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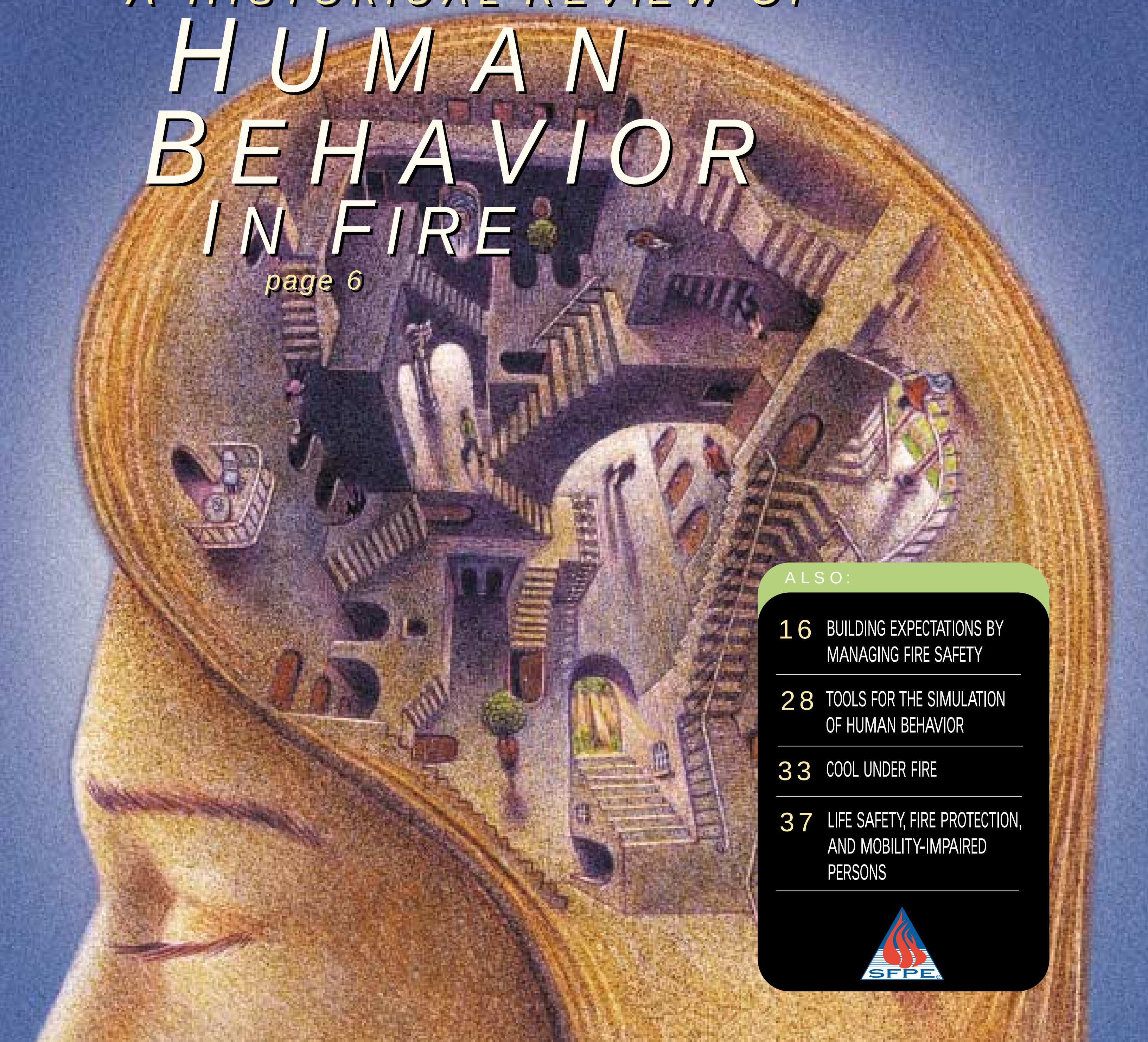

A HISTORICAL REVIEW OF HUMAN BEHAVIOR IN FIRE

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28 TOOLS FOR THE SIMULATION OF HUMAN BEHAVIOR

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A Future Where Engineering Supports People Adapting to Survive Fires

By Norman E. Grone, Ph.D.

Readers of this issue will learn that we already know a good deal about human behavior and fire. But how can fire protection engineers apply this knowledge in their everyday work of analysis and design? Finding answers to this question is central to advancing fire protection engineering. Fire protection engineering needs to advance beyond present tendencies to ignore human performance or use naïve and unvalidated safety factors and assumptions.

Given the best of all worlds, many engineers would prefer to plug data into calculation methods that predict the time people need to safely evacuate buildings. They could set aside considerations of human behavior and comfortably focus their efforts on physical design problems. In my view, this design strategy will not yield optimal designs wherever people in fires need to understand situations and make decisions accordingly. To make this point, I use a metaphor that relates the behaviors of people and fires. In both instances, valid predictions require a good understanding of the contexts in which the behaviors occur. Without such contextual information, levels of uncertainty are simply too great to make acceptable predictions. In the case of fire, the engineer needs some knowledge of ventilation, nearby fuels, room geometry, and interior finishes before any reasonable predictions are possible. Imagine being asked to predict fire behavior without information about the above-listed factors. In the case of human behavior, some knowledge about the information available to people from the social and physical environment is needed before reasonable predictions are possible. To predict human behavior, knowledge of the social and physical contexts is required.

Where will engineers acquire such contextual knowledge? From the design process itself. The job of the fire protection engineer is to constrain the uncertainty of fire behavior by designing the environment. The challenge for the engineer will be to reduce the uncertainty of human behavior by supplying people with accurate information by designing the social and physical environment such that they can make timely and reasonable decisions. Only when design constrains behavior will acceptable predictions be feasible.

To accomplish this task, fire protection engineers will need analysis and design tools that enable them to predict the value of their design decisions. In the physical realm, FPEs have models that allow them to predict the contextual effects of suppression, fire-resistant barrier, and smoke control systems. Engineers will need similar validated tools that enable them to predict the contextual effects of alarm systems design, communications systems, emergency response capabilities, and occupant training programs. With such tools, FPEs can potential specify requirements that will effectively support people in their efforts to adaptively respond to situations far better than they can at present.

Where can FPEs find such tools? While fields such as risk analysis and systems safety are relevant, I believe that the field of human factors and ergonomics (HFE) holds the greatest potential. Many HFE methods concern the analysis and design of technological systems that support humans in their interactions with products, environments, and equipment in performing tasks and activities. However, these methods were mostly developed to analyze and design systems that support well-trained operators interacting with tightly coupled systems using well-defined interfaces. Adapting such methods will require clear thinking and testing on real-world fire safety problems.

To use these tools, fire protection engineers will need to take a more expansive view of their analysis and design tasks. Please read the following excerpt from testimony that Beverly Eckert provided at the June 24, 2002, NIST public meeting for input about its plans for investigating the World Trade Center building disaster. Imagine a future where your design helps to avert such tragedy by providing information to people so that they can adaptively respond even to scenarios you were not asked to consider.

"I was on the phone with Sean for the last half hour of his life, beginning at 9:30 AM. He described the situation, what escape routes he had tried, and asked me for information based on what I was seeing on TV. He was calmly and rationally trying to assess his options. I reached 911 on another phone, but a full half-hour after the planes had struck they had no information to pass along... So despite advanced technology and a multitude of potential ways to transmit information to those whose lives depended on it there was no useful information being relayed, even though many of us were in contact with those who were trapped... Imagine the number of lives that would have been saved had those few who had found an escape route from the upper floors of Tower Two been able to communicate to authorities which stairwell was open. It could have been passed along to those in the tower who were in contact with the world outside."

Norman E. Groner is an independent human factors consultant in Santa Cruz, California.

UL Investigates Firematic Nickel-plated Sprinklers

NORTHBROOK, IL, – Underwriters Laboratories, Inc. (UL) is asking building owners and fire sprinkler contractors to submit samples of Firematic model S & A 160°F sprinklers for testing. UL recently tested field samples taken from a single Connecticut location, revealing that some of these sprinklers did not operate as intended. UL is seeking additional samples from throughout the country to determine if the problem is more widespread.

Firematic brand sprinklers are equipped with a heat-responsive element (HRE) that uses solder which melts at a specific temperature. Once the solder melts, the HRE assembly should separate from the sprinkler body so that water is free to flow from the sprinkler. The nickel-plating on the HRE for these particular Firematic brand sprinklers may prevent the solder from melting properly. This results in the HRE remaining intact, which may prevent these sprinklers from operating in a fire condition.

Firematic Sprinkler Devices manufactured the sprinklers from 1976 through 1979.

Testing on samples received from the one location revealed that the HRE assembly did not operate as intended in approximately 14 percent of the samples tested. UL tested nickel-plated sprinklers from another location and found all samples operating satisfactorily. More test samples are needed before UL can reach a final conclusion.

UL is requesting additional field samples of these sprinklers for operational testing. Although only samples of the model S & A rated 160°F have shown unacceptable results, the following additional models manufactured between 1967 and 1993 with ratings of 160°F, 212°F, 286°F, and 360°F should also be tested: "D," TU-57, TP-57, TU-80, TU-29, TP-29, TU-39, and TP-39. These models use the same HRE as the S & A 160°F sprinklers.

Building owners or fire sprinkler contractors desiring to have installed sprinklers tested should remove representative sprinkler samples from the installation and send them to UL for testing. Building owners may wish to consult with their sprinkler contractor or Firematic for information regarding removal and replacement of the test samples before submitting sprinklers to UL for testing. Once properly removed and packaged according to the instructions, sprinkler samples can be sent directly to Mr. Stephen Angeliu at Underwriters Laboratories, Inc. (UL), 333 Pfingsten Rd., Northbrook, IL, 60062; Phone: 847-664-3687; e-mail: stephen.j.angeliu@us.ul.com for operational testing.

In keeping with UL's not-for-profit, testing for public safety mission, UL will conduct these operational tests at no cost to the submitter during the course of UL's on-going investigation, with the exception of expenses related to sprinkler removal, replacement, shipping and handling.

Firematic Sprinkler Devices can be reached at 900 Boston Turnpike, Shrewsbury, MA, 01545; Phone: 800-225-7288; Fax: 508-842-3523.

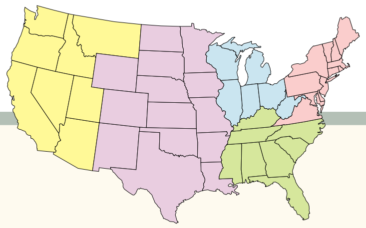
Federal Investigation Into World Trade Center Collapse

NEW YORK, NY – August 28, 2002 – The National Institute of Standards and Technology (NIST), a non-regulatory agency of the Department of Commerce, recently announced the details of its $16 million, two-year federal building and fire safety investigation into the structural failure and subsequent collapse of WTC Buildings 1 and 2 ("The Twin Towers") and WTC Building 7.

The investigation, which has been supported by the recent passage of an emergency supplemental appropriations bill, will focus on the building construction, the materials used and all of the technical conditions that contributed to the outcome of the WTC disaster. The study will involve the participation of experts from industry, academia and other laboratories, complementing NIST's own in-house capabilities.

NIST will also draw on the expertise of a private-sector coalition that includes professionals from the Structural Engineering Institute of the American Society of Civil Engineers (SEI/ACSE), the National Fire Protection Association (NFPA), and the American Institute of Steel Construction (AISC). NIST will also maintain liaison with the Society of Fire Protection Engineers (SFPE), the Council on Tall Buildings and Urban Habitat (CTBUH), and the Structural Engineers Association of New York (SEAoNY).

NIST expects to complete its investigation and issue a final report within an estimated twenty-four months from the start of the program. The investigation is part of a broader NIST response plan to the WTC disaster.



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A Selected Historical Review of Human Behavior in FIRE

By Dr. John L. Bryan

INTRODUCTION

This article reviews selected historical literature relevant to the behavior of the occupants during a fire occurrence. Although the primary emphasis is on the developments in this study area within the United States from the early 1900s until 2002, the literature cited is of worldwide origin. This article also presents an analysis of the recent influence of the performance-based code concept on the research on human behavior in fire with the resulting emphasis on evacuation models.

This review is an attempt to identify the development with both the academic and professional recognition of the study area consisting of the human behavior variables that appear to occur in fire incidents. The review of literature has attempted to recognize the sources of the significant and historical publications relative to these issues. Any omissions of significant and historical studies is truly unintentional. The emphasis throughout this presentation is on the history and development of this study area within the United States. For the purposes of continuity, this article has been organized into three chronological time periods: The "Prerecognition Years" period was arbitrarily selected as the period from the evacuation studies of the early 1900s to the 1970s. The time period for the "Productive Years" of the study area of research on human behavior in fire was selected to include the 1970s and the 1980s. The "Performance Code Incentive Years" were identified as the 1990s into the 2000s. There has also been an attempt to delineate the need for the use of fire-related validation data in the development of the human behavior models.

THE PRERECOGNITION YEARS FROM THE 1900s TO THE 1970s

The earliest documented human behavior studies in the United States involved capacity counts of pedestrian velocity for the New York City design of the Hudson Terminal Building in 1909.[1] The first (1927) edition of the National Fire Protection Association's *Building Exits Code* was developed from evacuation studies conducted during 1917-1927.[2] Classical evacuation studies involving railway terminals, subway stations, theaters, department stores, and federal government office buildings with both "normal" exiting flows and "fire-drill" exiting flows were conducted in the early 1930s and published in 1935.[1]

The London Transit Board and other evacuation studies were conducted in Great Britain;[3, 4] however, there was a lack of interest in the United States during the 1940s and the 1950s. Even in large loss of life fires such as the Coconut Grove, dedicated human behavior studies of the activities of the occupants were not conducted.[5]

The academic study of the behavior of people in buildings at the time of a fire occurrence was initiated in the United States in the 1950s. Interviews with selected occupants of the Arundel Park fire incident in 1956 verified a reentry behavior by members of family groups.[6] The prevailing rationale at this time was that fire protection engineers developed building features to enhance the fire safety of the occupants, to control the ignition of fires, and to effectively suppress the fires that did occur. However, it was recognized by some that a difference between a minor fire incident and a major fire incident often involved the human behavior of the personnel immediately prior to the fire incident or during the fire incident. The recognition of occupants' behavior often identified in engineering investigations of major fire incidents had long been documented, but little study and

analysis had been conducted to identify and determine the casual and intervening variables involved.

Two politically significant fires occurred in 1967 that created and accelerated a change in fire protection engineering. The first fire was the Apollo spacecraft fire on January 27, at Cape Kennedy, Fla., with the loss of the three astronauts.[7] The second fire occurred on February 7 in Dale's Penthouse Restaurant in Montgomery, Ala., with 25 fatalities and 12 injuries.[8] The U. S. House of Representatives Committee on Science and Astronautics conducted hearings in May and June of 1967 on the Fire Research and Safety Act of 1967. This act was signed by President Johnson in 1968 establishing the National Commission on Fire Prevention and Control, which resulted in the "America Burning" report of 1973.[9]

Thus, a clear mandate was given to the federal government to conduct research in areas of the fire problem previously not considered. The Center for Fire Research at the National Bureau of Standards in The Department of Commerce was formed in 1974 and became vitally involved with many questions of the occupants' behavior in fire incidents. Two individuals at the bureau were primarily involved in guiding and fostering this human behavior research, Harold E. "Bud" Nelson and Irwin Benjamin.

THE PRODUCTIVE YEARS OF THE 1970s AND 1980s

The most productive time span for research and publications on human behavior in fire in the United States was from 1970 through the mid-1980s. The National Fire Prevention and Control Administration provided a federal government focus on national fire problems. This organization guided the new and enhanced federal financial support for all facets of fire research, including human behavior. This agency envisioned the primary role of human behavior research being applicable primarily to the educational aspects of fire prevention.

During the 1970s and 1980s, the National Bureau of Standards through the Center for Fire Research, was the primary source for funding human behavior in fire studies in the United States. Some of the early and distinguished researchers supported by the National Bureau of Standards were John "Jack" Keating and Elizabeth Loftus from the University of Washington. These researchers established the parameters of the voice alarm system for the Seattle Federal Office Building.[10] Norm Groner and Bud Levin were also involved with some of the early studies sponsored by the National Bureau of Standards in the Center for Fire Research. They both have continued their involvement with the research on human behavior in fire, specifically with their studies involving areas of refuge, evacuation, and elevator usage.[11, 12]

It was during this period that there were two international seminars on human behavior in fire. The first seminar was conducted at the University of Surrey in March of 1977, having been organized by David Canter and the members of the Fire Research Unit at the university. Most of the papers presented at this seminar, with additional invited papers, became the first complete book on human behavior in fire.[13] The second international seminar was conducted in October of 1978 at the National Bureau of Standards. The researchers at both of these conferences were primarily involved with the examination and development of the methods for the investigation of the behavior of the occupants in fire situations in both the United States and Great Britain.[14, 15, 16, 17] Funding was also provided in the early 1970s by the National Bureau of Standards for the formation with Japan of the U.J.N.R. (United States and Japan Natural Resources) Panel on Fire Research and Safety in which the panel meetings included the study area of research on human behavior in fire. The emphasis of the studies in human behavior during this later portion of the "Productive Years" was in defining the behavioral actions of the occupants in fire situations, the examination of the then-popular concept of "panic behavior," and a new emphasis on the study of the evacuation process as it occurred in high-rise buildings. As a result of this decade of research in human behavior in fire, the study area attracted additional researchers and interest throughout the world.[18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33]

In the 1970s and early 1980s, two critical studies were conducted at the University of Maryland. The first study replicated the methodology of Peter Wood's study in Great Britain, in which fire service personnel interviewed 2,193 occupants from 952 fires from a structured questionnaire.[34] Peter Wood assisted in the development of the questionnaire for the University of Maryland study to assure the compatibility of the study data for comparative purposes. This study, which was conducted in jurisdictions in the Washington, D.C., and Baltimore, Md., area, involved 584 participants in 335 fire incidents and confirmed the reentry behavior where members of the primary group were involved. The study also established the tendencies of occupants to move through smoke and the fire-fighting behavior of occupants in residential occupancies.[35] This study was also one of the few human behavior in fire studies comparing the cross-cultural samples of occupant behavior from Great Britain and the United States.[34, 35]

The second study primarily involved healthcare occupancies and selected

significant fire incidents involving reports of human behavior activity.[36] This study was conducted by university personnel applying questionnaires and interviews of staff, patients, and first-arriving firefighters. A fire incident studied in a high-rise apartment building provided the first indication of the formation by the occupants of convergence clusters in selected apartments, which was later confirmed to a much greater degree in the fire incident at the MGM Grand Hotel.[37, 38] Two fire incidents in university residence halls involved jumping behavior by occupants previously injured while using the means of egress system in evacuation attempts.[39, 40]

In the United States, federal support for fire research started to emphasize computer modeling of fire dynamics in the early 1980s. Thus, the financial support relative to human behavior in fire since the early 1980s has been primarily directed to computer models concerned with the human behavior in building evacuation.[41, 42, 43, 44, 45, 46]

The International Association for Fire Safety Science from 1985 to 1996 had become the primary organization for the publication of research studies on human behavior in fire. At the first symposium in 1985, there were six papers, and at the 1996 symposium, there were nine papers, with two of the papers involving evacuation models.[47, 48] The 1994 symposium had a record number of human behavior in fire papers with a total of twelve papers, 75 percent of which involved evacuation models.[49]

The concern for the evacuation of occupants with mobility impairments and other physical constraints was initially established in the 1970s as a result of studies of the evacuation of high-rise buildings.[16, 32] This concern in the United States resulted in a two-session national conference on Fire and Life Safety for the Handicapped in 1980.[50, 51] This area of human behavior in fire has continued to receive emphasis through both interview and experimental studies, the examination of the use of refuge areas, and the use of elevators for evacuation.[2, 50, 51, 52, 53, 54, 55, 56]

The basis for most evacuation models which predict the velocity of movement and the flow of occupants in the egress system have been developed from evacuation studies by Jake Pauls, who conducted his initial study in 1969.[26] Since the mid- and late 1980s the emphasis of studies on human behavior in fire in the United States has been on the documentation of evacuations and the development of evacuation models, with consideration of the human behavior factors identified in the fire incident studies of the 1970s, ’80s, and ’90s. One of the most intensively studied evacuations was the bombing of the World Trade Center on February 26, 1993. This incident was studied with one interview study and two questionnaire studies relative to the behavior of selected occupants.[57, 58, 59] This fire incident evacuation was also the source of one of the few detailed and documented interview studies of the evacuation of disabled occupants.[60] Fahy utilized the data collected in a questionnaire study of the evacuation behavior of 406 fire wardens to improve her evacuation model.[58, 61]

Human behavior in fire in the United States has been neglected since the mid-1980s. The leaders in this area of critical fire research are now in Australia, Canada, Great Britain, Japan, New Zealand, Northern Ireland, Norway, and Sweden. The application of experimental studies with human subjects relative to wayfinding and smoke effects have been conducted in both Japan and Norway.[62, 63, 64]

THE PERFORMANCE CODE INCENTIVE YEARS OF THE 1990s INTO THE 2000s

The worldwide movement toward performance codes has created a demand for computer evacuation models that will provide an estimate of the evacuation time for a building.[44, 45, 61, 65, 66] The basis for most computer evacuation models has been the data provided from normal and practice evacuations in earlier studies.[67, 68]

Regardless of the perceived advantages or disadvantages of performance-based fire codes[69, 70, 71, 72], the utilization and adoption of these codes will enhance all of the research areas relative to the understanding of human behavior in fire. Thus, with performance-based fire codes, the fire protection engineer and the building designer can no longer adopt a policy of benign neglect of the results of the research on human behavior in fire. Meacham has included in his ten needs for the successful application of a performance code approach “to understand how people react in a fire situation.”[71]

Computer models of occupant evacuation have continued to be refined and to become more valid in their simulation of occupant activities in normal evacuations and evacuation drills.[65, 66] It is of interest to note that the only human behavior in fire study supported by the National Institute for Standards and Technology in 1996 or 1997 was EXIT89 evacuation model Fahy’s.[61] Shields and Dunlop have emphasized the areas of refinement and improvement needed in the computer models as: the accommodation of mixed-abilities populations, accepting management fire safety profiles, recognition of the phenomenon of contra flows in egress ways, and most importantly, to eliminate invalid assumptions.[55]

The future of research on human behavior in fire is indeed more promising today than at any time in the past, with the recognition of the need to determine valid evacuation times in the design of the building under the performance code concept.

However, with this increased application of computer evacuation models there is an increased need for model designers to effectively communicate to potential users the limitations of the model, e.g., if human behavior is not simulated by the model and the populations or occupancies for which the model has not been validated. In addition, the model designers should provide a detailed inventory and description of the validation procedures and studies to which they have subjected the model. Critical variables in human behavior have been identified as follows:

Proulx has found that the means of alerting occupants directly impacts the time delay before initiation of evacuation.[73] Proulx, Sime, and Fahy stress the need to accurately assess the time delay before evacuation when predicting evacuation times.[74, 75, 76, 79] They point out that this delay is influenced by building occupancy and population characteristics, and that it includes investigation, information-seeking, alerting others, assisting others, and firefighting.

In incorporating data from studies, developers of evacuation models must also recognize that evacuation drills are less stressful than evacuations from fires, since there is less ambiguity and physiological or psychological exposure to the effects of the smoke or heat in drills than in fires.[35, 36, 37] Drills are also different in that occupants do not seek out areas of refuge for communication, relief from contaminants, or psychological support as has been seen in fires in high-rise residential occupancies.[38, 72] The ambiguity of alerting cues in the fire-induced evacuations can prolong the time delay prior to evacuation.[6, 38, 75, 76, 77, 78, 79] Fire-induced wayfinding complications also reduce occupant evacuation velocity.[35, 37, 38, 77, 79]

In 1999, the Society of Fire Protection Engineers created a task group on human behavior. This task group is developing a guide for application by fire protection engineers to identify and develop the critical human behavior data in their utilization of the performance-based fire protection analysis and design of buildings.[80]

The Fire SERT Centre at the University of Ulster has produced significant studies relative to disabled individuals in the late 1990s. These studies have developed data on the mobility of the population in corridors, on ramps, through doors, and the perception of exit signs.[81, 82, 83, 84]

The University of Ulster also created and conducted the First International Symposium on Human Behaviour in Fire in Belfast in 1998.[85] This was the first symposium dedicated to human behavior in fire research in almost twenty years.[13, 14] The symposium was a landmark event, with 81 presentations on the following human behavior in fire topic areas: Fire-Related Human Behaviour; Fire Regulations and Fire Codes; Learning from Human Behaviour in Real Fire Situations; The Assimilation, Evaluation, and Use of Information by People Exposed to Fire; Characterization of Building Occupancies and Complex Environments; Evacuation of Disabled People from Fire; Assessing the Risk to People Exposed to Fire; Determining Evacuation Time and Evacuation Performance Measures; Occupant Characteristics and Human Behavior Transport and Ancillary Facilities; Wayfinding Performance in Complex Environments; Occupant Perception and Escape through Smoke; Evacuation Simulation Modeling and Approaches to Validation.[85]

The University of Ulster also formalized the Second International Symposium on Human Behaviour in Fire held at the Massachusetts Institute of Technology in 2001. This symposium included 56 presentations in the following topic areas of human behavior in fire: Human Behavior Theory; Evacuation Modeling and Functionality; Occupancy Characterization; Occupant Response; Toxicity and Smoke Effects; Non-Engineering Solutions for Reducing the Incidence and Impact of Fire; Visual Accessibility and Spatial Analysis; Human Performance Criteria for Inclusion in Regulations and Codes.[86]

CLOSING REMARKS

It is recommended that all interested fire protection engineers review the presentation on the development of the study area of human behavior in fire by Jake Pauls at the First International Symposium on Human Behaviour in Fire.[87] The increased interest and research activity generated by the performance code concepts and the Fire SERT Centre symposiums have created a promising potential for the utilization of research on human behavior in fire. The fulfillment of this potential is the responsibility of human behavior researchers, building designers, and most importantly, fire protection engineers. ▲

John Bryan is Professor Emeritus in the Department of Fire Protection Engineering, University of Maryland.

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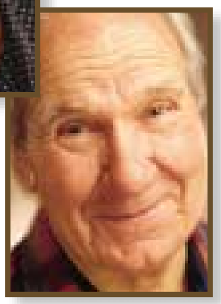

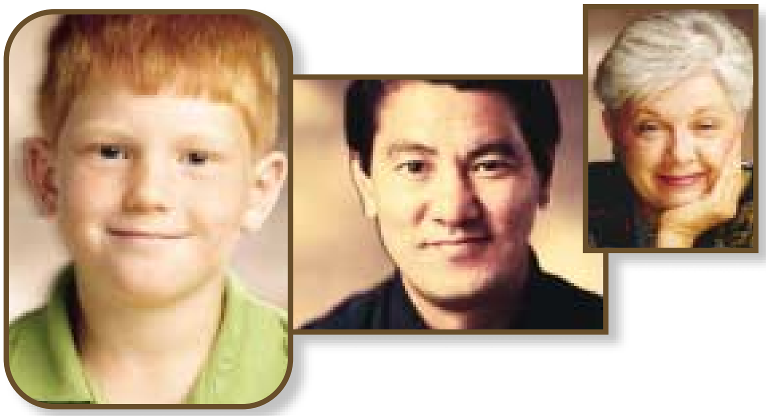

Building Expectations:

Managing Fire Safety by Putting People Back in the Picture

By Mark Chubb

For much of the past quarter-century, study and attention to the influence of human behavior in fire have focused almost exclusively on the actions people take in emergency situations. Despite very little ongoing commitment to such study, a great deal is now known about what people do in fires.[1] We know a little less about why people do these things and still less about how to influence their actions, but we certainly know enough to influence the way we design buildings.

What some consider the unpredictable nature of observed human behavior in fire situations belies its consistency, but such misunderstandings probably explain why many fire protection engineers seek to control or minimize the influence of people on fire outcomes through their designs. This bias stands in stark contrast to other engineering disciplines, like aerospace, biomedical, chemical process, and nuclear engineering, where human factors play a very significant role in defining and controlling the technology and, consequently, play key roles in achieving and maintaining safety and reliability.

Keeping in mind the old adage that men, women, and children represent the three leading causes of fires, can we afford to ignore or even marginalize the roles people play in fire protection designs? Putting people first will help us prevent fires in the first place and, failing that, help encourage them to take constructive and appropriate action when fires do occur.

PEOPLE AS CAUSE AND CURE

In the new era of performance-based design, consulting fire protection engineers spend most of their time concerned with two things: 1) buildings systems and services, and 2) the codes and standards that regulate their design, construction, and use. People and fires often receive attention from engineers only when code compliance cannot be achieved by dealing with the building or its component systems alone. And the solutions proposed under such circumstances often introduce unrealistic assumptions about what people will do or what fires will occur (or not occur) in an effort to demonstrate that some building feature or another is not required. Construction-cost considerations seem to play a significant role in this sad state of affairs.

Most building fires involve faulty interactions between people and the things that go on inside buildings. If these fires heavily damage or destroy the buildings where they occur or cause injuries or death to the people inside, they do so not only because the building did not respond well to the fire threat but because the people didn't respond well.

Recently reported research by Thomas and Brennan[2] offers a possible explanation for this and suggests why we should pay more attention to fire prevention in our designs. Their analysis of Australian fire incident reporting system returns indicates that the largest proportion of residential fire fatalities in Australia involved people responsible for the outbreak of fire in the first place. Although results of a similar assessment for nonresidential fires have not been reported, anecdotal evidence would seem to suggest that similar circumstances apply to commercial and industrial fire deaths as well.

Concentrating on the building's reaction to fire, although logically and legally necessary, will ensure the barn door gets closed only after the cow gets out. Putting people first will help us achieve both aims: 1) preventing the outbreak of fire, and 2) managing its consequences when prevention fails.

RULE-BASED APPROACHES

In the past, fire protection engineering practitioners spent a good deal of time looking at what made their clients tick. Insurance loss control specialists, in particular, paid a great deal of attention to process hazards in plants, management attitudes toward fire safety, and employee training and work practices. When financial incentives and disincentives influenced by underwriting practices and premiums didn't work, the industry relied on rules.

Beginning in 1927, the National Board of Fire Underwriters (NBFU) in the United States produced a model fire prevention code for use by its field engineers in their evaluations of local fire departments' fire prevention programs.[3] This document served as the basis for model code organizations' efforts when NBFU's successor organization, the American Insurance Association, suspended its publication in the mid-1970s. Fire prevention codes based on NBFU's national model, unlike today's fire codes which have become increasingly immersed in the building process and fire protection features, dedicated their pages to transcribing the lessons learned from past failures into prescriptions for preventing future catastrophes.

No one knows for sure how successful NBFU's approach was in controlling or motivating human behavior. We can say with some confidence, however, that fire prevention code requirements influenced designers and users of technologies to take account of active human error (slips) in the operation and maintenance of complex systems whose hazards had already become apparent. Arguing that this approach neglects the problem of latent human error associated with new or emerging technologies seems a fair criticism, but one easily addressed without relying on costly external controls that displace investment and marginalize the role of human operators.

Groner[4, 5] has suggested ways fire protection engineers can take account of human factors in fire protection design by focusing on what people are trying to achieve through their actions. This approach puts people at the center of systems and forces designers to consider how the environment they create influences people, and vice versa. Chubb[6] offered a complementary approach, suggesting that incorporating a values-centered perspective into the development and application of regulations could foster an environment more conducive to controlling human error.

How can fire protection engineers put such principles into practice in the meantime? They can start by keeping in mind that most people who build don't do so to save money. They build to make money or, at the very least, to preserve their wealth. This recognition brings with it an implicit acknowledgement that people accept the act of building brings with it risks associated with unwise investments or poor construction practices. Making these risks clear to clients is among the fire protection engineer's chief obligations.

Since clients rarely place fire safety – as distinguished from fire code compliance – among their chief concerns in the design of new buildings, encouraging appropriate investments in fire safety requires fire protection engineers to obtain a clear understanding of the purpose a new building serves for the client. This requires looking beyond the occupancy classification to learn how the activities, intentions, and expectations of people will influence their actions with respect to the use and maintenance of the building.

SIZING UP THE SITUATION

A building that provides shelter and security against external threats like weather, earthquake, and theft is next to useless if it creates new and potentially greater risks of loss or damage from internal threats. The enclosing nature of buildings creates new risks in the event of fire that owners and some fire protection engineers may easily take for granted.

Many buildings designed even a few years ago now find their construction out of step with owners' and occupants' expectations. Storage heights reaching towards the rafters, overstuffed closets filled with disused files and furniture, "open plan" office floors with cubicles and corridors that resemble rabbit warrens, and rats' nests of cables beneath floors and above suspended ceilings illustrate a few of the situations that occur when space does not magically expand to suit the users' ever-changing notions of what they need.

If the building can't cope with the users' expectations under normal circumstances, what chance does it have when a fire occurs? What chance do the people and property inside have? How will failure to account for these expectations affect performance-based designs that take little account of the future?

Oddly enough, older buildings constructed under prescriptive regulations or no regulations at all offer some interesting answers to these questions.

Maybe such structures are little more than the product of a simpler time, but many buildings designed and built at the end of the 19th and beginning of the 20th centuries have stood the test of time well, often finding themselves occupied by many new, even novel, uses during their lifespans. Their stout construction and attention to detail reflected the romantic notion that people can conquer any obstacle through little more than the application of scientific principles and perseverance. Without the sophisticated tools considered commonplace by contemporary engineers, designers built with a sense of place and permanence that embraced a scale sometimes larger than life itself.

It seems impractical if not outright impossible to approach building design this way today. The reasons for this have nothing to do with technology or the science that produces it.

As faith in science grew, so did impatience with the *status quo*. Political upheaval, a worldwide economic depression, two world wars followed by political stalemate, and the unsettling reality of internecine conflict that has come about since the collapse of Communism have replaced optimism with pragmatism. Getting things right is less important than getting them done quickly and economically, before it's too late.

What does all this have to do with fire safety? Nothing and everything.

Fire itself adheres to physical not human laws. People ignore or neglect these laws at their own peril.

The infatuation with fast, the lack of practical impediments to finding scientific support for virtually any proposition, the seemingly endless opportunities to shift accountability so as to avoid responsibility, and the increasingly remote experience of fire as a cause of human suffering have left those who own and use buildings with little reason to pay it or fire protection engineers much heed. People aren't intentionally indifferent about fire; they just have more important things to worry about. Or so they think until a fire occurs.

BUILDING EXPECTATIONS

Sadly, people living in our postmodern world expect bad things to happen. Most folks do not wish others harm, but they do hope that whatever ill next befalls society won't affect them directly. Far more often than not, they live on in a quiet yet mildly discomfiting confidence that this was in fact the case.

In the backs of our minds though, most of us live with some small fear that we could be next. Our limited attention to fire reflects the overwhelming need in terms of efficiency, effectiveness, and, indeed, sanity to attend only to those threats of which we are aware and that we can control. Anything else, particularly to the extent that it becomes a preoccupation or distraction, represents wasteful inattention to the more immediate and pressing concerns of daily life.

Raising awareness of fire and engendering a commitment to fire safety among building owners and occupants need not require us to unduly alarm people. Indeed, distorting the likelihood or consequences of fire can either fuel unfounded fears or more likely instill indifference in the form of learned irrelevance.

Fire protection engineers can engage people in meaningful activities that promote improved fire prevention and fire safety outcomes in a number of ways. Most of these approaches require attention not only to assumptions about the roles people play and the biases that affect them, but the behaviors and actions we want people to display in different situations.

For example, discouraging the wildly variable premovement delays observed in evacuation trials and actual emergencies requires us to overcome the consequences of learned irrelevance in the instance of fire alarm signals. Believing that most alarms they experience are false because they saw no sign of fire, most people "learn" to disregard these signals and treat them as little more than another annoyance of modern life.

Something as simple as providing regular, perhaps even automated, feedback to all building occupants, not just those who investigated the alarm, following each activation would indicate what caused it and provide reassurance that the system does work, even if too well in the instance of things that only look like smoke but aren't. What's more, when such alarms are caused by avoidable circumstances such as improper siting of detectors, poor maintenance practices or defective apparatus, providing such information to building occupants will usually stimulate expectations that someone will deal with the situation to prevent future inconvenience.

Designing fire alarm systems to tattle on their owners has become commonplace since the introduction of analogue/addressable systems with sophisticated microprocessor controls. But are we telling the right people when things aren't working right?

The failure to maintain test regimes, perform routine maintenance, or respond promptly to dirty detectors undermines the reliability of fire alarm systems required for the safety of the building's occupants. Why not tell someone who cares when these faults remain unaddressed for too long? A "Big Brother" approach need not become the norm either. Instead of notifying the local authority responsible for fire code enforcement, the system could just as easily and perhaps more effectively notify all the building occupants who rely on the system for their safety.

The idea that systems should engage the active attention of their users by creating intentional system states that command attention is not new. Only its application to technology in the everyday world of homes and buildings is. How can we harness this tool for fire prevention?

Alerting people to the potentially harmful consequences of their actions can produce many positive benefits. Lately, some home appliance manufacturers have incorporated audible warning devices into their refrigerators to alert users when the door remains open for too long. Shutting the door saves energy and prevents spoilage. Why can't comparable devices be incorporated into electric and gas ranges for example to warn users who leave cooking unattended for too long?

A simple device of this sort could incorporate a timer with limit states set in proportion to the heat output of the cooktop elements. A warning signal that intensifies as the time since activation increases would continue for a reasonable time limited by the burner heat output before interrupting the power or fuel supply to the element or burner. This arrangement might not prevent all fires caused by unattended cooking, but it certainly wouldn't make matters any worse than they already are.

Designing fire doors and smoke control door assemblies so they sound a mild but annoying alarm when left open too long unless held by an approved device represents another useful application of this idea. By the same token, designing such doors with power-assisted openers and time-delay closers that permit the door to remain open for a time before returning to a closed position could aid the movement and safety of the elderly, those with mobility impairments, and staff in hospitals and similar care facilities without compromising fire safety.

More and more building owners employ security systems to control access to their buildings and restrict movements within them to authorized areas. Clearly such security measures can be used to prevent incendiary fires or the unauthorized disabling of fire protection systems. Integrating such measures with fire safety systems could also provide a ready and accurate indication of the number and location of people requiring evacuation. With some enhancements, these systems can provide tailored feedback to users and occupants reminding them of important fire safety messages or other information useful in their day-to-day use of the building.

BACK TO THE FUTURE

To some fire protection engineers, these ideas may sound a bit far-fetched, needlessly complex, or too costly to merit serious consideration. But these same ideas have already changed the way computers, home appliances, and telecommunications devices are designed. And now they are gaining increasing currency within the building industry as cybernetic building software and systems are developed to help building owners deploy cutting-edge telecommunications infrastructure and manage their energy costs to achieve efficiency or gain new clients.

This leaves fire protection engineers with a choice between employing technology to overcome what they consider human frailties or to improve human performance by putting people back in the picture.

In most situations, how people perform will depend to a very great extent on what they expect to occur. This is clearly influenced by their relationship to the situation. Putting people back in the building fire safety picture will help us foster positive expectations of self-efficacy and engagement with situations that not only achieve better performance in the event of fire but may actually help us prevent fires in the first place. ▲

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Setting Standards for Excellence

Speech Intelligibility

INTRODUCTION

In situations where egress is complex or difficult, such as in high-rise buildings or large factories, human voice is often used to provide *information*. Failure to understand message content can result in several ways. A message that is not *intelligent* may not be understood. A message spoken in Spanish to an audience that only understands Cantonese will not be understood. A person talking rapidly or with a speech impediment can cause a message to not be understood. Even a well-spoken, intelligent message in the language native to the listener can be misunderstood if it is not audible or if its delivery to the listener is distorted. These last failure mechanisms are the basis for the specification, modeling, and measurement of speech *intelligibility* performance.

THE PROBLEM

Fires such as the King's Cross fire in London in 1987 and an apartment fire in York, Ontario, have been cited as situations where the lack of intelligible voice communication to occupants was a contributing factor in the losses.[1,2] We often see paging systems in places such as airports and meeting spaces with speakers every eight to twelve feet (three to four meters). How will the speech intelligibility of the adjacent fire alarm system compare when it has speakers spaced 40 to 70 feet (10 to 20 meters) apart?

No one argues that a tone signal must be audible to the listener and that a voice transmission must be intelligible. Disagreements regarding audibility led the fire alarm industry to adopt audio industry definitions and measurement methods. This moved the industry from using *subjective* evaluations of audibility to *objective* methods.

In 1997, the Notification Appliances Committee of NFPA 72 began working with the audio industry to learn more about speech intelligibility and how to establish objective performance requirements for emergency voice alarm communication (EVAC) systems. The goal was to define speech intelligibility performance in a way that could be objectively measured, eliminating subjective evaluations.

WHAT IS SPEECH INTELLIGIBILITY?

Figure 1[3] is useful in understanding the path of a voice signal from a talker to a listener.

The figure shows the types of error that can be introduced into the message at each stage. Problems or faults have a cumulative effect on message understanding. For example, a person might speak with an accent but still be understood by a listener who is face-to-face with the talker. The communications system might add distortion that results in the message not being understood. Or perhaps it's understood when there is little or no background noise, but not understood when there is background noise.

Researchers are addressing the two ends of the communications chain shown in Figure 1.[4,5] For the purposes of this article, speed of talking, language, and talker articulation are not directly addressed. They are indirectly addressed because a system that reliably delivers a message, with a limited amount of distortion, reverberation, and echo, is more likely to be understood even when a talker introduces problems or when a listener has impaired hearing. A system with a higher degree of intelligibility can offset some, but not all, deficiencies introduced by the talker or the listener.

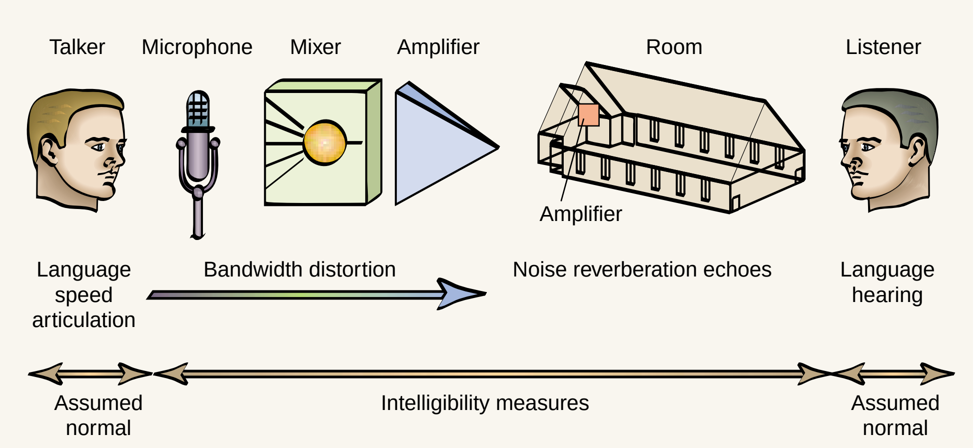
Speech intelligibility is the measure of the effectiveness of speech. The measurement is usually expressed as a percentage of a message that is understood correctly.[6] Speech intelligibility does not imply speech *quality*. A synthesized voice message may be completely understood by the listener, but maybe judged to be harsh, unnatural, and of low quality. A message that lacks quality may still be intelligible.

FACTORS AFFECTING SPEECH INTELLIGIBILITY

For speech to be intelligible, it must have adequate *audibility* (sound pressure level) and adequate *clarity*.

For audibility, we are concerned with the signal-to-noise ratio. Voice is highly modulated, and so while intelligibility measurements do incorporate audibility, it is not to the same standards used for audibility of tone generating systems.

Figure 1. Voice Signal Path (Courtesy of K. Jacob, Bose® Professional Systems[3])



Thus, a tone and a voice message that are both perceived as equally loud may have considerably different readings on a dB or dBA meter using fast or even slow time constants. That is one reason that audibility measurements are not required by the *National Fire Alarm Code* for voice signals.

Phonemes are the smallest phonetic unit capable of conveying a distinction in meaning in a particular language and are instrumental in accurate word recognition.[7] Examples are the *m* of *mat* and the *b* of *bat* in English. Clarity is the property of sound that allows phonemes to be distinguished by a listener.[8] Clarity is the freedom of these sound units from distortion introduced by any part of the sound system or environment. Recently, a major U.S. cellular telephone company has implemented a television ad campaign playfully pointing out the very real problem of phoneme clarity.

Clarity can be reduced by: 1) amplitude distortion caused by the electronics/hardware; 2) frequency distortion caused by either the electronics/hardware or the acoustic environment; and 3) time domain distortion due to reflection and reverberation in the acoustic environment.

Designers and engineers have the greatest effect on speech intelligibility by their choice of equipment, the number and distribution of loudspeakers, and the power at which they are driven.

MEASURING SPEECH INTELLIGIBILITY

The system hardware and the acoustic environment cannot be separated when evaluating speech intelligibility. Installation choices, such as wire size and routing, affect power levels and induced noise. Mounting locations and surfaces affect sound fields, and construction materials and furnishings affect acoustic parameters. Thus, the performance metric for speech intelligibility must assess all of the requisite parameters.

International Electrotechnical Commission (IEC) and International Standards Organization (ISO) standards already incorporate objective methods for evaluating speech intelligibility. The standard, IEC 60849, *Sound systems for emergency purposes*,[8] is similar to NFPA 72. Some of the methods recognized in the standard are subject-based, and others use instrumentation. ISO 9921 also references established methods.[6] For each of the recognized methods, there already exists an internationally accepted standard for the test method/protocol.

The IEC standard includes a chart that equates the scales for each of the different test methods to a common scale called the Common Intelligibility Scale (CIS). Evaluation of speech intelligibility may use any one of several methods cited in the standard. Four of these methods use test instruments. Three subject-based methods are also permitted. One method has both a subject-based solution and an instrument-based solution. These are summarized below in Table 1.

For the four instrument-based solutions, at present there are at least six different instruments available from four different manufacturers. Consult the references for more detail on each of the test methods.

The recommended minimum performance level for EVAC systems is that the average CIS score, less one standard deviation, be 0.70 or greater. This permits deviations, does not require an exact score, and

Table 1. Speech Intelligibility Test Methods

Method	Standard Ref. in IEC 60849	Comments
STI – Speech Transmission Index	IEC 60268-16 The objective rating of speech intelligibility by speech transmission index, 1998	This is an objective, instrument-based method. Requires hardware and software for measurement and solution. Available in a computer-based solution, as a feature of some multi-function audio analysis equipment, and as a handheld meter.
RASTI – Rapid Acoustics Speech Transmission Index	IEC 60268-16 The objective rating of speech intelligibility by speech transmission index, 1998	This is an objective, instrument-based method. Reduced STI method. Available in a handheld format.
PB – Phonetically Balanced Word Scores	ISO/TR 4870 Acoustics – The construction and calibration of speech intelligibility tests, 1991	This is an objective, subject-based method. ANSI S3.2 Method for measuring the intelligibility of speech over communication systems, 1989, is a better reference for evaluations using the English language. Notification Appliances Chapter permits ANSI S3.2 use, although ISO/TR 4870 is also permitted.
MRT – Modified Rhyme Test	No reference given	This is an objective, subject-based method. No standard listed. ANSI S3.5 notes that the method has the same limits as given in ISO/TR 4870 (PB). Good reference is ANSI S3.2 Method for measuring the intelligibility of speech over communication systems, 1989.
AI – Articulation Index	ANSI S 3.5, Methods for the calculation of the articulation index, 1969 ANSI S 3.5, Methods for the calculation of the speech intelligibility index (SII), 1997	This is an objective, instrument-based method. The 1969 version is referenced. This has been updated to the 1997 edition. Requires hardware and software for measurement and solution.
$\%AL_{cons}$ – Articulation Loss of Consonants	Peutz, V.M.A., "Articulation loss of consonants as a criteria for speech transmission in a room," *J. Aud. Eng. Soc.* 19, 12, December 1971	This is an objective, instrument-based method or an objective, subject-based method. Available in a computer-based solution.

ensures that approximately 84% of the space has a score of 0.70 or better – assuming a normal distribution of the results. The 2002 edition of the *NFPA 72 Handbook* contains a discussion of why a CIS of 0.70 was used as a baseline.[9]

PLANNING, DESIGN, INSTALLING, TESTING, AND USING

A reliable communication system must be properly planned, designed, and installed. Testing uncovers faults and allows corrections to be made, but also shows successful techniques for future reference. One issue that designers and authorities must face when planning a system is the question of where intelligible voice communication is needed.

In a large space used for public meetings, conventions, and trade shows, an EVAC system needs to be reliably intelligible because it is intended to give information to the general public that is not familiar with the space. In large public spaces, a person should not have to move any great distance to find a place where they can understand the message.

However, in a high-rise apartment building, is voice intelligibility required in all spaces? It may not be necessary for the EVAC system to be *intelligible* in all parts of the apartment even though it must be audible in all parts. It may be sufficient to provide a speaker in a common space to produce an adequate audible tone to awaken and alert. When the voice message follows, it may not be intelligible behind closed bedroom and bathroom doors. The occupants, in a familiar space, can move to a location where a repeating message can be intelligibly heard. The same signaling plan may work for office complexes – a person may have to open their office door to reliably understand the message.

Once the design team plans to have some type of a system and decides that the system must be intelligible in certain spaces or areas, the fire alarm code's requirements and recommendations for intelligibility may become part of the *performance design objectives* or goals. It is important that all of the stakeholders, including the code officials, agree on the design goals and objectives.

By agreeing upon specific design goals and objectives, multiple approaches can be used to achieve the desired performance. The *National Fire Alarm Code* permits designers to use any and all reasonable means to achieve the objectives. Designers and installers who are new to the subject or who want to learn more about proper voice system design and installation should consult more in-depth resources.[10]

Just as fire protection engineers can model fires, acoustic and audio engineers can model speech intelligibility before a building is built and before a system is installed. Acoustic properties of materials are well documented and result in reliable evaluations of proposed designs in the same way that a fire protection engineer might evaluate flame spread and smoke contribution of materials. The electronic performance of the communications system can be adjusted in the models based on data from the system manufacturer.

At this time, there is no requirement in the body of the *National Fire Alarm Code* that speech intelligibility actually be measured. The measurement methods are discussed only in the Annex of the *Code*. However, if it is decided to measure intelligibility, how many tests should made in a particular space? Currently, there is no guidance for *audibility* measurements regarding the number and locations of test points nor for *intelligibility* measurements. With audibility, we have an intuitive sense of where a system might fail, and we tend to concentrate our testing plan in those areas. How many designers, technicians, and authorities have such intuition regarding intelligibility? This is not an argument to not test intelligibility. That would just be a head-in-the-sand reaction. Rather, it means that we need to start testing and that we are likely to test a larger number of points initially as we gather experience.

As with audibility, there are methods to test when a space is not occupied and then "add in" the expected or measured noise level at a later time during analysis. This permits less-invasive testing. It is common practice to test the audibility of systems before a space is occupied. Experience and available data permit us to estimate the expected noise level and compare it to the nonoccupied system performance. Similar procedures are done for intelligibility measurements. However, the required data may not be readily available or apparent to the fire protection engineer. Also, as with audibility measurements, intelligibility measurements in a space cannot be reliably made unless those parts of the interior finish that affect sound transmission and attenuation have been installed. ▲

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Editor's Note – About This Article

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Tools for the Simulation of Human Behavior

By Rita F. Fahy, Ph.D.

INTRODUCTION

Evacuation models are important tools for the evaluation of engineered designs, because such evaluations require the estimate of safe evacuation time for the occupants. The time needed to escape must be less than the time available to escape, which would be estimated using fire and smoke transport models. The designer or engineer has a range of options for predicting evacuation time.

The available tools range from fairly simple equations to the evacuation counterparts to CFD fire models. Each option has its own advantages and disadvantages. The user needs to weigh the assumptions embedded in each method in order to determine which is most appropriate for the application at hand.

Just as fire growth models can predict the spread of smoke and other toxic products throughout a structure, evacuation models can predict the location of people as they move through a structure. Used together in the evaluation of a design, these models can provide some indication of the risk that occupants might face under a modeled scenario.

The engineer or designer also needs access to, and an understanding of, the currently available data that should be used either in combination with the methods or as input to methods like computer models. Finally, the engineer or designer needs to understand the role of safety factors and other tools for properly and conservatively interpreting results.

This article will discuss some different types of tools that are available to model human behavior in fires and the issues that must be considered in making the choice. A more complete discussion of the handling of human behavior in engineered designs will be found in the forthcoming SFPE guide.[1]

WHY AND HOW HUMAN BEHAVIOR IS MODELED

Methods for calculating evacuation time and modeling human behavior vary widely in complexity and sophistication. Before choosing a method, it is essential for the user to understand the components of total evacuation time.

The entire span of time it takes to leave a building actually starts at the onset of the fire event. At a later point in time, the first cues reach the occupants. Some additional time may elapse before the occupants react and first respond to the fire cues. The initial reaction may result in activities such as investigation (to confirm that there really is a fire), firefighting, alerting others, etc. Once the occupants decide to leave, additional time will probably pass while they make preparations, collect valuables, discuss options, etc. Then, once they begin to move to the exit or a place of refuge, the time it takes to travel to those points will pass. To account for total evacuation time, the engineer or designer must estimate:

- time to notification,
- reaction time (time to perceive the cues and realize that some action is needed),
- pre-evacuation activity time, and
- travel time.

Time to notification could be modeled using fire and smoke models, and models for detector activation, although human detection will always be a possibility and should be considered. The other three components require a combination of modeling human behavior and predicting travel time.

True predictive models of human behavior in fire do not yet exist. There has not been sufficient research on human behavior in fire conducted so that models can predict reaction and response, and the associated delays, with any degree of accuracy. However, a great deal of data has been collected that provides observed delay times in evacuations, in both fire and drill situations.[2] Unfortunately, not all types of properties, for example, industrial properties and healthcare facilities, are well-represented in the data sets.

TYPES OF CALCULATION METHODS

There are different types of evacuation models. There are simple, straightforward calculation methods for estimates of evacuation times. These equations or simple computer models may be based on observed movement from drills and experiments. The *SFPE Handbook of Fire Protection Engineering* provides excellent discussion of calculations to be used to estimate evacuation time, and the reader is referred to that discussion.[3, 4]

The next level of complexity is network flow models that handle large numbers of people. These models are useful for benchmarking designs and can indicate potential bottlenecks that would negatively impact an evacuation, but they cannot be used to predict what any one person might experience, since they treat the occupants like water in a pipe rather than as individuals. As a result, they cannot be used to determine the effects of a fire on occupants as they move through contaminated spaces. These models can be used to calculate optimal evacuation times because they move occupants in the most efficient manner. If such a model predicts that occupants will not evacuate a building before unsafe conditions exist, it is unlikely that an evacuation in real life could have a shorter evacuation time, and design changes will be necessary.

Behavioral simulation models are the most complex, treating more of the variables related to both movement and behavior. Their added complexity requires tremendous amounts of data for their development, if the assumptions they contain regarding behavior are to be based on reality rather than expediency. Their users also need a fuller understanding of the components of human behavior in fire in order to choose appropriately among available options. Although these models may produce visually attractive results, the user must be very careful to understand the basis of assumptions embedded in the model, since so little data on occupant behavior actually exists in the literature. These models often have quite extensive input requirements, sometimes requiring information on occupant characteristics, such as mobility or patience, that are not measurable and whose distribution in the general population is not known.

WHAT A POTENTIAL USER SHOULD LOOK FOR IN A CALCULATION METHOD

An evacuation model that attempts to include a huge range of occupant characteristics into movement or behavior calculations raises the question of where the data come from. What are the appropriate values or distribution of values to use, and where will the user find them? For example, it can be persuasively argued that a person's patience, motivation, and agility play a role in their actions and behavior during an evacuation, but if a model specifically requires a value for each occupant's "patience," "motivation," and "behavior," what data should be used? What are the appropriate values, and where have they been reported? What ranges of values are there for the general population that should be used when modeling a building whose design is under consideration? What are the uncertainty bounds around the values, and how do they correlate with each other? In the end, is precision gained or lost by using them explicitly?

On the other hand, a simpler model is implicitly making the assumption that certain details are not essential to the calculation of estimation of total evacuation time. For example, a model that does not have the ability to predict or estimate the delays that will occur for some people in an evacuation while they are moving out of the building is making the implicit assumption that people neither lose time during their evacuation nor change direction. Unless some other adjustment is made to compensate, either by the model or in the model input, such a model will consistently underpredict or underestimate the total evacuation time. The justification for this, however, is that the data on who will delay, for how long, and with what effect are not available, at least not in sufficient detail and quantity to credibly model or predict that behavior. Similarly, the data necessary to predict who will change direction, at what point, and to what effect are not available.

A list of questions that should be asked by an engineer or designer in choosing an appropriate calculation method was compiled for the *SFPE Handbook*.[4] Some of the major issues addressed on that list will be mentioned here but all are important considerations.

The first question the user has to consider is whether an optimization model or a more detailed behavioral model, or a risk assessment method, is most appropriate. In the course of working on a building project, an engineer might use a combination of models – a hand calculation or a network flow model to obtain a quick assessment of the evacuation time necessary, and then a more complicated model to test the impact of changes in assumptions about the fire scenario or occupant characteristics.

Behavioral models attempt to realistically predict the actions and decisions made by occupants during an evacuation. These models are attractive because they seem to more accurately simulate evacuations. However, due to the scarcity of behavioral data, they tend to rely heavily on assumptions, and it is not possible to gauge with confidence their predictive accuracy. Users of such models need to establish confidence in the assumptions before relying on the results.

To set up the travel options for occupants, evacuation models use either a network of nodes and arcs or a mesh structure. When spaces and travel paths are defined using nodes and arcs, the movement of occupants is restricted to those paths, and the predicted movement is seldom smooth. (Occupants tend to jump from node to node, for example.) A mesh structure lays a grid of "tiles" over entire enclosures on a floor plan, and occupants are able to occupy or move from tile to tile. This allows the more precise location of occupants throughout spaces. Setting up the description of a floor plan using nodes and arcs can be very time-consuming, but once done, it does not have to be redefined unless the structure is redesigned. CAD packages can often be used to input the floor plan description for a mesh structure, but models that use a mesh are generally more time-consuming to run, due to the complexity of the calculations used to move people through such open spaces.

The degree to which behavior is simulated varies extensively among available models. Some require the user to estimate and input the premovement delays that are appropriate for a particular scenario and structure. Others include behavior "rules" and will predict behavior according to those rules. The engineer must be cautious in choosing a model. The complexity of some models implies a greater predictive capability, but again the scarcity of data available on behavior means that a great number of assumptions are imbedded in the models, and the appropriateness of those assumptions is critical in evaluating the validity of a model's results.

Of particular importance are the questions concerning the appropriateness of a model to the task at hand. The user must be clear on the assumptions that are explicitly stated by the model developer. Even more importantly, the user must be aware of the assumptions embedded in a model. For example, if a model uses a constant travel speed for occupant movement, the user must understand the source of that value and its applicability to the scenario being modeled. If all occupants will move at the same speed, the user must be able to justify the absence of differently abled occupants. The user must determine whether the model has been validated; if so, how and to what extent was the validation performed? The validation should address these questions and assist the user in choosing appropriate input values and understanding the impact of those choices.

The user must take into consideration the issue of safety factors: do the model results incorporate safety factors? If so, how is that done? If safety factors must be applied to the results by the user, that must be specifically stated, and appropriate methods for doing so must be described. However, remember that a true safety factor is intended to compensate for the uncertainty in the calculation, not for a bias leading to systematic underprediction, as in most simple models. The same multiplier cannot be validly used for both, and the uncertainty and bias associated with evacuation prediction may each be longer than those associated with common models of fire effects. That means traditional safety factors may be too small and may need to be derived from direct examination of the uncertainty and bias of the evacuation models used. ▲

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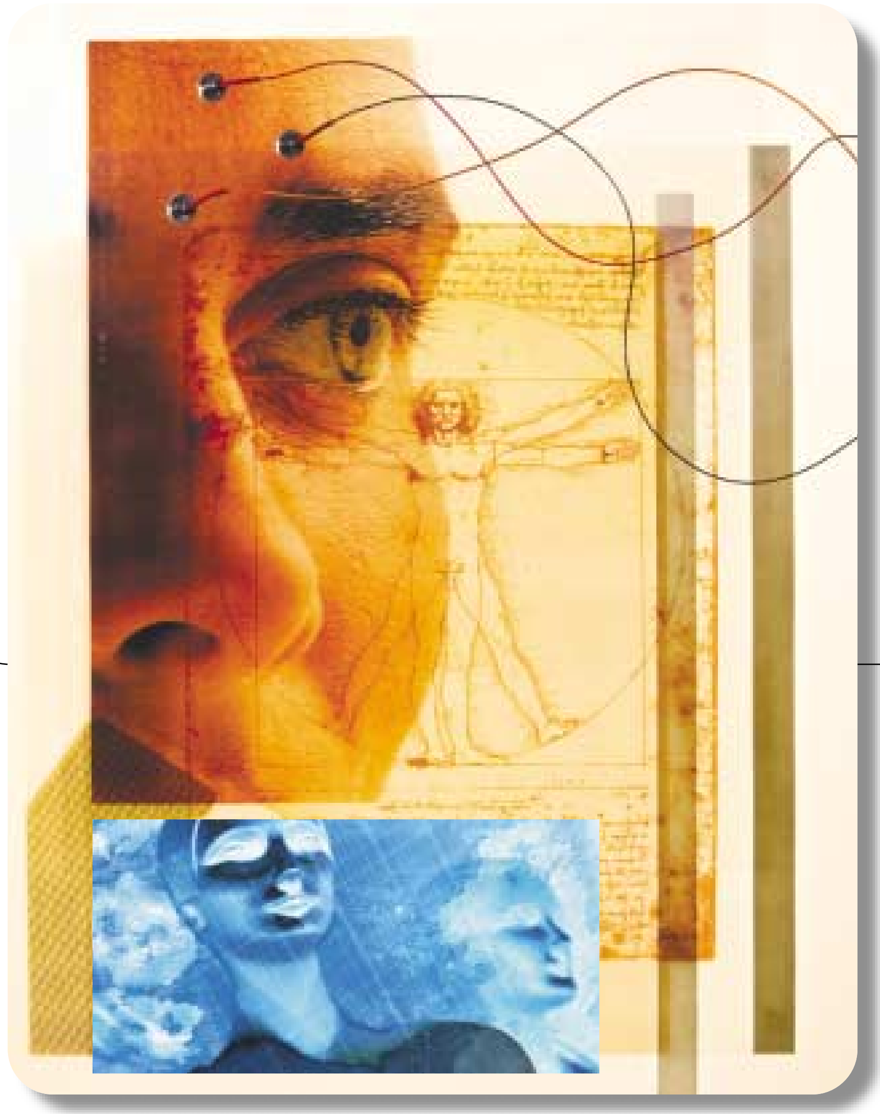

Cool Under Fire

By Guyléne Proulx, Ph.D.

DECISION-MAKING DURING A FIRE

Day-to-day decision-making such as choosing a meal from a menu or picking the best road to get to a meeting on time is quite different from decision-making during an emergency. Even major life change decision-making, such as the choice of a career, buying a house, or getting married is still different from decision-making during a fire.

There are three main reasons which differentiate decision-making during a fire from other decisions. First, there is much more at stake in a fire. The consequences of a decision could determine the survival of the decision-maker and of the people he or she values the most. Second, the amount of time available to make a decision is limited. Often the decision-maker will feel that a decision should be made quickly before crucial options are lost. Third, the information on which to base a decision is ambiguous, incomplete, and unusual. It is also usually impossible for the person to find more appropriate information due to the lack of time and the means to get information.[1]

Differences of decision-making during a fire from everyday life decision-making

- More at stake, possible life and death outcome for oneself or loved ones
- Limited time to make decisions which might be irrevocable
- Ambiguous limited information on which to base decisions

STRESS IS NOT PANIC

During a fire, the nature of the information obtained, the limited time to react, and the assessment of danger will create a feeling of stress. This stress will be felt from the moment ambiguous information is perceived until well after the event when the person has reached safety.[2] During the course of the event, the intensity of stress experienced will vary as a function of newly perceived information and assessment of the effectiveness of the decisions taken.

The media and general public often mention the potential of mass panic during fires, imagining a crowd that suddenly wants to flee danger at all cost, possibly getting trampled or crushed in the process. Although these types of behavior are extremely rare in fires, the expectation that people will panic is very strong. This belief is very much nourished by the media and movie industry, which plays on strong emotional images. In fact, panic in the form of irrational behavior is rare during fires, and researchers have long ago rejected this concept.[3, 4]

Actual human behavior in fires is somewhat different from the "panic" scenario. What is regularly observed is a lethargic response to the fire alarm, voice communication instruction or even the initial cues of a fire.[5] Except for low-rise residential buildings, where occupants feel that it is their responsibility to investigate an unusual smell, noise or movement, occupants are usually not very responsive in the initial moments of a fire. People are often cool during fires, ignoring or delaying their response to the initial cues of an actual emergency. Once occupants decide that the situation requires moving to an area of safety, the time left could be minimal.

If the person eventually assesses the situation as an emergency, instead of panic what is most commonly observed is an increased level of stress. Stress is not panic. It is considered that every person involved in an emergency will eventually feel some stress regardless of their age, gender, past experience, training, or cultural background. This stress is not an abnormal reaction or a negative response; on the contrary, stress is regarded as a necessary state to motivate reaction and action.[6] The performance of a person dealing with an increased level of stress will depend on the task demands, the environmental conditions, and the person himself or herself.[7] Decision-making under stress is often characterized by a narrowing of attention and focusing on a reduced number of options. This explains why training is so important, since people are unlikely to develop new solutions under heightened stress; a well-run decision plan learned and practiced beforehand is easier to apply under stress.

IMPACT OF SEPTEMBER 11

Unless very well trained, occupants in high rise buildings are usually reluctant to leave their floor and are prepared to stay in place when the fire alarm goes off. Phased evacuation or a protect-in-place approach are seen as less disruptive and more efficient by high rise building occupants and management. Staying in place during actual fires is sometimes the official fire safety plan in high rise buildings[8] or the chosen response by occupants.[9]

To make a decision during an emergency, people will process information, both perceived in the environment and drawn from past experience.[10] Part of this past experience now includes the events of September 11, which received unprecedented and sustained media coverage. Everyone has repeatedly seen the airplanes hit the towers, the fires, and the following collapses of the buildings; these terrible images may have changed the public perception of fire risk.[11] People may be fearful that a similar attack will be made on their building or that a fire could cause their building to collapse. If people have developed a new attitude toward safety, their response, in case of an emergency, might be different from our past expectations. On the one hand, it is possible to imagine that instead of a lethargic response to initial fire cues, people will have a different response in light of the events of September 11. They might refuse to protect-in-place and proceed en masse toward the stairwells to evacuate. On the other hand, the public is known to be fairly resilient at changing their behavior and attitude; they might have already forgotten and resume their past behavior. These are contradictory speculations. To better understand the impact of the events of September 11, it is essential to conduct thorough studies. It is important to know if a new attitude toward fire safety exists and the potential consequences of different evacuation scenarios. The design of buildings, fire safety features, and fire safety plans might need to be modified to accommodate this new attitude toward fire safety, or maybe nothing has changed. We need to know.

LOOKING AT THE BIG PICTURE

To study and understand occupant behavior in fire, it is essential to take into account the characteristics of three interacting dimensions of the event. These dimensions are the occupant, the building, and the fire. The first dimension that should be considered is the occupant characteristics. The characteristics of the occupant are an essential component that impact on their likely response and egress from a fire. Research has demonstrated, for example, that gender, age, physical ability, and group formation will have a substantial impact on response time and speed of movement.[12] Intuitively, it is known that a number of other occupant characteristics such as past fire experience or familiarity with the building should play a part in the response to a fire, but there is limited data to back up these insights.

A second dimension of the fire event is the building where the situation is happening. In building codes, occupancies are usually classified according to their size and use. These classifications, although extremely useful for professionals in the construction industry, are ill-defined to look into human behavior in fire. The occupant response to a fire alarm signal in a theater, a museum, or an airport is likely to be different although these are all assembly buildings. Instead of looking at buildings from their occupancy classification, the focus should be on some specific building characteristics that could explain occupant response. For example, the information provided through a voice communication system is a better indicator, than the occupancy type, to predict occupant response. The type of activity that occurs in a building is also an important factor that could explain occupant response. For example, if the fire alarm goes off at an airport, while a person is walking toward the exit with her bags on a trolley, she is likely to have a different response compared to a man that is waiting for an international flight inside the security gates.

The management of a building is another very important building characteristic that can contribute to the success or failure of occupant evacuation. It is documented that the activation of the fire alarm signal is rarely sufficient to trigger evacuation movement in public buildings, unless this signal has been supplemented with well-trained staff or live information provided through a voice communication system.[13] However, the information content that is most likely to prompt a specific response from occupants is not very well known at the moment.

Fire characteristics are the third element that will impact the occupant decision-making. Some preliminary studies show that the smell of smoke is probably not sufficient to waken sleeping adults.[14] How people tend to react to smoke, based on its color, smell, acridity, or thickness, is still an important area of research. What is known at the moment is that people are prepared to move through a fairly significant quantity of smoke, however, the characteristics of the smoke, the distance traveled and the conditions surrounding such a decision are not well understood.[12] Fire scenarios have to be thought through and taken into account when assessing the likely behavior of building occupants.

To predict human response, it is necessary to take into account how the occupant, building, and fire characteristics will interrelate in a specific case. This is not an easy task.

MISSING DATA

Some data on human behavior in fire is already available, but if misused, it can lead to fuzzy deductions. For example, it is acknowledged that a good marking system will support way finding in a building; however, a well-lit fire exit sign above a door may not be enough to cause occupants to leave through that door during an emergency. Understanding decision-making in fire is necessary to envision occupants' likely response during an emergency. Practitioners have to acknowledge that there is a lot more than simple common sense to human behavior in fire. Human behavior in fire is a scientific field that identifies facts, concepts, and relationships established through systematic observation and experimentation. Drawing conclusions about occupant behavior on the account of the fire chief or a few bystanders is not sufficient.

A number of areas of human behavior in fire require more systematic data to be collected using sound scientific methodologies. In the short term, research should be concentrated on a few main topics. One of these topics is to determine the responses that different cues will trigger from occupants. Traditionally, the expectation was that everybody starts evacuating when the fire alarm signal activates. Numerous cases have demonstrated that it is not always likely to occur.[9] The cues or information that will instigate the best response according to the occupant and the building characteristics is still not fully known.

Response time is another area where more research is needed. A few case studies have been conducted to measure occupant delay time between notification of a fire and the beginning of evacuation. These studies represent only a small sample that can hardly be generalized at the moment. It is suspected that training can have a major impact on occupant response, but no data on this dimension seems readily available yet. The presence of staff on the premises is another important factor that can influence the behavior of occupants, but there is no way to take this factor into account at the moment. The social interaction among people involved in the event can certainly influence the occupant response but this dimension lacks data. The impact of occupants with a disability is another area where knowledge is slowly building up and where more work is required. Finally, we can question if all the data already accumulated is transferable from different continents and if cultural differences actually exist. As in many young sciences, the field of human behavior in fire requires more data to be gathered through sound methodologies in order to eventually come up with solid models and theories that can be verified and validated.

GETTING DATA

There are a variety of means to conduct research in human behavior. They all complement one another and add to the knowledge base of this scientific field. Invaluable data can be accumulated following actual fires. There should be a systematic method used to obtain victim and fire service accounts to create a large statistical data bank. This would help in drawing comparisons among countries and identifying trends and recurring events. Specific interviews and a walkthrough with fire victims, contrasted with expert accounts are invaluable sources of data. Recordings from closed-circuit televisions should be used if present in a building at the time of a false or genuine alarm. Conducting field studies such as organized fire drills can also provide good insight into the possible initial behavior and movement of occupants. Controlled experiments could obtain precise data for well-defined conditions. It is the accumulation of this data from different sources that will help develop a better understanding of human behavior in fire. ▲

Guylène Proulx is with the National Research Council of Canada.

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Life Safety, Fire Protection, and Mobility-Impaired Persons

By Brian D. Black

INTRODUCTION

Immersed in the thousands of articles, papers and reports on the tragedy of the attack on the World Trade Center were items addressing the issue of life safety for, and evacuation of persons with, disabilities. Stories were told of people in wheelchairs who died in the resulting collapse of Towers 1 and 2, and anecdotal reporting told of at least a few saved before the buildings were lost.

Most professionals agree that as horrendous as September 11 was and will always be, the field of fire protection engineering cannot and will not be driven by that single event. Indeed, for those of us involved in the field of life safety for persons with disabilities, the World Trade Center is becoming the anomaly that masks the true loss of life that consumes disabled persons day after day across the United States. This article steps away from our nation's losses in downtown Manhattan to take a broader view of the challenge of life safety and the disabled.

"Disability" as a topic poses additional problems and raises issues that far exceed the limits of this article. Under federal statutes, disability includes the loss of sight experienced by an 85-year-old retiree, the deafness of a child exposed to rubella *in utero*, even the drug or alcohol abuse of an unemployed man in a single-room occupancy in the "bad" section of town. This article is limited to the fire protection and life safety needs of persons with mobility impairments – specifically, those unable to use stairs as an independent means of egress from buildings.

U.S. HISTORY OF ACCESSIBILITY AND LIFE SAFETY FOR PERSONS WITH DISABILITIES

The movement for accessibility in our nation's public buildings and facilities began after World War II and the return of soldiers who had incurred spinal cord injuries during battle. As America entered the postwar construction boom of the 1950s, veterans sought to change our nation's construction practices to include what was referred to as barrier-free design.

In 1959 the American Standards Association, acting on the request of the President's Committee on Employment of the Handicapped, called a general conference of groups interested in accessible design. This conference initiated a project to develop prescriptive requirements for access, and *Making Buildings Accessible to and Usable by the Physically Handicapped, A117.1-1961* was born.

All of eleven pages long, even this early document made passing reference to the problem of egress for persons with mobility impairments. It stated:

"Because entrances also serve as exits, some being particularly important in case of an emergency, and because the proximity of such exits to all parts of buildings and facilities, in accordance with their design and function, is essential (see 112 and 2000 through 2031 of American Standard Building Exit Code, A9.1-1953), it is preferable that all or most entrances (exits) should be accessible to, and usable by, individuals in wheelchairs and individuals with other forms of physical disability herein applicable." [1]

The concept had a number of flaws from the start:

- even in single-story buildings, it is not necessarily true that all entrances serve as exits (or that all exits are normal building entrances);
- the note is in nonmandatory language, and suggesting something is "preferable" does not make it a requirement;
- "entrances" are normally at or near grade, and the question of how to address exiting from stories above or below grade remained unanswered.

And while many experts agreed that such provisions were vague and ineffective,[2] United States federal guidelines[3] and standards[4] would continue to include similar perfunctory language regarding egress for persons with disabilities without adequately addressing the issue.

Why this lack of attention to a fundamental problem of life safety occurred is in many ways a uniquely American phenomenon. When requirements for accessibility were first introduced in the country, they applied to a very small number of buildings, typically owned by a government entity or funded by the federal government.[5] Private offices, restaurants, hotels, and similar occupancies continued to be built with stairs and narrow doors that rendered access into the buildings impossible and the question of egress by mobility-impaired persons moot. However, the 1970s ushered in a disability rights movement in which nondiscrimination on the basis of disability (and a resulting access into more and more buildings) was perceived as a civil right, similar to those rights afforded others for whom discrimination on the basis of race or ethnicity was prohibited. The battles for these newly claimed rights were waged in the legislatures and courts, and thus not exposed to the health, safety, and general welfare tests imposed by building codes and standards. And because life safety concerns were often seen by disability advocates as red herring excuses for not installing ramps and elevators, *"How will you get out once you're in?"* became a challenge to a civil right and not a legitimate concern for building design. Laws and regulations in virtually every state mandated access into more and more buildings and facilities, increasing the likely exposure of persons with mobility impairments to fires or other catastrophic events, while correlating requirements for egress were kept off the books.

By comparison, accessibility in other countries was paired with concomitant regulations for "egressibility" for persons with disabilities. British Standard BS5588 noted in its forward: *"A basic tenet of building law is that access provision has to be linked to egress provision...,"* [6] while the Public Works Canada Barrier-Free Design Standard included comprehensive provisions for accessible means of egress as early as 1985.[7]

By 1989, the model code groups in the United States began to tackle the problem of egress by persons with disabilities from multistory buildings. The Council of American Building Officials' Board for the Coordination of Model Codes (BCMC) developed both a standard set of accessibility criteria that was soon adopted by the model building codes[8] and accessible means of egress requirements that were included in both the model building codes and the NFPA *Life Safety Code*. The provisions addressed in *Engineering Solutions* (below) are now found in the "Means of Egress" chapter of the International Code Council *International Building Code* (IBC)[9] and are scheduled to be adopted by reference in the 2002 Americans with Disabilities Act Accessibility Guidelines.

PERCEPTIONS VS. REALITY

Throughout the development of the model code accessible means of egress package, a shared perception drove the BCMC deliberations. However, a cursory review of the history of fire in America and its effect on persons with disabilities suggests a far different reality.

PERCEPTION

A 30-year-old paraplegic business executive dies in a tragic conflagration in a high-rise office building, trapped in the fire and smoke because she cannot use the elevators or stairs to exit the building.

REALITY

A 54-year-old double-amputee with alcohol-related diabetes falls asleep while smoking in bed in his apartment, causing a fire that kills not only himself but three others in the building.

The events of September 11 and the attack on the World Trade Center have served to aggravate this difference between perception and reality, and while the risks mobility-impaired people may face in high-rise office buildings cannot be ignored, neither should the real dangers of fire and disability in the home.

In the years 1989 through 1998, 70% to 75% of civilian fire deaths and injuries occurred in residences.[10] Data on the number of these suffered by persons with disabilities are scarce as neither the National Center for Health Statistics (NCHS) nor the National Fire Incident Reporting System (NFIRS) indicate whether a victim was disabled.[11] In those reports where disability was noted, the incidence of physical disability was 7%,[12] though even in these

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cases it is difficult to determine the degree to which mobility impairment was a factor in the resulting casualty.

Nonresidential civilian deaths or injuries remain in the minority. The National Fire Data Center reports that of all nonresidential structure fires in 1998, stores and offices were involved in approximately 18% of the incidences.[13] Couple this with research that indicates that persons with disabilities remain significantly unemployed or underemployed, even after passage of the Americans with Disabilities Act in 1990, and the exposure of people with mobility impairments to potentially lethal office fires remains extremely low. Conversely, most disabled adults live in apartments or houses, places where risks remain relatively high.

The juxtaposition of perception and reality remains a problem and threat to persons with disabilities. Both U.S. federal regulations and the model building codes require life safety provisions for persons with disabilities in nonresidential building design, yet neither addresses the problem in single-family construction.

ENGINEERING SOLUTIONS

Many of the advances in fire safety in the built environment that benefit all building occupants benefit persons with disabilities to an equal or greater degree. Referred to as the "macro-approach – improving building design for all building users without positive or negative discrimination,"[13] requirements for compartmentalization, fire-resistive construction, and sprinkler protection make buildings safer for all occupants and provide additional safeguards for persons who cannot use exit stairs to evacuate a fire floor or building.

Special accessible means of egress provisions now included in the ICC *International Building Code* and *NFPA Life Safety Code* represent a "micro-approach," and afford mobility-impaired persons with an additional and necessary layer of safety.

The IBC[9] states that every accessible space in new construction must be served by at least one accessible means of egress. Where two or more means of egress are required from a space, at least two accessible means of egress must be provided. Where areas of refuge are used as part of accessible means of egress, travel distances for the occupancy in question also apply, which may demand more than two accessible means of egress from larger spaces.

Accessible means of egress include one or all of the following components:

1. Accessible routes;
2. Stairways within exit enclosures, 48 in. (1220 mm) wide as measured between handrails to accommodate a three-person carry of someone in a wheelchair;
3. Elevators equipped with firefighter service and standby power;
4. Platform lifts in very limited applications;
5. Horizontal exits; and
6. Smoke barriers.

Like all means of egress, these components when linked together must lead ultimately to a public way.

In buildings not equipped throughout with an automatic sprinkler system, areas of refuge are part of an accessible means of egress from levels above and below the level of exit discharge. Each must be immediately adjacent an accessible means of egress stairway or elevator and be sized to accommodate at least one wheelchair for each 200 occupants or portion thereof. Equipped with a two-way communication system linked to a central control point, an area of refuge becomes a staging area for a person to be evacuated from or a location to "protect in place," separated from the remainder of the story by a smoke barrier. Finally, an exterior area of rescue assistance may be provided where an accessible exit discharge is not practicable, providing a level of protection for the disabled person similar to that provided by areas of refuge.

Obviously, accessible means of egress from levels above or below a level of exit discharge are significantly different than the regular means of egress used by ambulatory persons. Simply, an elevator on an accessible means of egress will often not be available for independent operation by a disabled person, having gone into firefighter service and been recalled to a designated floor. And stairs are never negotiable for the mobility-impaired persons for which accessible means of egress are intended. Accordingly, building code requirements and facility design will fail to accomplish their intended result of an equivalent level of safety for persons with mobility impairments if procedures to use these new egress systems are not put in place and used.

BEYOND BRICKS AND MORTAR

In 1995, the United States Fire Administration funded "Emergency Procedures for Employees with Disabilities in Office Occupancies,"[14] a guide developed by the National Institute of Standards and Technology and the National Task Force on Life Safety and People with Disabilities. In the fall of 2001, the group that helped to develop this document met again to develop a guide for firefighters and other first responders who will face evacuating disabled persons from buildings involved in fire or other emergency conditions. All participants agreed a standard set of procedures or protocol is needed to ensure that the assets provided in our built environment by the building codes provide an equivalent level of safety for persons with disabilities.

For a number of years, the Eastern Paralyzed Veterans Association (EPVA) has suggested the following protocol for evacuation of mobility-impaired persons from new and existing buildings.

1. Protect in place. This is common in high-rise construction, where zoned evacuation is the norm. Because removing a person who uses a wheelchair demands extraordinary (literally, beyond the ordinary or norm) activity and because leaving the building is not always necessary to the safety of the disabled occupant, protecting in place should be the first option.

This is obviously a contentious proposal in the disability community, as well as in the profession of firefighters and other first responders. If everyone else is asked to leave a building, disabled people should be evacuated as well. But areas of refuge (and similar provisions in existing buildings) are provided specifically with the intent that people who cannot use stairs will remain in a building longer than their able-bodied counterparts. "Philosophically, in addressing the problem of life safety for people with disabilities, the goal should be equal opportunity of life safety – not necessarily equal possibility of egress."[2]

2. Elevator egress or evacuation. This option, while questionable to some, has been used in high-rise construction for decades as a means of evacuating people in wheelchairs from the upper stories of buildings. Understanding the risks of losing elevator operation due to loss of building power or a shutdown of the elevator due to water in the hoistway, first responders will still be in a position to determine whether an elevator car, lobby, hoistway, or machine room are either involved in a fire or in eminent risk from fire or smoke. They can determine when an elevator is a safe way to evacuate a building and assist mobility-impaired persons accordingly.

3. Stair evacuation. This should be the "option of last resort" and used only when a person with a disability is at immediate risk. Many people with disabilities have conditions such that transferring them to an evacuation device or bumping them down a stair in a three-person wheelchair carry could cause serious (and even fatal) injuries. For those untrained in evacuation procedures, attempting to carry someone down a stairway could cause injuries to themselves as well. Last is a moral dilemma. Evacuating a person in a wheelchair in an exit stairway will render that exit unusable to everyone else. Emergency personnel are thus faced with effectively removing an exit for use by all other building occupants while evacuating a mobility-impaired person down a stair or waiting until the building is empty before saving the disabled person (and themselves). Clearly, a usable and safe elevator is the preferable option.

CLOSING REMARKS

Requirements for accessible means of egress in our nation's codes are less than ten years old. As of this writing, similar requirements in the Americans with Disabilities Act requirements have yet to be adopted. Clearly, these provisions will be revisited and modified as they are tested in real-world fire situations.

This being said, there are still a number of "frontier" issues in the field of life safety for persons with disabilities that beg further attention. Should evacuation chairs for controlled descent down exit stairways be required in accessible buildings? Do the events of September 11 indicate some type of accessible means of egress should be required in existing buildings? Should accessible means of egress from accessible dwelling units be required?

Disability advocates, code developers, property owners, and fire protection engineers all have valuable expertise to lend to these issues. ▲

Brian Black is with the Eastern Paralyzed Veterans Association.

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Products/Literature

Adjustable Deadband Pressure Switch

The Adjustable Deadband Pressure Switch (ADPS) has independent set and reset points that are adjustable throughout the entire operating range. It utilizes a 15A SPDT mercury-free microswitch with a manual test actuator. Two models are available: the 300 psi model (12 psi minimum deadband) and the 600 psi model (25 psi minimum deadband). Complies with NFPA 20 fire pump controller codes.

www.pottersignal.com

—Potter Electric Signal Co.

Service Entrance Cable

Tyco Thermal Controls announces the System 1850-SE™ Service Entrance cable system, an alternative to concrete encasement of service entrance cables. The MI cable, manufactured from copper and magnesium oxide (both inorganic materials), will neither release toxic fumes nor propagate flame during a fire. Installed in an enclosed steel tray, the system has gained approval for use in major cities including New York, Philadelphia, and Washington, DC.

www.tycothermal.com

—Tyco Thermal Controls

Speakers & Speaker-Strobes

Edwards Systems Technology has added speakers and speaker-strobes to its Genesis family of emergency signals. Extending only one inch from the wall, the UL-listed speaker-strobes are compact and have features including clear audio output and field-configurable light and speaker output settings. Both settings remain visible after installation, allowing at-a-glance verification and simple adjustment, which means contractors have fewer parts to stock and adjustments can be made on the fly.

www.est.net

—Edwards Systems Technology (EST)

UL-Listed CPVC Pipe

BlazeMaster® CPVC pipe and fittings are now UL-listed for use with listed light-hazard, quick-response, extended-coverage sprinklers and may be installed without protection (exposed) when subject to the following additional conditions: 1) exposed piping is to be installed below a smooth, flat, horizontal ceiling construction, and 2) when using fittings 1½-in. or greater, only schedule 80 fittings may be used.

www.blazemaster.com

—BlazeMaster® Fire Sprinkler Systems

Gas Analyzers

The Servomex 4012 gas analyzer achieves fast response and precise oxygen, carbon dioxide, and carbon monoxide measurements necessary to achieve accurate calorimetry results. Several Servomex models are available. The Servomex 4100 may be fitted with up to four gas sensor transducers in a 19-in. rack-mounted instrument and can simultaneously measure up to four gas streams.

www.servomex.com

—Servomex Group Ltd.

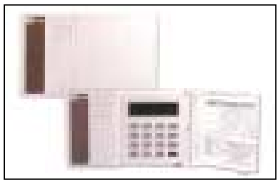
Permanent, Watertight Seal

The Metraflex MetraSeal is a fast, watertight, rubber seal that takes minutes to install around round pipe, including concrete, steel, plastic, cast iron, and copper, with a snug, permanent seal. No drying or curing time is needed. The seal is made of a blend of interconnected rubber links and is available in a variety of sizes (rated to 20 psig). It is engineered to be a permanent, positive, mechanical seal resisting aging, water, ozone, and sunlight for up to 25 years.

www.metraflex.com

—The Metraflex Company

Wireless Interface Module



New D8125INV Wireless Interface Module works with Radionics' 9000 Series panels. It is an integrated interface module and keypad that allow users to connect Inovonics FA400 Receivers and up to 238 wireless transmitters. Each unit can support up to two FA400 Receivers. The keypad is used to access the programming and diagnostics functions of the wireless portion of the system. The D8125INV has a self-prompting user interface and can be used to troubleshoot system RF transmitters.

www.radionicsinc.com

—Radionics, Div. of Detection Systems, Inc.

"Smart" Surge Protectors

The "Smart Module" for low-voltage uses not only allows for snap-in, non-hard-wiring installation, but also lets service technicians and end-users know at a glance that it is working. When the unit sacrifices itself to protect the devices it is hooked to, an indicator light will let the technician know that it needs to be replaced (with no tools or test equipment required). Easy to remove and replace, the module has minimal arc circuitry.

www.ditekcorp.com

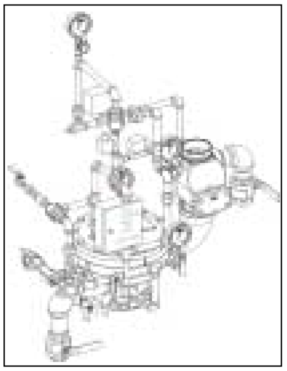
—DITEK

Heavy-Duty Fire Damper

The TFD-75 heavy-duty fire damper is a flanged-framed, airfoil-bladed damper that has been tested to British Standard BS476, Part 20 (stays closed in extreme heat), and operability requirements of NFPA 130 (remains fully functional after being exposed to a temperature of 482°F for one hour). They may be installed in high fire potential areas, industrial applications, and as isolation dampers to prevent fire from spreading. Standard version has an 8-in. deep channel frame; other versions are available.

www.american-warming.com
—AWV

Preaction System



The SureFire™ noncycling preaction system has built-in features that ensure protection while preventing water from entering the system. This allows it to operate as a regular preaction system under normal conditions or as a dry system if primary and backup power fail. Available with both single and double interlock electric release in 1½- to 8-in. sizes.

www.vikingcorp.com
—The Viking Corp.

Pipe Hanger Catalog

Anvil International has published a comprehensive catalog of pipe hangers and supports. Formerly known as Grinnell, Anvil offers a complete selection of engineered hangers and supports, as well as custom design and manufacturing services. The catalog contains specs, illustrations, photos, and software information. Products highlighted include variable springs, constant supports, sway struts, hydraulic snubbers, rigid hangers, and special fabricated steel supports.

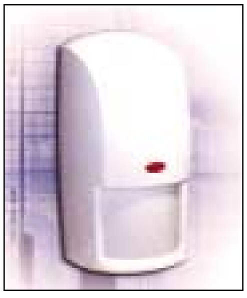
www.anvilintl.com
—Anvil International

Flanged Circuit-Balancing Valves

New 10- and 12-in. flanged Circuit-Balancing Valves are available in both angled and straight configurations. They feature pressure-differential readout ports on both sides of the valve body to allow for easier installation, a tamper-proof memory for ease of return to the balance setpoint, and a multi-turn adjustment range for maximum controllability. The new design also provides a maximum working pressure of 375 psi and has a body made of ductile iron.

www.armstrongpumps.com
—Armstrong Pumps Ltd.

Intrusion Detector



The new OD850 Outdoor TriTech PIR/Microwave Intrusion Detector features patented Motion Analyzer II (MAP II) signal processing. It also employs a new technology, Linear Travel Distance (LTD), which allows it to measure the linear distance traveled by a target, and eliminates false alarms from objects such as tree branches and hanging signs. It includes two user-selectable sensitivity levels, a timed relay output (adjustable from two seconds to 10 min.), and a user-selectable Day/Night mode.

www.dsworld.com
—Detection Systems, Inc.

High-Speed Detectors

Acclimate Plus™ is a new multicriteria technology smoke detector with the enhanced capabilities of NOTIFIER's Flash-Scan™ technology. Acclimate provides an optimum balance of stability and early warning to maximize fire detection while rejecting unwanted nuisance alarms, and responds to a broad range of fires at a fast speed. Flash-Scan protocol groups and scans 10 devices at a time, and constantly monitors so it can report an alarm within one second and turn on all outputs within two seconds.

www.notifier.com
—NOTIFIER

Resources

SFPE New 2002 Publications

SFPE Fire Protection Engineering Handbook, 3rd Edition

$202.50 members $225.00 nonmembers

Work with the essential desk reference for all engineers and engineering students, architects, and system designers involved in fire protection. More than 10 all-new chapters, including: Flammable Liquid Spill Fires; Water Mist Systems; Introduction to Fire Risk Analysis; Uncertainty and Safety Factors... and more. That's why an up-to-date copy of this trusted text should be the cornerstone of your technical library.

SFPE Engineering Guide to Piloted Ignition of Solid Materials Under Radiant Exposure

$35.00 members $50.00 nonmembers

The focus of the guide is the techniques and data available to engineers for predicting the time to piloted ignition of solids exposed to flame radiation and the determination of the safe separation distances required to prevent ignition. The guide reviews the concept of minimum ignition level and reviews five methods to calculate the time to ignition under constant radiative heat flux. The guide includes sample results for each method and an Appendix of relevant material properties.

ICC Performance Code for Buildings and Facilities,

International Code Council, Inc.

$31.45 members $34.95 nonmembers

This long-awaited code and commentary is the first broad-based, stand-alone performance code in the nation. It clearly defines the objectives for achieving the intended outcomes regarding occupant safety, property protection and community welfare. It provides a framework to achieve the defined objectives in terms of tolerable levels of damage and magnitudes of design events, such as fire and natural hazards. Distinctly different from a prescriptive code, it allows the user to systematically achieve various solutions. Published by International Code Council, Inc.

Industrial Fire Protection Handbook, 2nd Edition,

R. Craig Schroll

$72.00 members $89.95 nonmembers

The second edition of this publication offers practical techniques and a performance-oriented approach to effective fire safety. Promotes understanding of the issues involved with fire loss prevention and control and the applications of proven techniques to a work environment. It establishes best practices that often go beyond basic regulatory and code compliance. And it includes concrete examples from real work environments. It also includes discussions of new extinguishing agents, including wet chemical and clean agents designed to replace halon. Published by CRC Press LLC.

Fire Protection Engineering in Building Design,

Jane Lataille, P.E., FSFPE

$40.00 members $49.99 nonmembers

Information on mitigating potential fire damage through proper design and construction of buildings, industrial processes and utility systems is included. Specific examples are given as to how fire protection engineering can be integrated with mechanical, electrical, structural, and chemical engineering. The book also includes a section on writing fire protection specifications as well as a comprehensive reference list. Published by Elsevier Science.

Principles of Smoke Management,

John H. Klote, P.E., FSFPE and James A. Milke, P.E., FSFPE

$79.00 members $99.00 nonmembers

Principles of Smoke Management is the quintessential reference for those involved in smoke control design. It contains an exhaustive treatment of smoke management, including pressurized stairwells, pressurized elevators, zoned smoke control management in atria and other large spaces. It includes numerous example calculations and a CD of computer software for analysis of smoke management systems. Published by ASHRAE.

ISO Fire Suppression Rating Schedule Handbook, 2nd Edition,

H.E. Hickey, Ph.D.

$109.00 members $129.00 nonmembers

The first edition, issued in 1993, was well received as a necessary resource by thousands of Fire Chiefs, City Managers, and others interested in public fire protection. This new edition has six new chapters, as well as extensive revisions to make the Handbook even more helpful. Fire protection is the only municipal service where improved capability can result in financial savings to taxpayers through reduced property insurance premiums. This book will explain the process and help the reader understand and prepare for the grading evaluation. Published by Chicago Spectrum Press.

PE Exam Video Series

$495.00 members $695.00 nonmembers

Worcester Polytechnic Institute (WPI) and the Society of Fire Protection Engineers (SFPE) jointly announce the availability of a new series of VHS videotapes produced specifically to assist professional engineers in preparation for the PE exam in Fire Protection Engineering. This is a series of 4 VHS format videotapes with a total of 9 hours of instruction. The tape series covers all technical categories on the PE exam in Fire Protection Engineering. Included in the tapes are the following topics: Water Supplies; Building Systems; Water-based Suppression Systems; Non Water-based Suppression Systems; Detection and Alarm Systems; Fire Prevention; and Hazard and Risk Analysis.

Resources

2002 Price Changes for Publications:

(Due to Publisher Price Changes)

Enclosure Fire Dynamics,
Bjorn Karlsson & James G. Quintiere
$76.50 members $89.95 nonmembers

Introduction to Mathematical Fire Modeling,
Marc L. Janssens, Ph.D.
$128.00 members $160.00 nonmembers

SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings,
$53.00 members $59.00 nonmembers

Structural Design for Fire Safety,
Andrew Buchanan
$61.00 members $75.00 nonmembers

UPCOMING EVENTS

January 27-28, 2003
8th International Fire and Materials Conference
Info: www.intercomm.dial.pipex.com

February 25-27, 2003
Workshop on Fire Suppression Technologies
Mobile, AL
Info: jscheffey@haifire.com

February 26-18, 2003
Fire Asia 2003
Hong Kong
Info: lesliestevenson@uk.dmgworldmedia.com

April 6-8, 2003
Taipei International Exhibition on Fire, Safety, & Disaster Management
Taipei, Taiwan
Info: www.secutech.com

May 8-10, 2003
Strategies for Performance in the Aftermath of the World Trade Center
Kuala Lampur, Malasia
Info: www.cibklutm.com

May 18-22, 2003
NFPA World Safety Conference and Exposition
Dallas, TX
Info: www.nfpa.org

June 8-13, 2003
Third Mediterranean Combustion Symposium
Marrakech, Morocco
Info: www.combustioninstitute.it

June 22-25, 2003
13th World Conference on Disaster Management
Toronto, Canada
Info: www.wcdm.org

August 20-22, 2003
2nd International Conference in Pedestrian and Evacuation Dynamics (PED)
Greenwich, London
Info: http://fseg.gre.ac.uk/ped2003/

September 8-12, 2003
4th International Seminar on Fire and Explosion Hazards
Northern Ireland, UK
Info: www.engj.ulst.ac.uk/4thisfeh/

BRAINTEASER

You have six weights. One pair is red, one pair is white, and one pair is blue. In each pair, one weight is slightly heavier than the other, but otherwise looks exactly like its mate. The three heavier weights all weigh the same, as do the three lighter weights.

How can you identify the heavier weights in only two separate weighings on a balance scale?

Developed by Paul Curry, provided by Jane Lataille, P.E.

Solution to last issue's brainteaser

Find the values of *A*, *B*, and *C* in the following arithmetic sequence:

AB4, *B03*, *B3C*, *BA1*

A = 6, B = 7, and C = 2.
The difference between subsequent terms is 29.

CORPORATE 100

The SFPE Corporate 100 Program was founded in 1976 to strengthen the relationship between industry and the fire protection engineering community. Membership in the program recognizes those who support the objectives of SFPE and have a genuine concern for the safety of life and property from fire.

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HSB Professional Loss Control
Hubbell Industrial Controls
James W. Nolan Company (Emeritus)
Koffel Associates, Inc.
Marsh Risk Consulting
National Electrical Manufacturers Association
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Tyco Services, Pty
Wheelock, Inc.
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J.M. Cholin Consultants, Inc.
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Poole Fire Protection Engineering, Inc.
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New Specification for the Fire Protection Engineering PE Exam

Morgan J. Hurley, P.E.
Technical Director
Society of Fire Protection Engineers

The purpose of licensure as a professional engineer is to demonstrate that an engineer has at least the minimum level of competence necessary to protect public health, safety, and welfare in their area of practice. Licensure as a professional engineer typically entails a combination of education, experience, successful completion of the Fundamentals of Engineering, or "EIT," exam, and a Principles and Practices, or "PE," exam.

Recognizing that engineers employed in different job settings may perform different types of tasks, PE exams are intended to cover all aspects of engineering that are critical to protecting public health, safety, and welfare within the engineering discipline in which an engineer wishes to become licensed. Periodically, the specification (which describes what types of problems should be asked on the exam) of each PE exam is reviewed to ensure that the exam accurately reflects the tasks performed by engineers and the knowledge needed to conduct those tasks.

The Society of Fire Protection Engineers recently went through a process where the specification of the fire protection engineering PE exam was reviewed. This process began in the spring of 2001, when a committee was assembled to develop a survey instrument called a Professional Activities and Knowledge or "PAK," questionnaire. The committee that developed the PAK questionnaire consisted of licensed engineers with a diverse distribution of age, gender, geographic location, practice size, years of education, and years of practice. The PAK questionnaire that the committee developed was intended to cover all the important tasks that fire protection engineers perform, separated into practice areas called "domains," and the knowledge that fire protection engineers need to perform those tasks.

Once the PAK questionnaire was completed, it was mailed to everyone who is listed in the SFPE database who has indicated that they hold registration in the U.S. as a professional engineer. Respondents were asked to rate each of the tasks and knowledge areas in terms of their importance in the protection of health, safety, and public welfare. Survey respondents were also asked to provide a recommendation of the weighting of the test content from each of the domains and demographic background information. A detailed statistical analysis was performed on the responses to the PAK questionnaire.

Another carefully balanced committee was formed to review the results of the statistical analysis, and to decide what should be tested on the FPE PE exam and what percentage of the total number of problems on the exam should come from each domain. This new exam specification, which will take effect with the October 2004 FPE PE exam, is presented in Table 1.

In some ways, this new specification is very similar to the specification that is the basis for the current FPE PE exam (available from *http://www.ncees.org/profesional/pp_fire*). However, there are some notable differences. The percentage of the questions on the exam that will cover building systems has approximately doubled, while the percentage of questions on water-based suppression systems has been reduced by approximately 50%.

However, and more remarkably, the percentage of the exam that is dedicated to hazard and risk analysis and the fundamental principles that support hazard and risk analysis (fire science and human behavior) has approximately tripled. This change speaks volumes about the maturation of fire protection engineering as a discipline.

Table 1. Specification for the FPE PE Exam, which will take effect in 2004

Domain Content Weight	Subdomain ContentWeight	Knowledge Areas
20%		I. FIRE PROTECTION ANALYSIS
	12%	A. Types of Analysis
	8%	B. Information Sources for Analysis
10%		II. FIRE PROTECTION MANAGEMENT
15%		III. FIRE SCIENCE & HUMAN BEHAVIOR
	10%	A. Fire Dynamics
	5%	B. Human Response
35%		IV. FIRE PROTECTION SYSTEMS
	12%	A. Water-Based Fire Suppression Systems
	5%	B. Special Hazard Systems
	9%	C. Fire Detection and Alarm Systems
	5%	D. Smoke Management Systems
	4%	E. Explosion Protection and Prevention Systems
20%		V. PASSIVE BUILDING SYSTEMS
	12%	A. Building Construction
	8%	B. Means of Egress