	TC_D20;r=9ft+(gyp)	6.0	7.5	7.7	265	215	208	2.0	2.5	3.0
150	TC_D20;r=9ft+(plywd)	4.8	7.1	7.5	290	198	190	3.2	4.5	5.0
220	Flashover(gyp)	4.0	6.7	7.2	750	500	450	4.0	3.4	8.0
220	Flashover(plywd)	3.5	6.8	7.1	650	380	275	4.5	3.4	9.0
260	Start peak 9 (gyp)	2.6	6.1	7.0	2475	1230	1095	5.4	9.5	10.0
460	Start peak 9 (plywd)	0.0	1.1	3.8	0	5880	3904	8.0	34.5	42.0

FILLING RATE AT MAX $\dot{q}$ AND 5 FT IS:

Q_G= GYPSUM LINES--(5,200 cfm)
Q_P= PLYWOOD LINES--(13,600 cfm)
MIN ΔP (≈200°F) = 0.02

$$A_e = \frac{Q}{2{,}610 \Delta P^{1/2}} = \frac{5{,}200}{2{,}610 \cdot 0.02^{1/2}} = 14 \text{ FT}^2$$

$$= \frac{13{,}600}{2{,}610 \cdot 0.02^{1/2}} = 37 \text{ FT}^2$$

IF ONE CAR (FREIGHT) ELEVATOR SHAFT WERE USED TO VENT (OTHER OPENINGS IN SHAFT ≈ 4 FT^2)

EXTRACTION FAN NEEDS TO HAVE Q OF:

$$\text{(GYPSUM)} \quad \frac{4+11}{11} \times 5{,}200 \approx 6{,}700 \text{ cfm}$$

$$\text{(PLYWOOD)} \quad \frac{4+16}{16} \times 13{,}600 \approx 15{,}100 \text{ cfm}$$

FAN CURVE TO BE SUFFICIENT TO OVERCOME SHAFT FRICTION LOSS AND DISCHARGE BACK PRESSURES

FIGURE 24 Calculation of elevator shaft as vent from ASET.

RESPONSE OF THE "EXPOSED"

In this paper, the "exposed" are considered to be any person or item that may be harmed by fire. This discussion focuses on the persons occupying the building. Inanimate objects (unless physically rescued by a human) normally stay in a fixed place and the extent of damage depends entirely on the environmental conditions to which such objects are exposed and their ability to withstand those conditions. Humans, on the other hand, are mobile, capable of making decisions, and highly susceptible to harm from fire effects.

The human response model involves the sequence of information (or cues indicative of a fire threat) that reaches the building occupants, the decisions of the occupants in response to the cues, and the action they take. As noted in Figure 1, these can be actions that attack the fire or can be related to movements primarily aimed at emergency evacuation to flee from danger. Either activity will probably involve actions that could have an important environmental impact on the fire such as opening and closing doors.

INFORMATION

The information reaching people may come either directly from the fire in the form of smoke, heat, noise, odor, or other indicators or from one of the fire safety systems in the form of alarms or announcements. If alarms or announcements are triggered by the operation of smoke and heat detectors, the fire condition at the time of alarm can be predicted. Some of these predictions are outlined in Table 5.

DECISIONS

At this time there is no developed method for analytical prediction of either the time or type of decisions that humans will make under fire stress. However, fire investigations are generating a body of data that may someday provide predictive capabilities.

The model in Figure 1 subdivides the type of decisions into five generalized categories. When presented with a cue that may indicate fire threat, a person may decide that:

1. It is not a real threat (e.g., the alarm bell indicates someone stuck in the elevator rather than a fire).
2. It may or may not be a threat (e.g., there is a faint or moderate odor of smoke that may come from fire or a nonthreatening overheating of an electrical device).
3. A threat clearly exists (e.g., flame, heavy smoke, or a totally accepted alarm or emergency message is received).
4. Action is required. This decision is sequential to the above decisions and may actually result from any of the three.
5. Action must be selected. Action selection is sequential to the determination that an action is needed and is conditional upon the previous decision on the level of threat.

The behavioral decision responses are continuously reiterated by the persons involved as they maintain a consciousness of their surroundings and continually re-evaluate the situation.

Although the decision element in the model is not amenable to calculation, it is an element that can be greatly affected by planning, training, and education. The value of considering decisions in the model rests in the ability to provide persons responsible for emergency planning with information on the speed at which the threat may develop and the amount of time that will be necessary to escape any threat. With this in hand, the planner can start his planning exercise with an understanding of the amount of time that will be available for the decision process.

ACTIONS

The general model in Figure 1 shows a variety of actions that can be taken. These can be placed in the categories of no fire response action, investigation to seek additional information and knowledge, transmission of warnings, attacking the fire, confining the fire, rescuing persons or property, and escaping the fire. Although it is possible to model, and thereby predict, any part of these actions that involves physical human activity (i.e., attack, confine, rescue, or escape), the example problem presumes that the decision made by the occupants in the hotel is limited to a decision to escape and the predictions made here address only that area.

The example problem is divided into three separate parts:

1. The time elapsed between the decision, by a person laying in bed, to attempt to escape and the time that person leaves his room and enters the hotel corridor.
2. The time for all of the occupants of the floor to traverse the corridor and reach the stairwell.
3. The impact of the escape process on stairwell access and competition for stairwell space if a series of floors are simultaneously evacuated.

Time in Room of Origin

Data on the time involved in those simple actions of arising and moving through a room are sparse. Pearson and Joost (1983) have conducted experiments in a highly instrumented laboratory setting. Their data express the minimum amount of time to undertake those activities by persons who knew beforehand exactly what they were going to do. Pearson conducted 12 different scenarios of activities comparing the response of young college students to several other groups including handicapped individuals, some of whom were blind, and a group of senior citizens who suffered from arthritis. Figure 25 reports part of Pearson's data and demonstrates a relatively modest difference between the performance of college age youth and those of older persons with arthritis. The two action sequences in Figure 25 are typical of the type of activity that would occur in the hotel rooms depicted in the example problem. Therefore, it may be expected that to exit any room except possibly the room of fire origin would require between 1-1/2 minute and 1 minute.

Escape through the Corridors

A prediction of escape through the corridors can be made using the escape and rescue model developed by Alvord (1983). This model is a discrete event simulation model of emergency actions within a facility. It has the capability of assigning rescue actions that might occur in a hospital, old age home, or nursery as well as escape actions. For the example problem, only the escape actions are used. The model uses

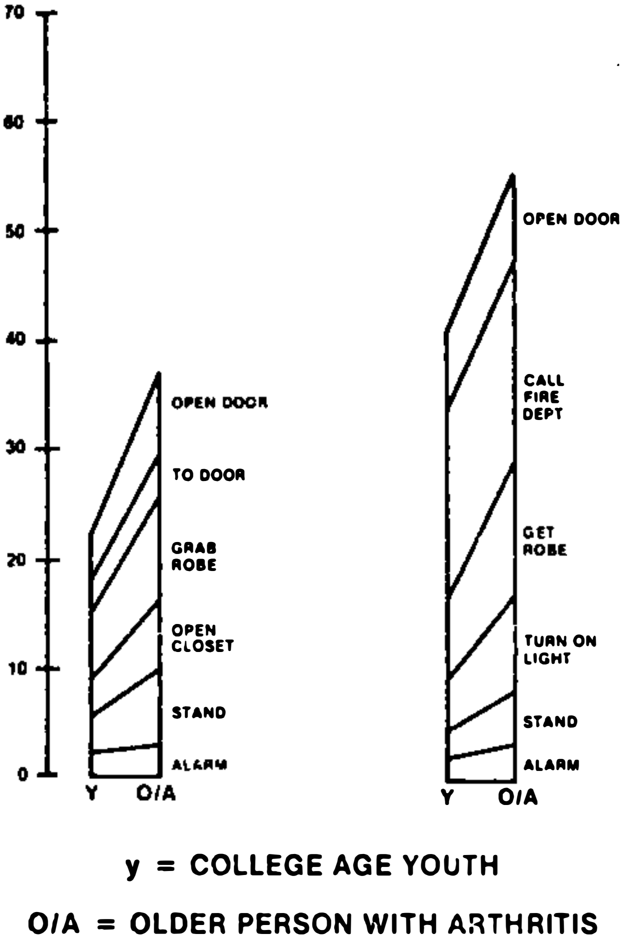
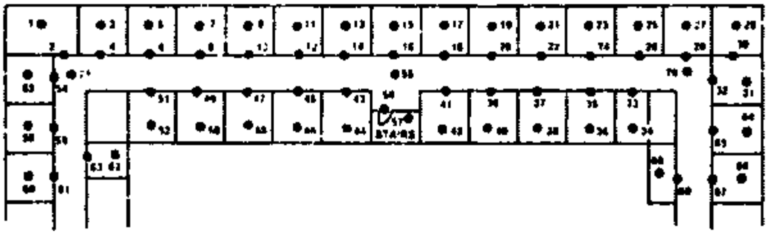


FIGURE 25 Timed response of subjects executing first response actions.

a network description of the facility and the location and response characteristics of all the occupants, which may include the reduced response capability of handicapped persons. For this example, however, all of the persons in the hotel are considered to be able to escape at a normal pace. Figure 26 shows a layout of one-fourth of the floor and the nodes necessary to run the model. The model demonstrates that even with four persons in each of the hotel rooms (an excessively high occupancy rate), it is possible for all the occupants to reach the stairway within 45 seconds of reaching their bedroom doors.

Evacuation of Multiple Floors

The impact of competition for the space in the stairways, a situation where multiple floors are simultaneously being evacuated is developed using the research work of J. L. Pauls of the National Research Council of Canada. Pauls work has been proposed by the NFPA Committee on Safety to Life as a new Appendix D, Alternative Calculation of Stair Width, to NFPA Standard 101, Life Safety Code (National Fire Protection



ESCAPE AND RESCUE MODEL
EXIT STAIRS SERVES 33 ROOMS
MAX ROOM POP.—4; MIN—0

E&R TRAVEL TIME THROUGH STAIR DOOR—45 SEC FROM ROOM DOORS—SHOWS NO CONFLICTS—PRESUMES NO CONFLICTS IN STAIRS

FIGURE 26 Layout for escape and rescue model.

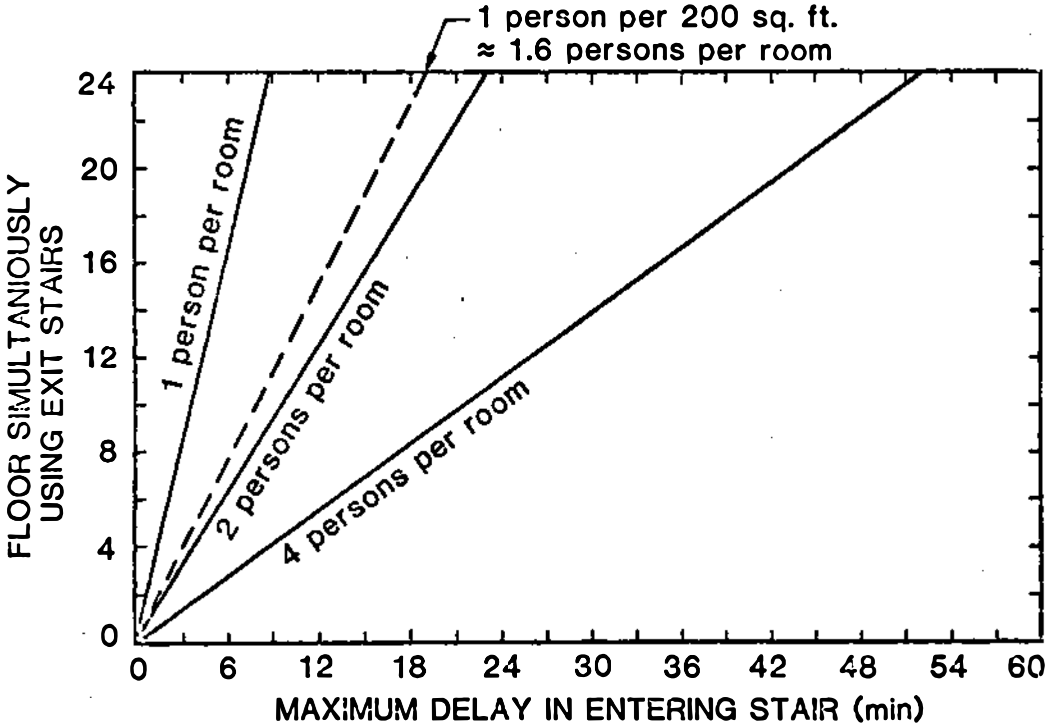


FIGURE 27 Maximum stairwell entry delay for evacuees.

Association, 1983a). The procedure can also estimate the delay in entering stairs if occupants reach the exits faster than they can pass through them.

Pauls has demonstrated through analysis of both announced and unannounced drills that flow in stairways and the capacity of stairs can be determined by assuming that the 6 inches of tread on each of the sides of the stairwell are unused. This assumption makes the flow approximately linear for the residual width of the tread and additive among all of the stairways that are in use. While there is some adjustment for differences in stair treads, the normal stairway will flow approximately 1 person per second for each 3.3 ft of effective width.

Pauls also has shown that typical travel time between floors is 15 seconds and that for optimum movement 4.5 persons per foot of effective width can travel between floors in that time. This number, of course, changes according to the number of landings and distance. The 4.5 persons per foot of effective width is used for the example cases. Obviously many more persons can be fit in the stairwell than the calculations proposed by Pauls. His work and the work of Fuin (1971) and Predtechenskii and Milinskii (1969) has demonstrated that there is a decrease of the rate of flow and that the number proposed by Pauls is a rational design value.

From Pauls' data, a formula can be developed to determine the amount of delay time for entering stairs. If people are exiting from only the fire floor, then the delay will occur on that floor. If the exiting procedure involves a number of floors, there is no effective way of predicting exactly where the maximum delay will occur. It must be expected that it can occur at a point where it may endanger some persons. The resulting formula can be expressed as

$$t_d = kEC/W,$$

where, t_d = the maximum delay time faced by the last person to enter a stairwell, k = a constant (3.3 in the English system), E = the total number of persons simultaneously attempting to escape from the building, C = the capacity of the stairs (i.e., 4.5 persons times the number of floors being evacuated times the total effective width of the stairs), and W = the total effective width of all the stairways being used.

Figure 27 graphically shows the results of this calculation for the evacuation of the 25-story hotel in the example. The graph shows the delays that would occur based on one person per room, two persons per room, or four persons per room. The dashed line represents the normal Life Safety Code assumption of one person per each 200 gross ft^2 of floor area (i.e., 200 per floor or 1.6 persons per room in the example floor layout). If all of the 24 floors (above the first) were to be evacuated simultaneously, the delay would range approximately from 9 minutes if there were only one person per room to as high as 52 minutes if there were four persons per room.

For the Life Safety Code occupancy load noted above, the minimum movement time to clear all persons from the fire floor into the stairs is calculated to be slightly less than 2 minutes if there are no other floors involved. This time includes 1 minute for start-up in bedroom, 45 seconds for travel to the stair entrance, and a 5-second delay at the stairs.

IMPACT

From the information developed, the time at which intolerable conditions will occur at a given place in the building and the time for people to avoid those conditions can be determined. Any human decision delays must still be estimated and allowed for in emergency planning.

In presenting the example, an attempt has been made to use only methods and data that are currently available to those engineers and other practitioners willing to make the effort to use them. At the same time, research is continuing and better information and models are in the process of development. As these emerge, more realistic and accurate design calculations will be possible.

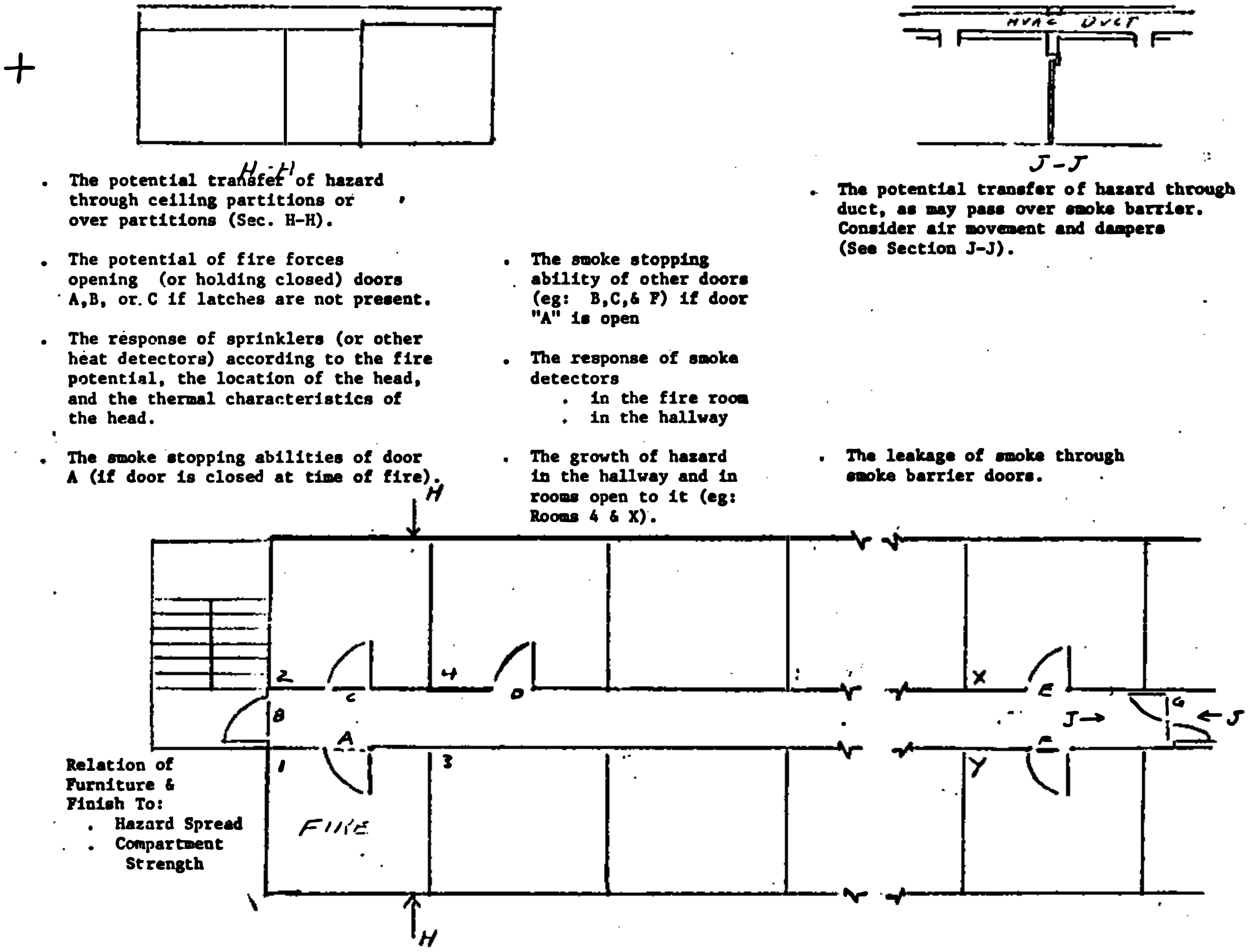
THE USE OF ENGINEERING MODELS TO APPRAISE SPECIFIC CODE TYPE CRITERIA

The preceding example is designed to analyze the total safety of a facility. The model allows for evaluation of alternative methods of protection and may well be used to analyze the impact of an individual parameter. Although the approach is general and workable in many facilities, its application envisions a specific design involving specific design cases. There are, however, numerous occasions when the desired evaluation is of a commonly applied criteria rather than a specific facility. Recently the NBS Center for Fire Research (CFR) has undertaken such an evaluation for the Department of Health and Human Services. It is felt that some aspects of this evaluation demonstrate the use of basic engineering methodolgy for such appraisals.

Initially the Department of Health and Human Services requested CFR to evaluate the impact of nine code requirements that are frequently questioned by design teams working on health care facilities. A capsule version of the questions asked is shown in Figure 28.

The process for applying engineering criteria to the questions has been organized as follows:

1. State the problem in code, architectural, or other field applicable terms.
2. Convert the code question to an engineering problem (e.g., What is the dynamic opening force that fire will apply to a door?).
3. Develop the engineering solution form (e.g., state the problem in terms of engineering data, formula, and models).
4. Identify data needs for the solution and determine the source of such data.
5. Execute a preliminary solution.
6. Verify the credibility of the approaches (use small- and large-scale tests).
7. State the credible engineering solutions.



- The potential transfer of hazard through ceiling partitions or over partitions (Sec. H-H).
- The potential of fire forces opening (or holding closed) doors A,B, or C if latches are not present.
- The response of sprinklers (or other heat detectors) according to the fire potential, the location of the head, and the thermal characteristics of the head.
- The smoke stopping abilities of door A (if door is closed at time of fire).
- The smoke stopping ability of other doors (eg: B,C,& F) if door "A" is open
- The response of smoke detectors
  - in the fire room
  - in the hallway
- The growth of hazard in the hallway and in rooms open to it (eg: Rooms 4 & X).
- The potential transfer of hazard through duct, as may pass over smoke barrier. Consider air movement and dampers (See Section J-J).
- The leakage of smoke through smoke barrier doors.

Relation of Furniture & Finish To:
- Hazard Spread
- Compartment Strength

FIGURE 28 Code questions being investigated.

Currently the project is at states (3) and (4). The approaches and methods to be used are similar to those previously expressed in this paper. The approaches listed in Figure 1 in the box "Growth and Transport" and the detection and extinguishment approaches listed under "Fire Safety Systems" are involved. In each case, the most advanced forms of calculation, model, and data are being used, and where competitive models exist the several models are being exercised to determine their relative effectiveness on the problem. The following 17 engineering tasks are being executed by members of the NBS staff:

1. Empirical furniture calorimeters burns.
2. Correlations with small-scale calorimeters.
3. Calculation of room ceiling jet.
4. Response of heat activated devices to room ceiling jet.
5. Response of product activated devices to room ceiling jet.
6. Development of multilayer conditions (hazard) in room.
7. Calculated time-temperature curve in room.
8. Development of multilayer conditions in corridor.
9. Calculation of corridor jets.
10. Response of corridor heat and smoke detectors.
11. Impact on rooms open to corridor.
12. Leakage into rooms with closed doors.
13. Leakage through ceiling voids.
14. Leakage through partition joints.
15. Leakage through ducts (inactive, supply, and return).
16. Leakage through cross corridor smoke doors.
17. Leakage at stair doors.

The validation phase will be accomplished by NBS in cooperation with the Factory Mutual Research Corporation. The current plan is to erect a large room and corridor arrangement with devices to determine leakage through the perimeter doors, vents, etc. A series of carefully controlled and instrumented tests will be undertaken to provide information that will allow an appraisal of the accuracy (and thereby the appropriate level of conservation or size of the required factor of safety) of the calculations proposed.

This approach is feasible because of technology and fire protection engineering advances that have taken place. The approach is proposed as a model for investigating and attacking important regulatory problems in a manner that will provide definitive answers supported by valid technical data.

CONCLUSIONS AND DIRECTIONS

The best means of achieving the underlying objective of rational, understandable, controllable, flexible fire safety requirements lay in the application of sound analytically based technology. Such technology has not previously existed for fire protection design but is now emerging. This technology also will provide the common language medium for the owner-operator (normally through his design team) to clearly communicate his needs to the research community and a route for responsive replies.

Fire protection engineering technology, while beyond the embryonic state, is still a newborn that is struggling and in need of support and encourgement. The underlying science and data are the milk for this baby, and the potential beneficiaries in the applied field must provide the love and encouragement.

The maturity of fire protection engineering as a fully useful and credible technology will occur. The pace and the speed at which technology replaces subjective judgment is a function of the level of interest, demand, and support given to not only the remaining research, but also, to technology development. Keys to technology development are both the assembly of research into appropriate useable forms (this paper being an embryonic effort) and the undertaking of proof testing and other verification programs.

Finally, I believe that the time of "burn to learn" fire research has passed. We now have made the critical advance to where all fire experiments, large and small, should be preceded by the best engineering predictions and the results used to verify and improve analytical engineering methods.

REFERENCES

Alpert, R. 1972. Calculating of response time of ceiling mounted fire detectors. Fire Journal 8(3).

Alvord, D. 1983. Status Report of Escape and Rescue Model. Report NBS-GCR-83-432. Gaithersburg, Md.: National Bureau of Standards.

Babrauskas, V. 1981. Will the Second Item Ignite. Report NBSIR 81-2271. Gaithersburg, Md.: National Bureau of Standards

__________. 1979. COMP F2--A Program for Calculating Post-Flashover Fire Temperatures. NBS Tech Note 991. Gaithersburg, MD: National Bureau of Standards.

Benjamin, I. 1980. Detector response in large buildings. In Proceedings, Engineering Application of Fire Technology workshop; pp. 1-12. Boston, Mass.: Society of Fire Protection Engineers.

Cooper, L.Y. 1982. Calculating Safe Available Egress Time (ASET)--A Computer Program and User's Guide. Report NBSIR 82-2578. Gaithersburg, Md.: National Bureau of Standards.

Evans, D. D. 1981. Characterizing the Thermal Response of Fusible-Link Sprinklers. Report NBSIR 81-2329. Gaithersburg, Md.: National Bureau of Standards.

Fuin, J. J. 1971. Pedestrial Planning and Design. New York: Metropolitan Association of Urban Designers and Environmental Planners.

Huggett, C. 1980. Rate of heat release--implications for engineering decisions. Proceedings, Engineering Applications of Fire Technology Workshop, pp. 233-245. Boston: Mass.: Society of Fire Protection Engineers.

Heskestad, G. 1982. Engineering Relations for Fire Plumes. Technology Report 82-8. Boston, Mass.: Society of Fire Protection Engineers.

Hekestad, G., and M. Delichatsios. 1977, 1978. Environments of Fire Detectors (Phases 1 and 2). Reports NBS-GCR-77-86, NBS-GCR-78-128, and NBS-GCR-78-129. Gaithersburg, Md.: National Bureau of Standards.

Iding, R., H. Niazmuddin, and B. Bresler. 1977. Fires-3. Fire Research Group Report UCB FRG 77-15. Berkeley: University of California.

Jones, W. W. and Quintiere, J. G. 1983. Prediction of Corridor Smoke Filling by Zone Models. In Combustion Science and Technology, Vol. 11. London: Gordon and Breach Science Publishers.

Klote, J. H. and Fothergill, J. W. 1983. Design of Smoke Control Systems for Buildings. NBS Handbook 141. Gaithersburg, Md.: National Bureau of Standards.

Lee, B.T. In press. Effects of Wall and Room Surfaces on the Rates of Heat, Smoke, and Carbon Monoxide Production in Park Lodging Bedroom Fire. Gaithersburg, Md.: National Bureau of Standards.

__________. 1982. Effect of Ventilation on the Rates of Heat, Smoke and Carbon Monoxide Production in a Typical Jail Cell Fire. Report NBSIR 82-2469. Gaithersburg, Md.: National Bureau of Standards.

National Fire Protection Association. 1983a. Report of Committee on Safety to Life, Proposal 101-678. Appendix D Alternate Calculation for Stair Widths. In 1984 Annual Meeting Technical Committee Reports, pp. 502-506. Quincy, Mass.: National Fire Protection Association.

Pearson, R. G., and M. G. Joost. 1983. Egress Behavior Response Times of Handicapped and Elderly Subject to Simulated Residential Fire Situation. Report NBS-GCR-83-429. Gaithersburg, Md.: National Bureau of Standards.

Predtechenskii, V. M., and A. I. Milinskii. 1969. Planning for Foot Traffic Flow in Buildings. Moscow: stroiidat Publishers. (Translated from Russian by Amerind Publishing Co. Put. Ltd., New Delhi, for the National Bureau of Standards and National Science Foundation.

Report of Committee on Signaling Systems. In 1984 Annual Meeting Technical Committee Reports, pp. 541-570. Quincy, Mass.: National Fire Protection Association.

THE CODE DEVELOPMENT AND WRITING PROCESS*

Lorne W. Gold
Associate Director, Division of Building Research
and
J. Kenneth Richardson
Head, Technical Section, Codes and Standards Group
National Research Council of Canada, Ottawa

Linking fire research to the development of building codes and the needs of owners and operators of buildings is a challenge of major dimensions. Research needs cannot always be clearly defined. Even when they are properly identified, it is not a straightforward task to determine how they can be satisfied. In addition, the degree of satisfaction achieved in a particular case depends on several factors, including the current level of knowledge, the availability of research resources, and true ability to evaluate research results critically and to transfer useful information to practice.

This paper considers the nature of the relation between fire research and code development. It is based primarily on the experience of one research organization--the Division of Building Research of the National Research Council of Canada (DBR/NRCC)--and with one code--the National Building Code of Canada (NBCC) (National Research Council of Canada Associate Committee on the National Building Code, 1980). The history and process of development of this Canadian model code is briefly described. This is followed by general comments on the nature of communication between research and technical areas of application such as building codes and construction. A brief description is given of the Division of Building Research and examples are presented of the interaction between it and the committees responsible for the writing of the NBCC. The paper concludes with suggestions for improvement in communication among researchers, code writing bodies, and owner-operators.

NATIONAL BUILDING CODE OF CANADA

Until 1941, municipalities in Canada either recognized no building code or had building bylaws based on British and American codes. In 1940,

---

*The paper was presented at the conference by Dr. Gold.

the Department of Finance and the National Research Council of Canada had undertaken, on behalf of the government of Canada, the task of writing a set of model building regulations that could be used uniformly in all areas of the country. This initiative had been taken in response to a need for uniform housing regulations and resulted in the 1941 edition of the NBCC. Later, responsibility for the National Building Code of Canada was given to the NRCC alone, and the subsequent seven editions have been published by it. The NBCC is now published on a five-year cycle, with the next edition expected in 1985.

When NRCC was given responsibility for writing the National Building Code, it established the Associate Committee on the National Building Code (ACNBC) as the body responsible for development and maintenance of the NBCC. This is a committee of volunteers appointed by the NRCC from industry, enforcing authorities, and other NBCC users. The ACNBC, in its turn, set up standing committees to assist in technical matters. These are made up of people knowledgeable in specific technical areas, including fire safety. All decisions affecting the content of the NBCC are made by the ACNBD and its technical committees. The supporting staff of the NRCC are not voting members on committees and serve only in an advisory capacity.

The main committee of the ACNBC is responsible for establishing the operating policies of all its committees, for coordinating committee activities, and for final approval of all changes to the NBCC and its associated documents. Each standing committee is responsible for the technical content of the part of the Code assigned to it. The NRCC has also established an Associate Committee on the National Fire Code (ACNFC) to develop model fire prevention regulations in Canada. Its committee structure and operating policies are similar to those of the ACNBC.

Like similar codes in the United States, the NBCC is written as a model code. It has no legal status until it is adopted into law by a province or municipality. All provincial and municipal codes in Canada are based, however, on the National Building Code. Some provinces have issued their own codes, while others have simply adopted the NBCC by reference in their legislation. The time between publishing a new edition of the NBCC and its incorporation into a provincial code ranges from less than a year to approximately five years. It may be seen, therefore, that acceptance of fire research results in the NBCC leads to widespread application in Canada within a reasonable length of time.

Technical changes to the National Building Code are initiated by the standing committees as a result of input from the public, committee members, or research. All recommended changes are circulated for public review before final approval is given. The standing committees assess the public comment and then recommend to the associate committee those changes that are considered to be appropriate. If the associate committee accepts the recommendations, the changes are included in the next edition of the NBCC.

The Division of Building Research, through its Codes and Standards Group, provides the code committees with all necessary secretarial and technical services, including the preparation of minutes, handling of correspondence, and the preparation of background technical papers on code issues. The division also publishes and distributes the NBCC following approval by the ACNBC. Research sections of DBR/NRCC, including the Fire Research Section, provide technical input through research advisors who act as liaison resource persons between the sections and the code committees.

CODE DEVELOPMENT AND RESEARCH

Building codes, because of their nature, are conservative. Since they specify standards of life safety and health and may influence several billions of dollars of annual investment, they should be based on proven information and technology. This causes a bias that must be recognized when considering linkages between research and the code writing process, a bias that can be accentuated by time limitations and by actual or perceived limitations of the means of evaluating new information and technology.

The word "research" applies to a full range of activity from curiosity-motivated to problem-specific study. One would expect that an applied fire research laboratory would emphasize problem-oriented research, but if it is to be an active participant in the development of the science underlying fire safety engineering, it must carry out curiosity-motivated research as well. The results of problem-oriented reseach are usually more readily evaluated for application than are the results of curiosity-motivated research.

A study of the management of flow of technology by Allen (1977) is applicable to the communication systems that exist between the fire research community and code writing bodies or owner-operators. Allen divides research into two broad categories: scientific and technological. The two groups transmit knowledge in quite distinct, largely independent ways. Scientists give primary allegiance to science. They usually choose their own problems, and the results of their research are transmitted, through publications, primarily to a peer group. Reputation and advancement depend to a considerable extent on their publications and judgment by their peer group.

Allen identifies technological research with that occurring within companies. This work is determined by the interests of the company and is often confidential; information is transmitted largely through personal contact. In this sphere of activity, required knowledge can be developed without any direct links with the scientific research community. Although the situation for companies is not the same as that for code writing bodies and owner-operators, there are instructive similarities. Both are interested in the application of science and technology, both rely heavily on information transfer through human contact, and both are outside the traditional communication system of science.

Some individuals perform effectively in both areas of research activity, although they may concentrate their efforts in one or the other. Such people are technical gatekeepers. They are present not so much because a communication system deliberately provides for them, but rather because of the interest and personality of the individual. We all know examples. They are busy people both within and outside their organizations; they read, they write, they are high performers. People tend to go to them for information. They are probably the most effective means by which information and technology are transferred from the scientific to the technological spheres of activity. Because of them, communication networks develop in spite of, or independent of, formal networks or organizational boundaries. It is important to recognize these people and to nurture them in their gatekeeping role.

The conclusion to be drawn is that if knowledge is to flow from the scientific area and needs are to be communicated back to it, there must be interested individuals to transmit and receive the information. In addition, experience shows that this communication is more effective if it results from demand from the technological area, for example, or from a code writing organization rather than from promotion from the scientific side. This, in turn, means that we must encourage, and develop, the technical gatekeepers in the area of technology application (i.e., individuals with a good knowledge of current scientific research and available information).

DIVISION OF BUILDING RESEARCH EXPERIENCE

The experience of the DBR in operating at the interface of research and code development may be of interest. The DBR is one of 15 divisions of the National Research Council of Canada. Unlike the NRC of the United States, the NRCC operates national laboratories covering a broad range of science and engineering, similar in some respects to the function of the U.S. National Bureau of Standards. The DBR was established in 1947 to provide a research and information service to the construction industry. This is Canada's largest industry, accounting each year for about 16 percent of the gross national product. It is a fragmented industry in which research is generally limited to the large manufacturers of building materials and components. The research program of DBR, which complements private sector activity, covers a comprehensive range of topics, including structures, acoustics, geotechnical engineering, materials, building services, thermal performance of materials and building components, fire, and building performance. DBR has a staff of about 280, of whom approximately 80 are researchers.

Communication of the results of research is a major challenge for the DBR. Its primary output is publications. Further dissemination occurs through seminars, lectures, personal contacts, response to inquiries, and participation on technical committees. As an organization it operates in both the scientific and technological areas, and most of the results of its research are submitted initially to a scientific peer group. Each researcher is expected, however, to be an information officer and, thus, is drawn into the personal contact mode of communication.

One of the largest groups in the DBR is the Fire Research Section, which was established in 1950 to develop better understanding of building fires and methods of controlling them. It has a staff of 30, of whom 12 are research officers and 16 are technicians. In addition, the section usually has one or more research fellows who are supported by industry. Its comprehensive fire research program can be divided into five areas: fire performance of structural components, flammability of materials, products of combustion, growth of fire, and the effect of design of buildings on fire safety. A significant part of this research effort is undertaken in response to current information needs. Another effort is directed to long-term studies designed to build up basic knowledge of fire-related material and product properties and of fire processes. Some commercial testing is done when the capability does not exist in the private sector or when it is justified by special circumstances.

The Fire Research Section is housed in a relatively large building opened in 1958. It contains a number of specialized pieces of equipment including a wall furnace, a floor furnace, a Steiner tunnel, a corner wall test facility, a column furnace capable of applying loads of up to 1000 metric tons, and sophisticated instrumentation for the analysis of products of combustion. Recently a field station was established on 180 acres of land. Its major facilities include a burn hall 180 by 100 by 40 ft and a 10-story tower for studying smoke control and fire propagation in tall buildings. The two facilities are joined by a service unit housing office and workshop space, a chemistry laboratory, and computer and control equipment.

The DBR is in the unique position of being a comprehensive building research establishment closely associated with a model code writing organization. This has both advantages and disadvantages. As mentioned, there is a relatively close coupling between some areas of research and the committees for the National Building Code and the National Fire Code (National Research Council of Canada Associate Committee on the National Fire Code, 1980). This close relation with the code development process has existed since the division was established. About 25 percent of the current research program at the DBR is a response to, or is relevant to, the needs of the two code writing committees.

Care must be taken in managing the interaction between the DBR and this code development process. Because of its position, the DBR can exert undue influence on the work of committees. The relationship is relatively straightforward when a need is identified by the committees and the DBR has the resources to respond to it. This interaction is often informal, but it may be in response to a request directed to a section or to the director of the division.

The situation may be quite different when the initiative comes from the other direction (i.e., from a researcher). There is sometimes a desire on the part of researchers (when they consider that they have information relevant to building codes) to submit it directly to code committees. The committees may not yet be ready to receive it or have the expertise to evaluate it, particularly if it concerns a matter at the forefront of development of a subject area. This situation can lead to misunderstandings.

It is the preferred policy of the division to publish results of research in the scientific or technical literature where they will be available for evaluation by professional expertise at large. In the ideal situation, an informed peer group will recognize useful new knowledge for codes and create a demand for its consideration, In practice, researchers who wish to have the results of their work considered may have to exert considerable effort to make them known and understood by a technically capable group.

In summary, the DBR encourages sympathetic participation of its research staff in codes and standards writing work. It encourages information and technology transfer through informal interaction, but it guards against taking advantage of its standing in the Canadian building research community to exert undue influence. Following are some examples of the interaction that has occurred and the various means of communication:

1. In 1957 the DBR had the opportunity to burn six dwellings and two larger buildings that had to be removed for the construction of the St. Lawrence Seaway. Radiation measurements made during the burns provided the basis for exposure tables in the NBCC that state required distances between property lines and buildings to prevent fire propagation. This is an example of a research opportunity that resulted in information that was rapidly incorporated into a building code.

2. By the late 1960s construction of high-rise buildings had created the need for measures to control smoke movement in such structures. The Fire Research and Building Services Sections of the DBR developed smoke control provisions, based primarily on computer modeling, that were incorporated into the code in 1973. Now, with the opening of the field station, the DBR has been able to obtain a facility in which experiments can be carried out to confirm and further develop these provisions. This is an example of a response to a defined need.

3. During the 1960s it was recognized that appreciable information already existed about materials on a generic basis that would, if properly validated and presented in an appropriate way, greatly reduce the need for fire tests and, thereby, the cost of design. The DBR and the ACNBC established, jointly, an ad hoc committee to compile this information. Staff of the division made a major contribution to this task. The committee has now become a standing committee of the ACNBC and continues its work of establishing fire performance ratings for materials and components on a generic basis. It is responsible for one of the chapters of the Supplement to the NBCC (National Research Council of Canada Associate Committee on the National Building Code, 1980, Chapter 2), and the DBR staff participate actively in its work, both by compiling information and by carrying out tests. This is an example of a code writing body and a research organization interacting continuously on a particular subject to improve the technical base and reduce the cost of design for fire safety.

4. With the development of plastic pipe have grown opportunities to use it in construction, but questions have been raised concerning the effect of penetration of plastic pipe on the fire resistance of fire separations. The DBR initiated a research program in response to that information need. Most of the work has been carried out by a research fellow supported by the plastics industry. The DBR has insisted that the results of this work be published in the open literature before being used for other purposes. If these results are to influence decisions of building code committees, they must be freely available for evaluation by all interested parties.

5. One of the subject areas of great interest to the DBR Fire Research Section is the development of a rational approach to design for the fire condition. That subject is currently receiving widespread attention. Incorporating such an approach into the NBCC would, however, means that the code will become more performance oriented. To take this step, NBCC committees and the design profession require greater knowledge of the fire condition than exists at present. The DBR proponents of this approach are working, primarily through publications and committees of the ASTM (formerly the American Standards for Testing and Materials), the American Concrete Institute (ACI) and the Canadian Standards Association, for the critical evaluation of research results that is needed during this development phase.

These are examples of interaction between the DBR and the ACNBC. The ACNBC, of course, also interacts in similar ways with other bodies. It is clear that many avenues of communication are possible. Their effectiveness depends on the ability of the code committees to define their needs and to receive and evaluate information, on the ability of information sources and research organizations to respond to these needs, and on the goodwill and capability of the individuals through whom communication is accomplished. In its support of the ACNBC, the DBR has been fortunate in having, as part of its Codes and Standards Group, a technical section through which much of this communication is accomplished. To some extent, the members of this section act as the technical gatekeepers discussed earlier in that they provide an active link between research and code writing operations.

In addition to this interaction with the ACNBC, the DBR responds to needs of organizations responsible for design, production, and operation of public and private buildings. This may be reactive (e.g., by providing interpretation of the building code, commenting on the fire safety aspects of proposed designs, assisting in the investigation of fires, and conducting special tests and research studies). The DBR also may take the initiative (e.g., by preparing, in cooperation with a consultant, the Manual for Fire Safety in Homes for the Elderly, [Richardson, 1980]; by investigating the toxicity of fire gases; and by developing fire test methods).

IMPROVING COMMUNICATION

The background material for this conference states that it is based "on the hypothesis that a large gap presently exists between the fire research community and those who are responsible for managing the process of designing, producing, and managing buildings." But the gap does not exist for all these people; there are some well informed designers and building managers, but these are people who have put forth a special effort to obtain their knowledge, much of it through personal contact. The research system could not cope with the communications problem that would occur, however, if all information and technology had to be transferred in the personal contact mode.

It is difficult to maintain continuous communication between areas of interest that coincide only periodically. Owners and operators tend to be interested in fire safety matters only as required, and this interest may be limited to the design and construction of a single building. Unfortunately, they and the fire safety consultants who serve them do not form a coherent body able to define and place priorities on their collective needs in the manner a code writing committee can. An organization such as the DBR must rely, to a large extent, on individual contacts with this group to gain an appreciation of their needs and concerns. If building owners and operators and their consultants were to form an association that could define their fire safety research needs, most organizations engaged in fire research could interact with it, as they do with code writing bodies. They would appreciate the guidance such interaction would provide for their research programs. Such interaction would probably improve further if, in addition to identifying needs and priorities, the association of owners, operators, and their consultants could also provide money to support and augment the total research effort.

The background material also recognizes the contribution to fire safety of code-writers and fire safety engineers but states that they provide only an indirect link between research and the owner-operators. The activities of both groups overlap those of researchers and owner-operators. The code writers and fire safety engineers must keep themselves informed of current research results and activity if they are to stay on top of their respective areas of interest. Owner-operators must comply with the code and often use the fire safety engineer as a consultant. They need not communicate with the research community unless they wish to.

Perhaps code writing bodies and specialists such as the fire safety engineer should be looked upon as direct links in the communication system between researchers and owner-operators. The two groups have, or should have, the ability to evaluate results of research critically, possibly rephrasing them in terms that are more readily understood by the owner-operator. This is not to say that meetings between the fire research community and owner-operators should not be encouraged. They should be, but it must be recognized that such meetings will probably be of a special character and occur only occasionally.

How should these occasions be provided? As recognized by the steering committee for this conference, it is possible that existing societies and associations can assist. Organizations such as the National Fire Protection Association, the Society of Fire Protection Engineers, the American Society for Heating, Ventilating and Air-Conditioning Engineers, and Societies of Civil Engineering could hold occasional conferences and seminars that would attract the full range of interests, from researcher to owner-operator. They might be organized and scheduled to provide continuity and develop dialogue between the various interests. This, of course, presumes that there is some body to undertake and coordinate the program and bring about the necessary cooperation.

One of the key elements in an effective communication system is education, at the university level, in fire safety engineering and the sciences underlying it. Fire safety engineering is a profession just beginning to be recognized in Canada. No Canadian university as yet offers a degree in this discipline, and very few give courses that provide an introduction to it. The relatively few specialists in Canada obtained their training outside the country or developed their expertise on the job. But although trends in construction have increased the need for better knowledge concerning the fire situation, for both design and operation, there is not yet sufficient demand for experts in this field to encourage universities to take the initiative and train them.

To have effective communication between the fire research community and owner-operators, it will be necessary to develop a deeper appreciation of the fire situation in the professional groups responsible for design, construction, and operation of buildings. Architects and engineers with the appropriate knowledge (fire safety engineers in particular) can be, and are, an effective peer group for applying the results of fire research and defining research needs. It is this group that has the technical ability and professional need to evaluate and digest the results of research and to translate this knowledge into practice (i.e., to serve as technical gatekeepers). It is this group, also, that must interpret and apply the fire safety requirements of codes, particularly those that are performance oriented. The DBR is so convinced of this need that it is seriously considering ways in which its staff can increase their contribution to the education process that is required.

REFERENCES

Allen, Thomas J. 1977. Managing the Flow of Technology. Cambridge, Mass.: MIT Press.

National Research Council of Canada Associate Committee on the National Fire Code. 1980. National Fire Code of Canada. Document NRCC 17306. Ottawa: National Research Council of Canada.

_________. 1980. The Supplement to the National Building Code of Canada. Document NRCC 17724. Ottawa: National Research Council of Canada.

National Research Council of Canada Associate Committee on the National Building Code. 1980. National Building Code of Canada. Document NRCC 17303. Ottawa: National Research Council of Canada.

Richardson, J.K., Ed. 1983. Manual for Fire Safety in Homes for the Elderly. Ottawa: National Research Council of Canada.

THE ECONOMICS OF RESEARCH AND FUNDING AS A DRIVING FORCE

Robert H. Barker
Professor, School of Textiles
Clemson University, Clemson, South Carolina

In any consideration of the economics of research and technology development, the tendency is usually to concentrate on levels of funding and the general availability of support. These are frequently accompanied by discussion of the allocation of support for the various categories of endeavor: fundamental vs. applied research; hard sciences and technology development vs. behavioral and social sciences, etc. The different disciplines and special interests compete for funds: military research or hardware procurement, space exploration, medical research and drug development, innovations for occupational or consumer product safety, and a myriad of others. Certainly the fire community is an active participant in these discussions and competitions.

Primarily through the Center for Fire Research (CFR) at the National Bureau of Standards (NBS) and to a lesser extent as a part of the activities of the Department of Defense (DOD) and the Federal Emergency Management Agency (FEMA), the federal government provides financing for a broad program of fire-related research. A number of very good projects are conducted within the CFR, while additional studies are funded at universities and research institutes. These projects have been the core of our nation's efforts to attack the fire problem and their success has been significant. There is no question that continued funding at current or increased levels is absolutely mandatory for continued progress in fire safety.

Money is the obvious driving force for the conduct of research. But to stop there is to miss a major dimension of the overall problem. So many times, in areas ranging from education to defense to technology development and international trade, we have seen federal policy-makers throw money at the problems with no significant result. In some instances the programs and projects were ill-conceived or poorly carried out. More often, important new information was developed but real progress toward solution of the practical problems was not made. In these cases, the lack of tangible results can usually be traced directly to the technology and information transfer processes. The research results were never communicated to those who would benefit most from them or, if the information was communicated, it was not in an appropriate form for application or implementation.

This, of course, is exactly the problem that this conference has been charged with addressing. To do this, I believe that it is imperative that we focus not just on funding as an incentive for the conduct of research, but also on providing financial incentives for the information and technology transfer process. Both the sources and the allocation of funds are important. The use of normal market forces and proprietary interests can provide a key to commercialization of new technology and the incorporation of new knowledge and concepts in designs, codes, and regulations. Unfortunately, the federal government, as the prime source of research support, is notoriously ineffective at utilizing these forces. Even in regulatory matters, the federal government has difficulty in translating research results into practicality, except for a few areas such as occupational or consumer safety. Fire safety is an area where such translation should be expected, but it generally has not occurred since the fire code enforcement problem is within the purview of state and local governments.

IMPACT OF RESEARCH FUNDING

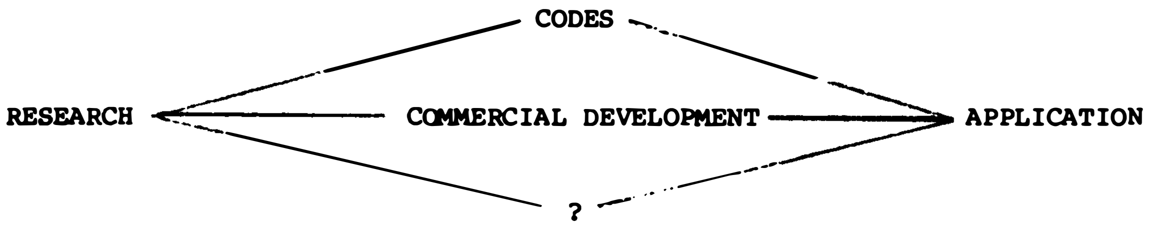
The level of funding affects both the quantity and quality of research. There is a minimum level of funding that is necessary to maintain in the scientific community the expertise and interest to produce quality research proposals, but it must also be noted that there is an optimum level beyond which there are diminishing returns in terms of the quality and significance of projects conducted. What is needed is a sound sense of priorities in developing a funding policy for both public and privately supported research. We must determine exactly what information is truly needed to solve the most significant problems and we must match this carefully with a sense of what we can afford. At the same time, there is a need to be cautious of false economies. As a commonly encountered example of such false economies I would point to the lack of appropriate support for information dissemination activities associated with heavily funded research projects. Saving a few dollars on dissemination can have the effect of negating much of the impact of the best research.

In this context I would suggest that the sources and allocation of support are as important to the ultimate solution of practical problems as the overall level of funding. Policy decisions on funding affect the balance of long- and short-term (i.e., fundamental vs. applied), research. As a result, there is an effect on the balance of public and private sector information transfer, open publication, patents, codes, and commercial production. Several very important policy questions are involved here: What are the proper roles of the public and private sectors? What are the proper governmental roles in the information and regulation processes? How should federal and local governments interact with voluntary standards organizations and commercial interests? What is the proper role of the private sector in the funding of fundamental research having no immediate commercial application? Unfortunately, most research funding occurs without any in-depth consideration of these questions.

There is some perception that the fire problem and, thus, fire research are unique in their technology transfer and information dissemination needs. This really is not the case. There are numerous analogous situations. Consider, for example, medical and nutrition research. As with fire, medical research by necessity is heavily weighted toward fundamental science, but the user community is generally lacking in scientific expertise. For both, the highly technical research results need translation by the researchers themselves or other professionals. This requires a special effort and the incentive must be provided to get the requisite effort expended. Funding decisions provide the opportunity to develop these incentives.

INFORMATION TRANSFER PROCESSES

In the area of fire, information based on research results is transferred by three primary, but not mutually exclusive, routes as shown below:



Codes are the normal vehicle for the implementation of the results of most of the government-funded fire research. This occurs directly in a few instances but more commonly involves intergovernmental cooperation or the voluntary standards organizations. The frequency of direct translation is primarily the result of the funding of a large share of the research at the federal level while primary regulatory responsibility lies at the local government level. There may also be considerable private sector involvement in facilitating the translation of technical information into standards and codes if there is sufficient proprietary interest (e.g., the insurance industry or suppliers of fire resistant materials).

The commercial development pathway offers one of the most potent information transfer resources since it utilizes traditional market forces and the profit motive. Unfortunately, the track record of most government agencies in using this route is notoriously poor, and useful commercial products rarely result from publicly sponsored research. This problem has been recognized and addressed by recent legislation to provide better access and proprietary protection to those who would capitalize on publicly held patents. How successful this approach will be remains to be demonstrated. However, in the context of the fire problem, the potential for this route is exemplified in the development of commercially successful residential smoke detectors. Work on detectors at the NBS Center for Fire Research was aimed at the development and standardization of detectors. The commercial interests were factored in at the appropriate points to facilitate rather than hinder commercial production.

There would appear to be a great opportunity for more private sector information and technology transfer, particularly for joint academic-industrial and academic-government cooperation. Successful models for interaction based on experiences with the Experimental Technology Incentives Program (ETIP) of the Department of Commerce and the Small Business Innovation Research (SBIR) program of the National Science Foundation provide an indication of the viability of such cooperative efforts. Furthermore, the current Department of Commerce emphasis on research and development limited partnerships should be exploited as should opportunities which may arise as a consequence of the pending legislation to facilitate joint research ventures among commercial firms.

The direct transfer of research to application, with or without the involvement of codes or commercial development processes, has probably the greatest potential for success. Individual researchers have more inherent interest in broadcasting their own results than anyone else, including the sponsors; they must be tied into the communication channels. Traditionally this route has been underutilized except in special cases, such as the research carried out by the insurance industry. The key to success seems to be incentive and financial support. Funding has not usually been provided to researchers for dissemination of their results, and no particular importance has been attached to dissemination functions when grant and contract applications have been reviewed. It would be interesting to see what would happen if dissemination plans were weighted in funding decisions on an equal basis with research plans. Direct transfer of information by individual researchers requires that the projects be closely tied to ultimate application goals. This is not often done, particularly with the more basic projects where communication problems are frequently the greatest.

SUMMARY

In summary, the fundamental economics of fire research would indicate that: funding does make a difference; the source and allocation of funds are critical to the successful culmination of practical research projects; all three paths for information transfer can be facilitated by appropriate funding policies; and emphasis needs to be given to information transfer and dissemination of results from the time of program inception and funding.

ORGANIZATIONS AS A COMMUNICATING AND COORDINATING MECHANISM TO BRIDGE THE COMMUNICATIONS GAP AND AS A MEANS OF CAUSING DIRECT INTERACTION

Jack C. Sanders
Fire Marshall
State of Oklahoma, Oklahoma City, Oklahoma

I will be addressing the conference from two vantage points: on one hand, as a state fire marshal and, on the other, as Chairman of the Board of Directors of a large organization, namely, the National Fire Protection Association (NFPA), whose primary responsibility is communicating with a broad segment of the fire protection and fire prevention community.

The first two sessions of this conference focused on the existence and definition of a gap between the researcher and the practitioner. Now is the time to suggest a few solutions involving communication to close the gap. What can organizations do to bridge the gap between the researchers and the owner-operators of buildings? The obvious answer: Communication links must be established and maintained if the necessary interaction is to take place. The solution sounds easy until one considers that the gap exists due to differences in goals, motivations, philosophies, and perspectives both within and between organizations--in effect, the very essence of organizations. This paper will briefly address perceptions of the gap, influences affecting the gap, a rationale for diminishing the gap, and, most importantly, recommendations for future organizational linking mechanisms to bridge the gap. The nature of the organizations involved will be examined to give definition to the barriers creating the gap and, thus, to possible solutions. I hope we can then propose some effective bridges that can be put forth by the same organizations.

Researchers include scientists such as our distinguished colleague Howard Emmons of Harvard University. Research institutions include the government, universities, and private laboratories which support research. An example would be the Center for Fire Research at the National Bureau of Standards. The purpose of the researcher is to find new knowledge and technology. In this endeavor, the researcher is driven by great intellectual adventure. The resulting side effects of such motivation are measured in terms of progress, comfort, quality of life, and, for us, a more fire safe environment. The researcher's work is thereby based on human invention and stimulated by human curiosity and the need to seek truth. In this quest the researcher needs time and a long-term commitment of resources. For example, fibre optics was on the scene in 1970 and has only just become part of the National

Electrical Code as Article 770--almost 15 years to become a major factor in modern technology with its inherent safety considerations.

To some, 10 or 15 years seem like an awfully long time in this age of instant solutions, especially in "applied" research where most fire protection research is conducted. I suggest to you that fire protection practitioners and the institutions representing them are cautious and conservative by nature. This is as it should be because protection from the threat of fire is an awesome responsibility.

The second session of this conference examined the research programs themselves and the end use of results. The agenda of research ranges from the general to the specific, from the fundamental level of flame size and shape to computer simulation modeling of fire behavior in buildings. The outsider would expect an abundance of activity in fire research from fundamental to applied given the magnitude of the fire problem in America: 6000 lives and $6.4 billion in property damage in 1982. Sadly, this is not the case. As there has often been a lack of effective and available technology, evaluation of solutions has been based largely on consensus--consensus not only in the development of codes and standards, but also in the application of alternative solutions such as the Fire Safety Evaluation System developed by NBS/CFR utilizing the "delphi" technique. Traditionally, the formulation of research and development programs has been based on: analysis and evaluation of loss reports and trends, research and development organizational policy and priorities, and research on specific problems, usually because there is "cost" or "loss." The results of research are scientific products, unpublished and published reports, patents, students graduated, and new commercial products. In addition, the researchers have their own internal network, seminars such as given by the Center for Fire Research, and external programs such as grant projects.

The "front line" includes the fire service, fire marshals, fire protection engineers and consultants, those working in major industry, fire safety educators, and those responsible for meeting code requirements. Organizations involved are those serving specific audiences or constituencies--the Building Owners and Managers Association (BOMA), the building code groups, the Society of Fire Protection Engineers (SFPE), the American Institute of Architects (AIA), and the National Institute of Building Sciences (NIBS).

In the next category are those responsible for the design, production, and operation of public and private buildings. Their purpose is to build the most efficient and effective space possible within budget constraints and regulatory requirements. They provide for a tremendous incentive to improved fire safety by placing importance on getting "cost-effective" fire safe designs from the fire protection engineer. They, too, have their own network and communication system.

As a communications link between the pure researchers and the owner-operators of buildings, there are several "middlemen" organizations in a good position to serve the needs of both sides in achieving common goals. In a word, these organizations can help "bridge the gap." The organizational framework available includes many possible ways of accomplishing this "bridge building" function such as broad-based audiences; existing people networks on national, regional, and local levels; support of the organizational structure and mechanisms; and a noncompeting and objective vantage point. In this category fall such organizations as the NFPA, the National Research Council (NRC) of the National Academy of Sciences (NAS), the American National Standards Institute (ANSI), American Society for Testing and Materials (ASTM), and the National Safety Council (NSC).

The first session of this conference acknowledged the existence of a gap between researchers and users and addressed some reasons for it. A number of forces tend to widen the gap even further between researchers and owner-operators of buildings, and a brief discussion will help to identify and hopefully reduce these on an organizational level.

LANGUAGE

Each group has its specialized terminology or "jargon." Research reports are written in a language that is not easily understood by outsiders. Consequently, results are not translatable in English language terms and this leads to the next barrier, "the challenge of technology transfer."

TECHNOLOGY TRANSFER

Research results are often not available in pragmatic, usable forms or there is a lack of effective and available application technology. An example of this is the work of the Fire Detection Institute to determine spacing requirements for heat detectors. The NFPA Committee has to "translate" the research results into a guide for spacing which is proposed as an appendix for the NFPA 72 series of standards.

There is limited direct exposure of one group with the other and, thus, owner-operators are not often exposed to the research that is available, which, in turn, leads to inadequate or nonexistent use of the results.

Operational time scales are often miles apart. Researchers need time whereas the owner-operators require immediate answers.

Lack of understanding of another's responsibility leads to friction between those who want to do it "right" down to the last decimal place and those who have to build buildings today. And there are different networks in place.

The economic downturn has affected both sides. Overall there is more limited private and public funds for research. This atmosphere has resulted in government backing away from basic research money and turning its attention to quick results. On one hand, government and private sector funding sources for basic research are drying up. At the same time, pressures are higher than ever to hold down the cost of new buildings. Without basic and applied research to evaluate the effectiveness of proposed fire safety trade-offs in building construction, the code enforcer and the standards-maker are reluctant to accept innovations and new technology. Much progress has been made, however, in recent years.

Even with scarce resources, each group internally has a common set of assumptions about important problems to be studied and appropriate methods of study. This often differs from the researcher to the building owner-operator.

NEED TO DIMINISH THE GAP AND CREATE LINKING MECHANISMS

Despite the several barriers that create the gap and appear to keep organizations and people separated, many more factors and reasons exist today than ever before to close the gap to build the bridge in the interest of safer conditions for users of buildings at lower costs. One major factor is the need for increased research funding in a period of inflation and less government support. Research of a more complex and applied nature requires the use of more realistic environments and sophisticated experimental equipment and facilities. Interaction with building groups will provide the researcher with the potential for long-term funded projects and permit even more flexibility and independence provided the researcher and the owner-operator are willing to work together within the regulatory code and standards development process. Materials suppliers and equipment suppliers to the "built" environment have been successfully working within the codes and standards-making system for years. From the owner-operator side there is an increased need for new technology required for future projects and a need to meet increased environmental, societal, and regulatory pressures.

Various mechanisms can be utilized to promote closer relationships that further the interest of both sides, the researcher and the practitioner. Obviously organizations will be the prime mover in the creation, implementation, and effectiveness of such mechanisms. Individual relationships and endeavors, as well as case-by-case cooperative efforts, although important, cannot provide the long-term continuity to build the bridge. Only organizations can provide the continuing impetus and depth of experience, knowledge, and structure necessary in the increasingly complex world we live in today.

The specific forms that these communication mechanisms can and will take are a function of the needs and capabilities of the organizations involved and their individual characteristics. And obviously, since I am most familiar with the NFPA, specific examples relating to NFPA work will be used to demonstrate and illustrate possible approaches. The purpose will be communication--to promote and require meaningful dialogue.

A look at the existing links is a starting point for creating enhancement and expansion as well as innovation. The present links are tied to individuals, groups, and products. As an individual, the fire protection engineer can reflect the work of the research community in his/her advice to the builders and owners. Although fire protection engineers and consultants are logical translators, they deal only with certain aspects. Insurers, suppliers, and manufacturers are also channels of linkage. More specific, but limited, cooperation is enhanced through owners' providing direct dollars for research and the directed use of government laboratories by federal owner-operators. I understand that partnership is fostered through the design societies and the interactive forum of the Federal Construction Council.

Similary, the NFPA has and will continue to play a major role. Through its programs in the areas of public education, fire investigations, and applied research and the development of codes and standards through the balanced committee and appeal systems, the NFPA serves as an excellent example of the avenues available to create and stimulate the dialogue. NFPA codes are an indirect method of institutionalizing fire research results. So, too, are the model building codes. Codes bring communication between the researcher, enforcer, and user. However, as a social instrument for assessment, the codes deal only with part of the technological information available from research.

Some basic and applied fire research will perhaps never result in a code change but will be disseminated and communicated in other ways. Owner-operators are exposed to research and researchers learn of the building industry dilemma through briefings, conferences, statistical and research reports, technical papers and information bulletins, case studies, films, and educational journals and magazines. These include the *Fire Journal*, *Fire Technology*, section newsletters, specific bulletins, and the publications of BOMA, the AIA and other organizations targeted to specific audiences.

FUTURE LINKING MECHANISMS

However, in a more complex technological world, the present--generally indirect and sporadic--conversations will not suffice. More direct and extensive mechanisms will be required that calls for the structure and commitment of organizations.

From an examination of the fire safety needs, and the requirements of both researchers and building owner-operators, and a look at a similar gap and efforts to bridge it in the area of university research/industry partnership, a list can be established of sample linking mechanisms. These avenues of exploration can constitute new directions for organizational communication.

Direct Contact

Owner-operators should be in a position to learn more about research by direct contact as well as should the researchers.

Research and Development

The agenda of Research and Development can be shaped for more practical application and pertinent studies through funding considerations. This would include direct funding by owner-operator organizations, a surcharge targeted for research imposed by insuring organizations, and specific tax incentives to organizations.

Educational

Educational mechanisms can provide direct and indirect links. This very conference is an example of where all concerned parties have been brought together for the purpose of increased communication. More symposia, seminars, and conferences in this direction should be part of the agendas of all of our organizations.

Another example is the NFPA Public Education Program, which has built into its aims and approaches the results of human behavior and educational research. Examples include the MGM and Westchase Hilton fire behavior studies and the work of Dr. John L. Bryan and Dr. John Keating.

Interdisciplinary Research

Many factors demonstrate the necessity of interdisciplinary research (IDR). The world trend is definitely toward countries using science and technology for themselves. As economic tools and, consequently, research become more complex, the number of disciplines is increasing with each becoming more specialized. Thus, problems become more complex and the nature of the problem itself creates the need for integration. At the same time, as research continues and possibly expands, budgets continue to be limited. And yet, more time and money will be needed to search for solutions. Dr. John Bryan aptly expressed this correlation when he said, "You can't learn about fires without digging in the ashes."

IDR is not now rewarded in most university and organizational settings, and this should be changed. In fostering interdisciplinary research, the future role of organizations will be to serve as "honest brokers" to first identify problem components and relevant expertise and then to encourage integration of effort between different individuals or organizatons with specialized expertise on a common problem. Because of its applicability and far-reaching impact, IDR has commonly been associated with solving problems of social significance by creating a common problem focus and commitment.

A sterling example of this is the NFPA Toxicity Advisory Committee--the setting up of a special committee to create an integrated, interdisciplinary approach to examining a complex problem. Other problem areas that would benefit from an IDR approach are combustible interior finishes and furnishings, smoke control management, fire warning communications and control, and multistory egress. IDR can mimimize the gap by overcoming the barriers such as language, exposure, differing objectives and views, and technology transfer.

Increased Applied Research

IDR also would result in more applied research (i.e., analyzing fires and incidents and asking why fires occur in buildings). The engineering aspect has long been a focus of the NFPA as reflected in the codes and standards, but a look at human behavior is a relatively recent endeavor. Study into autopsy protocols and medical areas is just beginning as evidenced by the Fire Fighter Fatality Study and exploration of a Protocol for Autopsies, as called for by NFPA's Long-Range Plan.

A further example of applied research is a project, funded by the U.S. Department of Housing and Urban Development (HUD), in which methods were developed for quantitative evaluation of the fire safety levels of various residential design configurations using a computer simulation called the Building Fire Simulation Model (BFSM). The model is being made available in its present developmental stage for use by knowledgeable professionals for research and educational purposes. The BFSM shows a thrust in fire protection to apply a systems concept to fire problems.

A cooperative effort specifically related to increased communication between the researcher and the owner-operators of buildings was the Residential Sprinkler Project. The sprinkler industry, the manufacturers, government, researchers, the front line, and NFPA banded together to develop and test a low-cost, quick-response, life-safety-oriented residential sprinkler system. In Los Angeles, the Fire Department ran fire tests of a prototype of new residential sprinklers in an actual residence. This was the first time rigorous tests of this nature were run outside the lab in a residential setting. Factory Mutual was responsible for instrumentation and data reduction while NFPA provided the steering committee and served as administrator of the project. The new technology and developments were incorporated into the code process and resulted in the revision of NFPA 13D. Further demonstrations were run in Ft. Lauderdale to demonstrate the feasibility of this technology for hotels.

A relatively new forum for applied research is the recently established National Fire Protection Research Foundation that will foster communication through sponsored research projects which are specifically tied to needs in the field. In fact, the stated objective is "for research and development connected with the protection of life and property from fire and particularly, but not exclusively, research that is related to improved effectiveness, efficiency, and safety in the delivery of fire protection to the public." Further, the Foundation will "consider only such projects that have demonstrated applicability to the fire problem and that will provide a usable end product in dealing with the fire." By establishing these parameters, the Foundation, on an organizational level, has established a structure and reward system that cannot operate without bridge building.

Code Enhancement

The volunteer consensus standards making system supplies an outstanding example of bridging the gap on the organizational level. Both the researcher and the owner-operator are participants in the balanced committee system and bring their needs and expertise to the table. Through this effort occurs the utilization and application of new research and technology in the building industry. The future thrust in this area should be to enhance and utilize this forum and process to its fullest extent. The NFPA is currently examining this by looking at closer links between its computerized Fire Incident Data Bank and the code process. The recommendation was the result of a Task Group on Fire Statistics formed under the NFPA Systems Concept Committee. Implementation would provide for fuller use of the existing fire data as well as a more targeted information request by the technical committees. A special resource person on fire statistics will be designated at the NFPA to respond to a technical committee's need for interpreted fire statistics. This liaison function could also be accomplished between organizations to forge direct links.

Joint Programs

Joint programs are not new areas of cooperation. The NFPA has been working for a decade on a cost-sharing program with the federal government to investigate significant fires, initially with the National Bureau of Standards and more recently with the U.S. Fire Administration. These activities have helped to bridge the gap by requiring active communication between our investigators and the researchers at NBS, which has led to an established protocol to communicate with the researchers on a case-by-case basis. A more recent effort is the joint program with the model building code groups in the area of fire investigations. This cooperation will pay off in better information about fires and the "whys" of losses, which will be translated by building code developers and users. However, the potential for this mechanism has just barely been tapped.

Common Language

Directly related to a considerable barrier is the development of a common language. The NFPA, along with other fire protection organizations, took a major step in this direction in the late 1960s with the development of NFPA 901, "Uniform Coding for Fire Protection." Further development of data systems, based on this common language, in the form of the NFPA-designed and -operated Fire Incident Data Organization (FIDO) System and National Fire Incident Reporting System (NFIRS), has made it possible to provide information to both the researcher and the front line. NFIRS has stimulated continuation and enhancement of cooperation between the FEMA/USFA and NFPA in an environment of reduced government spending. The systems provide quantitative information on frequency, causes, and consequences of fires and identify general trends in the national fire experience. Yet, the organizational potential of this avenue has not been completed. Expanded use and dissemination, as well as more comprehensive data, will be needed in the future.

CONCLUSION

There are exciting and unlimited possibilities for expanded communication and clearinghouse organizations, such as the NFPA and the National

Research Council, will continue to play a major role as the connecting links between researchers and practitioners. I can assure you that the NFPA is preparing for the "Hi-Tech Age." We know that in order to accomplish our goals, we must foster research to its fullest potential and we must communicate to the research community the practical needs of our society and then seek methods to effectively transfer research results and data into a form usable by the practioner.

Our fire safety problems are complex and comprehensive. Solutions will require scientific analysis and approaches to materials, systems, and philosophies. The gap of understanding and communicating can conceivably become more pronounced, but I believe the organizations can and will effectively bridge the gap in a common effort to make our environment safer from the ravages of fire.

THE ENHANCEMENT OF THE PROFESSIONAL QUALITY OF PEOPLE

[INVOLVED IN BUILDING
FIRE SAFETY]

David A. Lucht
Vice President
FIREPRO Incorporated, Wellesley Hills, Massachusetts

INTRODUCTION

On February 16, 1983, Dr. Dorothy M. Simon, Vice President of Research for AVCO Corporation and Chairman of the NBS Statutory Visiting Committee, reported to the Chairman of the House Subcommittee on Science, Technology, and Space as follows:

> Improvements in the cost-effectiveness of fire protection systems can have significant economic returns. The construction of new buildings and the rehabilitation of existing buildings runs about $230 billion annually; $7.6 billion is spent on fire safety. Forty percent of this expenditure could be saved by making more informed decisions on the trade-offs between safety, cost, and function.

The overall thrust of Dr. Simon's report concerned payoffs to be anticipated from work performed by the fire research community. She has suggested that some $3 billion could be saved each year as a result of new decision-making technology in building fire safety.

This paper concerns the professional qualities of people involved in building fire safety. I will discuss this topic within the overall context of building fire safety decision-making processes that result in today's fire safety investment. Some of the shortcomings of these processes will be outlined. The paper will conclude with my views concerning the future in terms of short-term and long-term professional development.

TODAY'S FIRE SAFETY INVESTMENT

The decision-making processes that lead to some $7.6 billion per year invested in building fire safety should be outlined before we discuss the professional qualities of the participants in that process. This decision-making system pertains principally to what I call the "mainstream" of facility design, development, construction and renovation. The mainstream that I am referring to concerns those properties where the greatest percentage of the property loss, death, and injury occur as a result of fire. Within this framework I am not including facilities such as high fire-challenge industrial properties where the potential for catastrophe is obvious and significant. In these cases, sophisticated expertise is often used in achieving fire safety and this is a "special case" for the purposes of this paper.

THE DECISION-MAKING PROCESS FOR NEW BUILDINGS

The process for achieving fire safety in new buildings varies from place to place and from industry to industry. However, a common scenario could be characterized as follows: A potential facility owner raises the necessary financial resources and engages an architect. Working together, the architect and the owner identify the functional requirements for the facility. The architect, along with supporting civil, mechanical and electrical engineers, prepares plans and specifications. Often, specialty hardware systems such as automatic sprinklers and detection-alarm systems are designed by industry personnel. Plans and specifications are submitted to a building department. The building official evaluates compliance with the building code. It is not unusual to also submit plans to the fire marshal. Some fire marshals enforce certain fire safety aspects of the building code. Sometimes, the plans and specifications are also reviewed by the potential insurance carrier. Once local officals are assured that legal requirements are met, the building permit is issued and construction is under way. Field inspections are performed by the building department, the fire department, and sometimes the insurance carrier. When local officials are convinced that construction complies with local requirements, a certificate of occupancy is issued and the building can be used.

THE DECISION-MAKING PROCESS FOR EXISTING BUILDINGS

The building code generally prescribes the minimum level of fire safety determined to be socially acceptable by the state or local government. As a general rule, once the building is built to this minimum level, it is presumed to be in compliance with the law even though the building code is changed in subsequent years. The imposition of costly building retrofit requirements is politically unpopular and done only in special circumstances. For example, it is not uncommon to have retroactive requirements for smoke detectors in residential buildings.

An existing building is not routinely inspected by the local building department. In many communities, fire department operating personnel visit existing buildings on a regular basis for the purpose of "pre-fire planning." Further, many buildings are regularly inspected by the local fire marshal to assure compliance with the fire prevention code. The fire prevention code is mostly a housekeeping, special hazard, and maintenance code.

Depending on the size of the facility and the potential for a major insurance claim, the building may also be inspected on a periodic basis by fire insurance personnel. Recommendations may be submitted to the owner as a result of these inspections. Compliance with the recommendations may or may not result in reduced insurance premiums.

SOME SHORTCOMINGS

Dr. Simon has estimated that we may be unnecessarily spending some $3 billion per year on building fire safety. While I am unaware of the source of her data, I have no reason to doubt the validity of her estimates. What are some of the shortcomings in the existing fire safety decision-making process that lead to an overinvestment in fire safety?

The Tools Available

With respect to new building construction, the building code is used regularly as the principal tool in fire safety decision-making. Most commonly, state and local building codes are based on or adapted from national models developed by organizations such as the Building Officials and Code Administrators International (BOCAI), The International Conference of Building Officials (ICBO), and the Southern Building Code Congress International (SBCCI).

The model codes are written through a process of consensus opinion. They specify with substantial detail the individual fire safety features that must be installed to comply with the code. For example, the codes detail when automatic sprinklers, fire extinguishers, fire hoses, fire detectors, fire alarms, fire doors, fire exits, and fire walls are required. Taken together, these individual requirements represent prescriptive solutions to categorical groupings of facility types. The model building codes do not specifically state an overall level of fire safety performance.

Many times the building owner relies almost exclusively on the codes (and insurance) to achieve fire safety. Such reliance can have significant shortcomings from the owner's point of view. The codes do not provide the owner with an understanding of the exposure to loss, the probability of loss, the potential severity of a fire or the nature of the risk in terms of property loss, death and injury, business continuity, unfavorable publicity or legal liability.

Technical compliance with applicable codes, as well as the standards of the insurance industry, does not necessarily assure the owner of the most cost-effective fire safety design solution. It should be remembered that codes are written through a process of consensus by groups of regulatory officials far removed from the owner's facility. The writers of the codes are only able to prescribe what they envision to be minimally acceptable fire safety features for generic categories of building types. Often other combinations of building fire safety features, which might technically violate the code, can provide equal or higher levels of safety at less cost. Other combinations of building features might also provide the owner with fewer hardware maintenance and replacement costs and longer term serviceability.

Finally, it should be recognized that there is a significant time gap between the emergence of new technology and the incorporation of that technology into state and local codes. If a building was built under a modern building code in 1970, chances are it reflected the technology of 1965 and earlier. Further, unless some other factors of outside influence come into the picture, the same building will depend upon pre-1965 technology for the life of the facility.

The People Involved in the Process

Obviously, there is a broad range of persons involved in building fire safety including the following major categories:

1. Building official
2. Fire official
3. Architect
4. Insurance representative
5. Hardware systems salesmen-designers

To the degree that these participants rely heavily on the codes in fire safety decision-making, the results of their efforts can fall short of formulating cost-effective solutions to the owner's problems. Many design-development processes lack an analytical approach to the owner's unique needs.

The building official is responsible for addressing many technical issues, fire safety being only one. A building official is not normally highly trained in fire protection engineering. Although some fire marshal offices employ fire protection engineers, this practice is not common. The architect is similiar to the building official in the sense that he or she is required to know something about a broad variety of technical issues. Architects are not highly trained in fire protection engineering; some use fire protection engineers as a member of the design team.

Some commercial interests such as the insurance industry and hardware systems sales-design personnel can be helpful in a design process, but these personnel do not have a total perspective of the owner's requirements and the broad range of variables that need to be considered in developing solutions.

Most codes allow for deviation from specific requirements in the form of "equivalencies" or variances where such deviations would be helpful in reducing hardship or improving the effectiveness of the overall design solution. However, appeals and variance processes can be cumbersome, impractical, or undesirable. On fast-tracked construction projects there may not be time to go through the bureaucracy of an appeals process. Sometimes the owner finds the appeals process undesirable as it might give the appearance of being "against fire safety." Sometimes this leads to last minute decisions to go ahead and comply with costly code requirements, based on the letter of the code, even though a fire protection engineering analysis would indicate these investments are not needed.

Another roadblock to achieving innovative fire safety design concerns a reluctance on the part of some regulatory officials to "go out on the limb" with an interpretation that varies from local tradition or does not match with a strict interpretation of the code. This reluctance can be due to limited background and training on the part of the official, an unfavorable work environment, or the lack of recognized criteria on which to base such judgment decisions.

THE FUTURE

The shortcomings in the fire safety decision-making process that I have just discussed are not meant to be destructive criticisms of either the codes or the participants in the process. All of these elements are simply "state of the art." Each of the participants is normally performing to the best of his or her ability. The prescriptive nature of the codes has evolved over the years and code writers have been doing their best to keep abreast of new technology and research findings. In other words, the real world of making fire safety investments is as good as we have been able to make it be to date. The following will discuss some of my views as to the future.

NEW TOOLS

In a recent discussion with a representative of one of the model code groups, I was told of the many education and certification programs under way or planned in the overall area of fire safety. The person mentioned that very little was being done in the structural area because it was well understood by architects and engineers, because the college and university system was adequately training structural engineers, and because the registered professional engineer could be relied on to utilize credible design methods. It is interesting to note that the evaluation and approval of structural systems in the regulatory process is almost pro forma compared to the trials and tribulations of writing, administering and enforcing volumes of fire safety requirements.

I have noted that Harold Nelson, one of the other speakers participating in this conference, presented a paper entitled "Credible Engineering Methodologies." Alternative engineering approaches to fire safety decision-making stand to yield the greatest payoffs in terms of achieving desirable levels of fire safety at least cost.

One example is the recent adoption of the Fire Safety Evaluation System (FSES), which is a method for assigning weighted values to various building fire safety features to determine "equivalency" with the National Fire Protection Association (NFPA) Life Safety Code. While the use of this method is basically a mechanical process that assumes little engineering capability, it is a step in the right direction. This tool can assist local officials who otherwise feel uncomfortable with making judgment decisions.

Hopefully the time will come when the model code groups will be able to recognize alternative engineering methods in the same mannner that they trust the structural engineer to use state-of-the-art techniques in structural design.

PROFESSIONAL QUALITIES

Future improvements in the cost-effectiveness of fire protection investments, whether in the form of better judgmental use of existing codes or the application of more sophisticated engineering design methods, will require participants having the professional qualities needed. Extensive activities are already under way that will have short term payoffs in terms of professional development. In the longer term, more in-depth and profound changes will be required in terms of professional capabilities.

Short-Term Professional Development

Over the years, ample professional development opportunities have been available to all of the participants in the building fire safety process. Firesafety seminars and short courses are abundantly available to statutory officials, architects and engineers, the insurance industry, and others.

More recent years have shown an encouraging trend towards a more rigorous, disciplined, and job-related approach to professional qualification.

The Council of American Building Officials (CABO) has been operating a Building Officials Certification Program based on written examinations. The examinations contain three modules including management, law, and technology. Portions of the technical module are devoted to fire safety.

BOCAI and the SBCCI, in collaboration with the Educational Testing Service, have been sponsoring National Certification Program Construction Code Inspector Tests. Two modules of this test series include "General Fire Protection" and "Fire Protection Plan Review." Also, the SBCCI has been offering a fire inspector certification examination for about 10 years. ICBO operates its own voluntary certification program and is currently developing a fire inspector category in cooperation with the Western Fire Chiefs Association.

The National Professional Qualifications System of the Joint Council of National Fire Service Organizations has also developed standards for job categories in the fire services. These standards are published by the National Fire Protection Association (NFPA). The standard related most directly to code enforcement is NFPA 1031, Fire Inspector, Fire Investigator and Public Fire Prevention Education Officer. This system relies on state organizations to perform the testing and to issue certificates. Some half dozen states are currently participating although, to date, none have applied for the Fire Inspector category of certification. The National Fire Academy has been using these professional qualifications standards in formulating courses offered to the fire services.

In the private sector, there has been recent movement towards national testing and certification. The National Fire Sprinkler Association, in collaboration with the National Institute for Certification of Engineering Technologies (NICET), has established a certification program featuring three levels of competence ranging from

Associate Engineering Technician to Senior Engineering Technician under the subfield of "Automatic Sprinkler System Design."

Recent years have seen significant activity in the professional engineer arena as well. In 1981 the National Council of Engineering Examiners developed the first national professional registration examination for fire protection engineers. At the current time, 21 state boards of engineering registration are offering the examination.

Overall, the net effect of this national movement towards testing, registration, and certification will be significant. As these national standards and certifications are used by employers for hiring, promotion and retention of employees, greater incentives will arise and the positive effects will be amplified.

Based on aggressive professional development efforts taken by a number of national organizations, the professional quality of persons involved in building fire safety will be enhanced.

Longer Term Professional Development

As the tools we use in making building fire safety decisions shift from a generic or prescriptive mode to an engineering analysis mode, the professional qualities of people involved will also have to change. This is because the analytical work will become more rigorous, requiring a heavier emphasis on mathematics, the physical sciences, and engineering judgment. If the current pattern of technological development continues, it would seem the emphasis will shift from professional qualities centered on how to interpret the code to professional qualities emphasizing engineering analyses. I suspect that the fire protection engineer will play an ever-increasing role in the building design process of the future.

New analytical methods must be translated into the form of textbooks and educational materials for use by schools of fire protection engineering and other educational institutions. New design methodologies will have to be incorporated into professional engineer registration examinations. And, finally, modifications may be needed in the training and certification programs for other participants in the overall building fire safety decision-making process. For new analytical methods to truly be accepted, these various participants must be sensitive to the strengths, capabilities, and limitations of these methods and be well-schooled in what they need to know to carry out their individual roles.

SUMMARY

It has been estimated that some $7.6 billion is invested annually in achieving building fire safety. Yet, in the mainstream of fire safety decision-making, there is often no assurance that the levels of fire safety achieved meet the owner's needs or that the same level could not be achieved at less cost.

Technical tools currently used are not analytically oriented. Rather, they prescribe generic solutions to generic problems based on consensus. The future will offer more sophisticated engineering tools.

Professional qualities of people involved in fire safety is improving on a national basis based on job-oriented testing and certification. In the longer term, fire protection engineers will play a more prominent role in achieving building fire safety based on engineering methods. Training, education, and certification programs will be required to accommodate new subject matter to help assure that the various participants in the process are equipped to give the new technology a chance to work.