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ALSO:

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SFPE

FIRE PROTECTION Engineering

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What Does the Fire Department Expect?

All fire departments perform a multitude of tasks while carrying out their mission of protecting life and property. Most are internally handled by fire departments in an expeditious and efficient manner. Occasionally, however, every fire department will face a problematic situation that will overwhelm their capabilities to address or rectify the situation at hand. Increasingly, fire departments are seeking solutions to these problems by working with the fire protection engineering profession. Through experience, the Boston Fire Department (BFD) has classified these situations into three broad categories:

1. *Unknown conditions.*
2. *Conflicting conditions.*
3. *Imminent danger conditions.*

Unknown Condition Example

Many times code officials are requested to review building or fire code appeals seeking variances or exemptions of code requirements which affect the safety of occupants or firefighters. Many times an appeal is based on conditions that are case-and site-specific and it is unknown what impact the appeal will have on life safety. In lieu of conformance to prescriptive code requirements, building owners often propose an alternative design utilizing performance-based design methodologies which a code official may not be trained to analyze.

When this occurs, the BFD requires that a disinterested third-party fire protection engineer (FPE) prepare a report at the building owner's expense that analyzes the adequacy of the design's assumptions, fire scenarios, and conclusions for ensuring life safety.

For example, a restaurant in a high-rise building sought a variance from a prescriptive code requirement for a third exit stairway based on the proposed occupant load of the space. The alternative design proposed utilizing the two existing exits with additional fire protection features such as detection, suppression, and smoke control systems in lieu of the third exit. The design team utilized computerized fire modeling to justify the granting of the appeal. The BFD required that a report be submitted by a disinterested third-party FPE to "peer-review" the appeal proposal. This peer review approach could also be utilized for evaluating code equivalency proposals and applications of new technologies.

Conflicting Condition Example

At times the code official will face a situation where both the code official and a building owner will each be convinced that their interpretation of a certain code section is correct. Usually, the building owner will appeal the official's interpretation to a legally mandated board, which could leave a building in an unsafe condition for a period of time.

The BFD believes that there is a solution. If both the code official and building owner agree, the owner would hire an FPE to review all the pertinent information relative to the interpretation at hand and prepare a report clearly stating the FPE's position on the disputed issue. The code official and building owner would also agree to implement the recommendations of the FPE to ensure a safe building.

For example, a major retailer of home and building supplies and the BFD disagreed on the application of code-required sprinkler protection concerning rack storage of different commodities. The parties involved in the dispute agreed to abide by the recommendations of a disinterested third-party FPE.

Imminent Danger Condition Example

Perhaps the most difficult decision that any code official faces is to discover a building that has serious code violations, but its occupancy makes it very difficult to close down. Usually the code official feels that he/she has only two options. Evacuate the building, or live with the situation pending correction of the violation. The BFD pursues a third path. The evacuation of the building will be ordered, but re-occupancy will be allowed based on a report from an FPE that the level of safety in the building is "acceptable". Often there are interim, and expensive, measures that are required to reach this level of safety. Measures that would be opposed by the building owner when the code official required them are acceptable if required by an FPE.

An example involved a situation where the BFD was asked to allow a fund-raiser in a "run-down" theater. The architect designing the renovations acknowledged that the existing building did not meet the codes and wanted to know what interim measures could be put in place to make the building safe enough to hold the fund-raiser. The BFD asked the architect why the building department was requested to review, yet not design, the building renovation plans but the fire department was expected to design and review a "fire plan". It was suggested that the owner follow the same process that was used for the building renovation plans, i.e., hire a qualified individual to develop a safe plan and the BFD would review the plan. The BFD does not understand why so many fire departments accept the role, and the liability, of consultant, in matters like these.

There is a fourth reason the fire service will continue to work closely with the fire protection engineering profession: employment. More and more fire departments are directly hiring their own FPE's. While important for all fire departments, this is particularly important for fire departments involved with plan review. The BFD believes that encouraging the use of FPE's creates an environment with increased flexibility and safety by increasing the amount of rationality used in the decision-making process.

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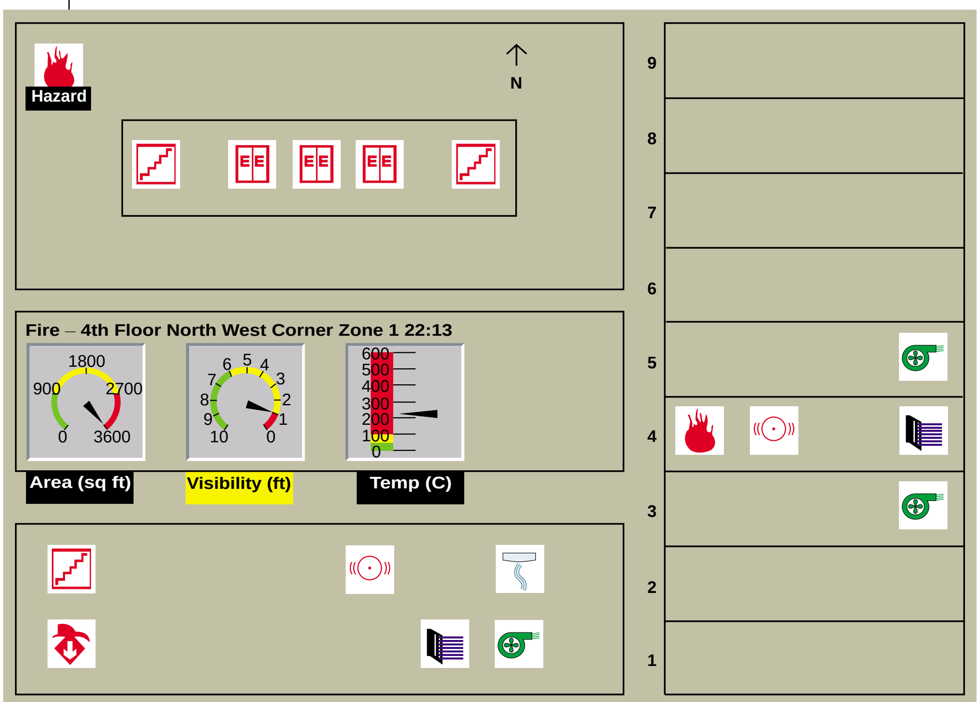
Development of a Standardized Fire Service Interface for FIRE ALARM SYSTEMS



Prototype of a standard Fire Service Interface in a nine-story building.

By Richard W. Bukowski, P.E., FSFPE

BACKGROUND

The National Fire Alarm Code[1] in paragraph 1-5.7.1 requires that,

"Where required, the location of an operated initiating device shall be visibly indicated by building, floor, fire zone, or other approved subdivision, by annunciation, printout, or other approved means."

Paragraph 1-5.7.1.1 states,

"The primary purpose of fire alarm system annunciation is to enable responding personnel to identify the location of a fire quickly and accurately and to indicate the status of emergency equipment or fire safety functions that might affect the safety of occupants in a fire situation."

Paragraph 3-12.6.5.1 requires a fire command center,

"... near a building entrance or other location approved by the authority having jurisdiction. The fire command center shall provide a communications center for the arriving fire department and shall provide for the control and display of the status of detection, alarm, and communications systems.

... Operating controls for use by the fire department shall be clearly marked."

In light of these requirements, it is disconcerting that many fire departments report seldom using the provided features because every system (from different manufacturers or even different systems from the same manufacturer) has a different interface. Displays and controls are not consistent, and there is no time to study the manuals. To address these issues, the National Fire Alarm Code, Technical Correlating Committee established a task group to develop proposals for a standard interface for the 2002 Code cycle (the author chairs that task group). NIST's Building and Fire Research Laboratory (BFRL) established a cooperative research project through the National Electrical Manufacturers' Association (NEMA) and the major fire alarm panel manufacturers to develop the technical basis for these proposals. This article describes the work done to date and planned activities that should lead to an interface that addresses the needs of the fire service.

FIRE SERVICE NEEDS

The first step was to determine the information needs of the fire service. This was done by arranging meetings with representative groups of fire service officers who have incident command experience. These meetings were structured like "focus groups" and were arranged by the International Association of Fire Chiefs (IAFC) at regional and national conferences.

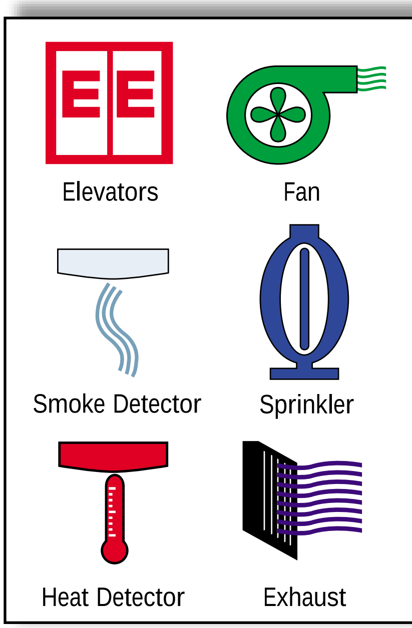
The participants were asked to address three questions:

- What do they want to know?
- When do they want to know it?
- How can the information be presented to be most useful?

The first two were closely linked because fire service information needs differ with time, but most relate to the most effective allocation of (usually limited) resources. The observations from these meetings were:

- AT DISPATCH: The most important item is to provide some metric for the likelihood that the alarm is genuine – particularly when it derives from a single device. Perhaps a three level metric (low, moderate, and high confidence) would be enough. The basis for assessing confidence is currently unclear but may involve heuristic algorithms based on sensors keeping history data and reacting to excursions from that history. There is significant concern among the fire service over liability for damage they cause by forced entry when an incident turns out to be false. They would also like information they could use to decide what resources are required. For small fires growing slowly, a single unit may be enough. For a fast-growing major incident, additional units dispatched early can be of great help in minimizing losses and assuring firefighter safety.

- AT ARRIVAL: (of first due units) The most important information (in order) is (1) the location of the fire within the building, (2) the location of occupants, (3) how to get to the fire, (4) a safe location to stage, location of standpipes, and other points of interest (hazardous materials, locked areas), (5) how fast is the fire growing, Temp/CO/O_2 conditions to determine if the OSHA "2 and 2" conditions[2] have been met, since violating this rule incurs liability to the department and has firefighter safety implications.



Sample Standard Icons

- DURING THE INCIDENT: The most important information (in order) is (1) location and rate of spread of smoke/gas and of fire, (2) conditions relative to the "2 and 2" regulation, measures of operational effectiveness and safety of crews, (3) potential benefits or dangers of ventilation.

The "how can the information be presented" was less clear. Concerns were expressed about graphical displays of building layout and fire location that do not clearly relate landmarks since most firefighters are unfamiliar with any building. Thus "how to get to the fire" must give clear orientation, e.g., from stairwells or other points of entry. There seemed to be consensus that they did not want information displayed in which no immediate actions are required (concerns about "information overload") but some indication that all is right may be reassuring.

There is "traditional wisdom" that firefighters need large controls that can be operated while wearing gloves. When queried specifically about this, the fire service groups indicated that gloves are not a problem for operating controls unless the controls are outside in the winter. When controls are inside, they remove their gloves.

The ability to obtain status information in vehicles en route, in a mobile command post, or even fire department headquarters was of interest. Further, since the main point of entry to the building is not always the best location from which to direct operations, the incident commander may want to be free to go to where he/she can best view ongoing operations. If the attack is largely exterior, that may be outside the building, across the street, or wherever one can see what is happening. Thus, the system should be compatible with wireless technologies.

DEVELOPING A CONCEPT

Germany and Sweden have adopted standard fire service interfaces for fire alarm systems. These are hardware specifications that detail the specific switches and lights to be used, and each manufacturer produces a panel that looks and works identically to interface with their system. We decided not to follow this approach because it can limit innovation and the ability to adapt to specific situations. Also, U.S. manufacturers prefer a more general specification that can be implemented in innovative ways that become competitive opportunities to compete in the marketplace.

Rather, we decided to develop a "look and feel" based on standard icons and functions similar to the user interface of personal computers. PC software uses numerous standard icons for common functions such as file open, save, print; cut, copy, or paste; and dragging a file to the trash can deletes it. By defining standard icons for fire alarm system components and functions of interest to the fire service, it is possible to produce an interface that is intuitive to use, even if implemented in different ways.

The icons, their meaning, and how users access information and functions associated with them would be standardized in the *National Fire Alarm Code* (NFPA 72). However, these could be implemented in many ways such as graphical displays over hard buttons, labels on hard buttons with lights, or on touch screens. Features such as local display only, wireless transmission nearby or off site, local control functions, and nonemergency status displays could be included as optional functions allowing individual manufacturers to be innovative and local authorities to require features that meet their needs.

FIRE ALARM ICONS

An initial set of icons was developed from icons used for similar purposes in Japan and from standard symbols for engineering drawings from NFPA 170 (see sidebar on page 6). Like most aspects of this project, these icons are subject to change if the fire service thinks they are not meaningful or if industry thinks they would be difficult to implement. Mostly they represent a starting point from which the concepts can be presented.

Several constraints on the icons were initially identified. First, the icons need to represent three states – function not present, function present but not active (no additional information available), and function present and active (more information is available). Thus, simply having an icon shown or not shown is insufficient.

Most people are unaware that fire alarm systems have few universal functions. There are systems with no automatic detectors, being activated only by manual devices or primarily provided for supervising sprinkler systems. There are fire alarm systems with no local indicating appliances (bells or horns) that primarily notify people at a remote location. Thus, it is important to be able to differentiate functions not present and functions present but not active.

Three states could be shown by the use of color, but we were cautioned by the fire service that firefighters may be color blind so this was considered inadvisable. Thus we decided to use the logic that if a function is present but not active the icon would be presented with a diagonal slash as is done with traffic signs. Icons are not present for functions not provided. Active functions are indicated by the icon being displayed. Another approach would be to use a flashing icon for an active function and a steady icon for inactive, but flashing indicators have another meaning on fire alarm panels.

A related issue is whether the system would provide information in nonemergency conditions. For example, systems might allow the fire service to query the status of devices or systems when there are no alarms present. Extracting data on ambient temperatures, background smoke, status of elevators, or pressures in stairways during normal building operations may be of interest to test the system function or to verify that areas are as yet unaffected during a response. While these would be optional system arrangements, the system design and operation need to allow for them. If nonemergency status information were provided, then functions would not need to be active (in alarm) for information to be available, and this needs to be communicated to the fire service in an unambiguous way.

A final issue is the provision of specific control functions. The fire service performs some systems control as part of their incident management. These currently include manual use of the emergency voice communication system, alarm silence and reset, signal acknowledge, and a few others. The fire service groups interviewed identified interest in very limited manual ventilation control to exhaust the top of stairways. There may be more. Generally, the fire service feels that they would like to see all information and interaction with the building routed through the interface panel to provide a consistent means of providing such interactions.

DEVELOPING A PROTOTYPE

Applying the concepts discussed above to the fire service needs derived from the initial focus groups, we began to develop ideas for a fire service interface prototype that could be used to test concepts and refine ideas. The prototype would incorporate features and arrangements that would be part of any proposed standard and demonstrate optional approaches that could be utilized in any specific product.

The interface should be useable on a range of fire panel sizes from small systems with only a few zones to large systems with thousands of addressable devices. Thus, the prototype was laid out with an icon display section and a separate text display section, similar to current small systems that have a row of programmable buttons and a four- or five-line text display. An active icon indicates that additional information is available and is displayed in the text window by pressing (clicking) the icon. This information is displayed as text, and data is displayed on gages. Fire service apparatus use dial and bar gages (e.g., pump panels on engines), so firefighters are accustomed to reading such gages. These gages typically show normal operating ranges for rapid status assessment.

The prototype incorporates building graphics in two other windows – one for a plan view of the floor of origin and one for a building elevation. With respect to these graphics, the industry complains that they have frequent problems obtaining accurate drawings and in maintaining correct information as buildings are remodeled. The fire service reported current graphical displays are inadequate for their purposes. We attempted to address both of these problems by suggesting the use of diagrams rather than drawings. The diagrams would show the information needed by the fire service without the details they don't need (the main source of problems for the industry). The diagrams relate important locations to stairways and compass directions, with details such as room numbers relegated to the text messages produced by point-addressable devices. Initial examination with the fire service indicates that this meets their needs and will minimize problems for industry.

INCIDENT MANAGEMENT INFORMATION

Currently, fire alarm systems (other than Proprietary[3] systems) report only that an alarm has sounded at a property. Annunciator panels located at the protected property display the number of zones or devices in alarm and their location(s) within the building.

Incident commanders reported that they generally use the information on zone or devices in alarm to estimate the area of the building involved in fire or smoke. For the older zoned systems, multiple detectors installed on a floor or subdivision of a floor report an alarm within the zone but not which device or how many devices in the zone are in alarm. Thus they cannot provide much additional detail. However, with point-addressable devices that industry sources report represent about 70% of new installations, each device alarm is individually identified. Since each detector has an associated protected area [under NFPA 72, for smoke detectors this is not more than $84 m^2$ (900 sq ft)], it is possible to determine the area of the building with smoke levels in excess of activation levels or, for heat detectors, the area with temperatures in excess of the alarm threshold. Further, point-addressable detectors could provide real-time data that could be transmitted to the fire service in the form of temperatures or visibility distances through smoke. Such information could be used to assess risk to lives and property and, therefore, to make informed decisions on allocation of resources to mitigate these risks.

Of course, point-addressable devices identify the exact location of the device in alarm, and they will also identify every device on the system. It is usually assumed that the first devices in alarm are the closest to the point of fire origin, but this is not always true. However, where analog devices are arranged to report conditions such as temperatures or smoke levels in real time, such data can be used to decide where suppression activities are needed to mitigate hazards to people and property. Further, such data can be used to assess hazards to firefighters, knowing the limits of their protective equipment. Informed decisions on safe staging areas and crew rotation can improve operational efficiency and safety.

Other building systems and components have specific roles to play during a fire emergency. The fire service needs to know that these systems and components are performing without providing so much information that it is distracting from the primary job at hand. Thus, the fire service interface would provide assurance that the system or component is performing within its design envelope but also be capable of providing more detail on request. An example is stairwell pressurization systems producing pressures that are not so high as to interfere with door opening, nor so low was to allow smoke infiltration.

Some of the information needed by the fire service is not available from the fire safety systems themselves, but may exist in other building systems. Thus, the fire service interface should be capable of obtaining and displaying such information. Building energy management systems often have room occupancy monitors that can identify the location of building occupants. Elevator systems also know which cars are occupied, and some systems know how many people are in those cars.

Other building systems may have useful information as well. By implementing a common protocol communications gateway it is possible to share such information among systems without giving up control or incurring liability. One such approach that allows fire alarm and HVAC systems to communicate is BACnet. Originally developed and standardized as an HVAC-industry protocol, BACnet has recently been embraced by the fire alarm industry, and most of the systems manufacturers now offer BACnet gateways.

Much of the fire service information needs from nonfire systems involves status information. HVAC and elevator systems have emergency operating modes related to fire. The incident commander would like to know if the HVAC system is operating properly in smoke management mode and if the elevators are in Phase I or II recall. There are operational and safety implications in learning from energy management systems whether high-voltage systems that might present a shock hazard to hose teams have been shut down or whether lighting systems are still operational.

Another category of information need concerns building features provided for fire service use. This may be internal firefighter communication, location of hazardous materials or secure areas, propositioned equipment such as air bottles, special extinguishing agents, or aids for evacuating disabled occupants. Such information may be permanent or may change with time, but is more likely to be accessible to the fire service if integrated into their interface system.

NEXT STEPS

Currently, we have an interactive prototype suitable for testing concepts with fire service people representing end-users. More "focus group" sessions will be scheduled, and the prototype will be refined. The National Fire Alarm Code task group has a number of people who have expressed interest in participation, but needs more fire service input. Suitable representatives will be recruited from participants in the focus groups and meetings scheduled to begin the process of developing proposals for the 2002 Code cycle.

Manufacturers are being kept informed of progress through the NEMA 3SB section by technical briefings twice a year at their meetings. They all have representatives on the NFAC task group, and they will participate in that process as well. The task group proposals will be published by the NFPA for public comment in the Spring of 2001. The task group is open to any interested party; more information can be obtained by contacting the author.

For more information on this NIST project or to view the complete working set of proposed icons, the reader can visit the Building and Fire Research Laboratory Web site at http://fire.nist.gov/panel/.

REFERENCES

1. NFPA 72, *National Fire Alarm Code*, National Fire Protection Association, Quincy, MA, 1996.
2. OSHA promulgated a regulation for firefighting that establishes environmental criteria which, when exceeded, require that no fewer than two firefighters may make entry for firefighting or rescue only when no fewer than two firefighters in full protective gear are available at the fire scene to provide assistance if needed.
3. In the 1996 edition of NFPA 72, a Proprietary Supervising Station Fire Alarm System is defined as one that "... serves contiguous and non-contiguous properties, under one ownership, from a proprietary supervising station located at the protected property, at which trained, competent personnel are in constant attendance."

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CONSIDER THE FIREFIGHTER

in Building and Fire Protection System Design

By James Knox Lathrop

Fire protection engineers need to understand some of the problems faced by firefighters with fire protection systems during an emergency. For some engineers, especially those that are, or were, in the fire service, this is second nature. For others, it may take a little extra work. Unfortunately, it is not at all unusual to find fire protection systems that are very difficult for firefighters in the field to interface with. This may become critical to the firefighter who is working under stress during fire conditions and does not have the time to learn or to recall how a sophisticated fire protection or mechanical system works, or to even find important system components.

PERFORMANCE-BASED VERSUS PRESCRIPTIVE CODES

During code development discussions regarding performance-based design over the last several years, one aspect that was not frequently discussed was the role of the fire service. Recently, this has begun to be addressed and has revealed that not everyone was considering the same thing when discussing the involvement of the fire service in building and fire protection system design. Is it the role the fire service may play in providing input in developing the design? Is it the role of the fire service in making the design effective (e.g., there is a fire station across the street, therefore response will be less than two minutes)? Or is it the poor, out-of-district firefighter who, at three in the morning, after two other working fires that night, has to figure out how to deal with the smoke control system?

In reality, considering the fire service is not new. However, as this article will point out, this is going to be affected, sometimes for better, sometimes for worse, by performance-based design. How often has a building owner or designer said "We don't need to do that; the fire station is right across the street"? In the past, the authority having jurisdiction did not need to give a detailed explanation, other than "the Code requires it" (although more explanation would have been helpful). Such simple explanations will not be possible with performance-based design. However, many of these issues do arise even with prescriptive codes.

Also performance-based designs will lose the "similar" or "typical" arrangement that firefighters rely on in many cases. An example of this may be the exit enclosure in a building. With a two-hour fire-resistance rating no longer being specified, can the firefighter count on the exit stair landing as a safe area to initiate fire attack? This article begins with some of those issues that apply with prescriptive codes and then goes further with those that are likely to develop or become more problematic with performance-based designs.

FIRE DEPARTMENT PREPLANNING

Much of what will be discussed in this article can be argued against with a very simple "That's why the fire departments have preplans." (Although truly a "prefire plan," or "pre-emergency plan," most fire departments simply refer to them as "preplans."). Firefighters should visit buildings, especially those in their first due area, to become familiar with the building and fire protection systems in the building. These visits should result in "preplans" on how to handle fire incidents in each building. However, preplanning does not replace the need for fire protection engineers to consider the firefighter.

Even with the best preplanning, what happens when the first due company is not first in or, worse yet, is not coming at all due to another fire? Second or third due companies and maybe even second alarm companies may be familiar with the building, but they will not have the same intimate knowledge of it. What if the battalion or district chief is from another district or is new to the district?

An incident was described to the author where a very sophisticated emergency power system was overridden by a battalion chief covering from another district. The emergency power system was critical to the performance-based fire protection design of the structure. The first due chiefs were aware of this; the covering chief was not.

Many fire departments have poor or no preplanning programs. Some may say that the lack of preplanning is the fire department's problem and that they should do their jobs. However, that does not change the fact that many fire departments lack effective preplans. Others have a very difficult time keeping preplans or in-service inspections current. This applies to all types of fire departments, but is especially true of volunteer departments that have a difficult time attracting and maintaining volunteers. Also, many of the intricacies of some building systems will easily be forgotten even with frequent refreshers. Trying to make all shifts intimately familiar with every building in the first due area is time-consuming and simply not realistic.

SPRINKLER DESIGN

Automatic sprinkler systems are relied upon to provide a minimum level of fire safety for many buildings. The effectiveness of sprinkler systems is reduced when the fire department is not able to quickly locate key sprinkler system components or the system is so complicated that it takes too long to figure out how the system works.

Keep sprinkler system layout simple.

Sometimes it appears that the goal of some sprinkler system designers is to make the systems a challenge to figure out, such that it takes anyone not familiar with the system, including the fire department personnel, an inordinate amount of time to determine what is going on. The author just recently stood in a fire pump room with another fire protection engineer, and it took over ten minutes to decipher the system. That was without the pressure of an ongoing emergency. This apparently is not just the opinion of the author. A recent article by Russ Fleming, Vice-President of Engineering for the National Fire Sprinkler Association ends with: "Most of all we must seek simplicity. Simple wet-pipe systems should be used whenever possible, and sprinkler and valve design should be kept simple, as well."[1]

Properly locate and identify sprinkler valves with the firefighter in mind.

NFPA 13 *Standard for the Installation of Sprinkler Systems* requires valve identification. Some valves may be properly identified when the system is first installed; however, over the life of the building, signage is often lost or becomes misleading, or inadequate. It would be better if the systems were designed so that the location of the valves and their function are obvious regardless of signage, although sinage would be beneficial. Fire protection engineers should consider whether it be obvious to someone who may have some training on sprinkler systems but was not involved in the design. While it might cost a little more to arrange it that way, the cost of water damage caused by water flow while it takes the fire department an extra five or ten minutes to shut down the system could compensate for the added cost. The consequences could be worse if the valve was closed and should have been open and could not be found fast enough. Recently, hidden control valves were a possible factor in a fatal residential high-rise fire in New York City[2]. If the valves were not hidden, in-service inspections may have found the closed valves. Proper supervision of the valves could also reduce this problem.

> The needs of the firefighter must always be considered in planning and design.

A fire protection engineer serving as a firefighter in a large U.S. city provided another example. Recently, during a fire in a large home improvement store, he was assigned to locate the main sprinkler valve and shut down the sprinkler system, as the fire had been extinguished. He undoubtedly got this task since the officer knew he was a fire protection engineer. Unfortunately, the building still had extensive smoke in the upper layer of the building. It was finally discovered that the main sprinkler valve was at the roof level up in the smoke. The valve was difficult to close because it had to be closed by a chain which jumped off the wheel when it was used. Was it really necessary to locate the main sprinkler valve at the roof level where smoke would obscure it and a chain was needed to close it? Probably not, but it apparently was done by someone not thinking of the needs of the fire department or anyone else that needed to work on the system, for that matter.

When planning sprinkler risers and siamese locations, take the firefighter into consideration.

When not familiar with a building, many firefighters will look for the fire department connection as an indicator of where the sprinkler riser may be. When it is not nearby, valuable time can be lost. However, this must be balanced with a need to carefully analyze where the fire department connection should be located. NFPA 13 requires that the location be approved, which means acceptable to the authority having jurisdiction. Unfortunately, the authority having jurisdiction is not necessarily the fire department. It should be a requirement that the fire department approve the location, not just the authority having jurisdiction. Examples where the authority having jurisdiction is not the fire department are building officials, state fire marshal offices, and local fire marshal offices that are independent of the fire department. This does not mean that these types of authorities having jurisdiction never check with the fire department. Many do; but by NFPA 13, they are not required to. It is not at all uncommon to find fire department connections behind bushes, on the back of the building with no vehicle access, too high, or in some cases on another building. Again, the argument against locating fire department connections in obvious locations will be aesthetics and some added cost. But if the fire department were considered from the very beginning of the design, some of the added cost and aesthetic problems could be avoided.

There are several questions to answer when determining where to place a fire department siamese connection. Where is the nearest fire hydrant? Where is the fire apparatus going to come from most of the time? What does the landscape architect have planned? Or if there is no landscape architect, where is the owner likely to plant bushes? How will snow or other weather conditions affect access to the fire department connection for the sprinkler system? Should a freestanding connection be used? But most important, the fire department should be contacted regarding fire department connection locations. Some smaller fire departments may need assistance in determining an appropriate location. The designer can assist by taking into consideration the above questions. Most larger fire departments will know exactly where they want the connection.

An example of a recently encountered problem, a situation involved fire department connections for buildings in a prison. The designer specified the fire department connections in the "usual place" – i.e., without regard to fire department needs, but which involved the shortest amount of pipe – i.e., the cheapest way. The fire department was given a courtesy review of the plans and noted the amount of hose that would have to be laid inside of the compound to hook up to the connections. Fortunately, prison officials were supportive of the fire department's concern since they did not want large quantities of hose within the compound. Revisions were made so that the fire department connection location for each building was standardized on the end of each building closest to the fire hydrant. In fact, the private fire service mains and fire hydrants were rearranged so that every building had a fire hydrant, and it was located near the end of the building most convenient to the approach of the fire apparatus. By doing this, very little hose would be required within the secure compound. This reduced security concerns for the prison administration and reduced time for the fire department to connect to the sprinkler system, as well as increased the overall level of safety.

Another consideration with regard to fire department connections for sprinkler and standpipe systems is the potential for using freestanding fire department connections (fire department connections not mounted to the building but usually out near the street). Falling glass in high-rise buildings is a serious problem for firefighters. Although most of the experience with falling glass shards has been in nonsprinklered or partially sprinklered buildings, this does not mean that it could not occur during fires in sprinklered buildings. Also, there is at least one case that NFPA investigated[3] where a firefighter was killed due to a wall collapse while working at a fire department connection. A freestanding connection may not be needed, and in fact may be undesirable in some situations (freezing, corrosion, and vandalism are some undesirable aspects), however, they should still be considered. Prisons again are another good example of where freestanding connections installed outside the fence lines could be a benefit. Keeping hose lines, fire department vehicles, and firefighters outside the fence line improves firefighter safety and prison security.

Admittedly, it is not always going to be possible to put the fire department connection in a convenient location and at the same time have it near the risers. Many designers strive for an efficient and cost-effective system. Sacrificing some short term cost-effectiveness for more efficiency and user-friendliness may be more advisable, and in the long run may be more cost effective.

Assure fire department connections are compatible with fire department threads.

It is amazing that, to this day, threads in fire department connections (the siamese for sprinklers and standpipes, as well as for fire department hoses on standpipe systems) are occasionally incompatible with the threads of the fire department hoses. One of the important lessons learned from the major conflagrations of the last century was the need for standard fire department hose connections. NFPA 1963, *Standard for Fire Hose Connections,* provides for standard fire hose threads. Although there have been improvements, there are still numerous types of threads in use. It is imperative to determine local threads before installing couplings for fire department connections. Also, the type of cap on the connection is important. With extensive vandalism to these connections, some fire departments are using caps that provide security. It is important that these be standardized.

FIRE ALARM SYSTEMS

Modern fire alarm systems can greatly improve life safety. But these same systems can be designed to be either very firefighter-friendly or decidedly unfriendly. Here is one area where working with the fire department, or at least having an understanding of their concerns, can have a significant benefit to building fire safety. Trying to predict what the fire department wants is almost impossible. One example is the location of fire alarm controls and annunciators.

Locate control and annunciator panels where they will best serve the firefighter.

At least one model building code[4] requires that in high-rise buildings, fire alarm controls be located in a one-hour rated room. Many chief officers would rather have such equipment in the lobby. This does not make the requirement wrong; It just points out that not all fire departments operate in the same manner. Therefore, the fire alarm designer needs to confer with the fire department first. Fortunately, all three major model building codes[4,5,6] in the United States do require that for high-rise buildings the central control station with fire alarm controls be in a location approved by the Fire Department. NFPA 101, the *Life Safety Code*, requires that such controls be at "a convenient location acceptable to the authority having jurisdiction."[7] If the authority having jurisdiction is not the local fire department, the designer could be missing important input for a user-friendly design.

An example from a small town with a combination paid-volunteer fire department can be used to illustrate this point. A new building protected by automatic sprinklers was being built. When the fire department was asked about the fire alarm system, they requested a remote weather-resistant annunciator outside, adjacent to the fire department sprinkler connection. Their logic was that during the day when staffing was low, the first crew could connect to the sprinkler system and determine the alarm location at the same time, saving both time and, in this case, manpower.

Arrange and identify fire alarm zones so that the firefighter can understand them quickly.

With regard to annunciators, two additional issues are often a problem for fire departments: zoning and identification of zones. Zones sometimes appear to be created in buildings for the convenience of the fire alarm installer or designer. However, these people are not the ones that are called upon to fight a hostile fire in the building. Zones should be established that are logical to someone that might have little or no familiarity with the building. The NFPA *Life Safety Code*[7] has a useful provision that allows fire alarm zoning to coincide with sprinkler zones, even though NFPA 13 and NFPA 72 *National Fire Alarm Code* have different area requirements. The *Life Safety Code* also allows both of these systems to be zoned to coincide with the smoke compartment requirements of healthcare facilities. This makes finding the alarm zone much easier. This kind of forethought on the part of the fire protection engineer can save precious time during an emergency as well as get firefighting equipment back in service quicker from false or nuisance alarms.

> Fire alarm design should be logical to people with little familiarity of the building.

The identification of zones can be a big problem, especially in smaller buildings that use "simpler systems." Here the zones are only identified by a light on the panel or a number. Determining where in the building the number corresponds may be difficult. Originally there may have been a piece of paper with a legend, but that may be either gone, out of date, or faded. Building or tenant space renovations can make the legend inaccurate. Zone identification should be simple and be able to withstand possible renovations. For example: "third floor east wing," rather than "XYZ Company." XYZ may move, but east is east, and rarely does the third floor move. It may be beneficial to indicate north if compass directions are used. As noted earlier, first due companies may be aware of where north is, but they might not be first in. Also, winding roads can easily confuse one's "internal" compass.

> With many systems, it is very easy for the firefighter to make simple mistakes that result in big problems.

Markings for the annunciator must be durable. Sometimes annunciators appear to have been prepared by a fire alarm contractor who used disappearing ink to indicate the zones. The light may be on but it tells nothing as to the location of the fire.

Keep controls and annunciators simple and consistent.

Another problem for firefighters is the difference in fire alarm control panels. Even with extensive preplanning, the numerous fire alarm systems in any company's first due area (and don't forget, the first due company might not be there) combined with the fact that almost no two fire alarm control panels operate the same create a nightmare for firefighters. One saving factor is that the more complex the system is, the larger the building and the greater chance that there is someone there 24 hours a day. Hopefully, that person is well trained on the operation of the fire alarm system. In fact, at least one major city in the United States does require that larger buildings must have a fire safety director on duty within the facility 24 hours a day. This person must be certified and be familiar with all the fire protection features within the building. This fire safety director mandate recognizes the problem with building/systems complexity, and few fire departments have this benefit. Again, when designing fire alarm control panels, remember the firefighter that will have to interface with it. Make it obvious how the various functions work and label the panel with clear instructions.

A former county fire department fire protection engineer provided information about an instance where the design of a graphic annunciator for a seven-story building was far too complicated to expect responding firefighters to interpret the annunciator effectively. The nomenclature used to describe the zones was logical to the engineer and the systems designer, but was essentially meaningless to a firefighter since it did not relate well to the firefighter's perception of the building layout. The zones were not sufficiently descriptive of the building and did not reflect the sprinkler system zone boundaries, fire pump location, or the location of the fire command station. Integrated into the graphic panel was an overwhelming smoke control graphic. The graphic was very impressive from an engineering perspective but was not at all user-friendly.

SMOKE CONTROL SYSTEMS

Smoke control systems are used to limit the spread of smoke beyond the area or floor of fire origin. Each smoke control system is designed for a specific building. Therefore, of all the systems in the area of fire protection for buildings, smoke control systems could easily be nominated for the one that could cause the most problem for fire-fighters.

Make smoke control systems understandable to those that must use them – the firefighters.

The lack of consistency with these systems and the resulting dangers that could result are significant. Probably the biggest contributor to this problem is the lack of standards that can be referenced. Although there are several good references, most are guides or recommendations. As a result, there is little consistency between systems. Both Ford and Colt demonstrated the advantages of interchangeable parts. In fire protection, there are advantages of consistency between systems of the same type. Although it can be argued that each smoke control system is unique to the building, there are many items that could be standardized to make it easier for the firefighter to use. One example that was recently debated at the 1999 ICC hearings in Costa Mesa, California,[8] involves the color of indicator lights on the smoke control panel. When does one use green, yellow, red, etc.? Does green mean normal or does green mean open? This may not be important on an individual project since the designer and the building owner know what it means. A firefighter may have a dozen smoke control systems in his/her first due area and they all are different, consistency could be very important. And if the first due company is not the first arriving, they will have to learn the legend very quickly. Here is where standards would be very beneficial. However, when performance-based codes are used, a standard may not be followed.

In general, smoke control systems tend to be too complicated and susceptible to adjustment by unqualified people. With many systems, it is very easy for the firefighter to make simple mistakes that result in big problems. It is not uncommon to hear firefighters say that the first thing you do with a smoke control system is disable it. It is not very beneficial to design a system, spend the money to install it, have it part of a fire safety plan, and have the very people that respond to the emergency not use it (or worse, abuse it) because it is too complicated.

PERFORMANCE-BASED CODES AND STANDARDS

The day of performance-based codes and standards is here (or rapidly approaching depending upon how you look at it). Almost every publication dealing with fire and building safety standards has recently had articles discussing performance-based codes and standards. To some people, this is long overdue; to others, it is a disaster waiting to happen; to still others, it is another way of doing "equivalencies". The merit, or lack thereof, of performance-based codes and standards is not within the scope of this paper. However, the possible effect on the firefighter doing his or her job is.

There are already some architects/engineers wanting to use the fire department as part of the design. In other words, "we don't have to put XYZ in the building because the fire station is only two blocks away." This can generate numerous problems depending on what the XYZ is. There are so many questions that must be answered. What if that station is empty due to any number of reasons (another fire, training, repairs, inspection duty, etc.) at the time of a fire? What if an out-of-district company is in the station during a major emergency? One major U.S. city takes less-busy companies and puts them in busier stations a couple of times a week to keep up their skills. They are not in familiar territory at that time. What if response patterns are temporarily changed due to street work? What if the station is closed (some may remember the '70s when numerous fire stations were closed during severe municipal budget cuts, and this issue continues to this day)? It would be interesting to see a major building shut down or have to make major renovations because the city council closed a fire station. (This might be a new approach to keep stations open – have at least one performance-based design building in each district based on fire department response.) What if the fire department in general is delayed due to weather, numerous calls, or other reason? What if permanent street closures or rearrangements alter response patterns? These and more must all be answered satisfactorily before any such consideration can be given. There may be cases where it is warranted, but in the opinion of the author, they will be relatively rare and not for any significant fire protection feature.

A fire protection engineer for a major U.S. Government agency related one example of using the fire department in this manner. This involved the use of a federal fire department in the evaluation of a building. In this case, there is more control on the existence of the fire station. However, many of the questions above would still need to be addressed.

Earlier, this article discussed problems with systems based on prescriptive codes and standards with regard to user-friendliness. Performance-based codes and standards will magnify almost everything discussed before (sometimes for better, sometimes for worse). This is not intended to be a doomsday type of warning. But it is intended to alert fire protection engineers to the fact that the needs of the fire service must be a factor in performance-based designs.

Up to this point, many of the "performance-based" designs that have been described in various journals and discussed at various conferences have really been a performance-based approach to address one or two issues in an otherwise prescriptive-based design. Some may refer to this as "performance-based equivalencies." This may address the need to reduce structural fire resistance, increase travel distance, reduce the number of exits, and similar issues. With these types of issues, there is little impact on the fire service. Note that this author did not say no impact, since there can be some. For example, if there are fewer exits or longer travel distances, firefighter access must be considered. The paths that civilians use to get out are the same paths that firefighters must use in most cases to get in. Standpipe connections are usually required at exits. Longer travel distances would impact fire department operations since the distance from standpipe connections might also be longer. If the design stays with connections at the exits, there could be significant problems with the amount of hose a firefighter will have to carry as well as put in service. With standpipe connections at the horizontal exits or exit stairs, firefighters have an area of protection to make connections and prepare the hose for water. Locating connections out on the floor could decrease the protection afforded to firefighters setting up the hose lines. Although this can be an issue with some prescription-based designs, it could be even more of a problem if travel distances are increased in performance-based designs.

Many of these buildings have "standard" fire alarm systems, sprinkler systems, standpipe systems, exits, emergency lighting, etc. One of the issues mentioned earlier is that the fire service takes many actions based on "typical" scenarios. This may just be based on an individual's experience or on more rigorous standard operating procedures or a combination of the two. If nonstandard systems are used,the impact should be considered.

If a "performance-based" high-rise building was constructed with one-hour rated (or even nonrated) exit stair enclosures, protection is still necessary for firefighters that are using the stair to attack the fire. (Note: The need for fire-rated exit enclosures was specifically addressed during the Report on Proposals and the Report on Comments for the 2000 edition of the *Life Safety Code*,[7] the committee removed any specified minimum fire-resistance rating for exit enclosures in the performance-based option). A model may have shown that all the civilians got out of the building fine. If the design uses only one exit stair, it might be necessary for people to exit the building while the fire department is trying to gain access.

One of the problems discussed earlier dealt with smoke control systems. One of the reasons that smoke control systems can be so difficult for the fire service is that there really is no "standard" design. But, many system designs have been guided by standards. Many features required in the installation standards today are based on experience (usually bad experience), and much of this cannot be modeled using the tools available today. Or if it can be modeled, it will also be necessary to consider the effect on the fire service.

SOME FINAL THOUGHTS

It is not the intent of this paper to be critical of performance-based codes and standards or to criticize anybody's specific design. However, as performance-based designs become more prevalent, fire protection engineers should become more aware of the needs of the fire service. Not all firefighters are going to be able to spend countless hours studying a design. Even if they could, they will not usually have the opportunity to stay constantly refreshed on it. The firefighter, assigned to the closest station may be transferred tomorrow or might be at another call when the building you are working on needs the fire department. Remember, the engineer worked on the project, usually from the beginning, and therefore it all makes sense to him or her. The firefighter might be arriving at three in the morning, not having been in the building for months (maybe years), and is expected to make rational decisions with the systems. Don't count out the firefighter. If the engineer does, the system may be shut down, overridden, or worse – misused.

One of the best ways to help is to keep it simple, keep it logical, consider all variables, and remember the person that has to use the system during an emergency.

With regard to performance-based design, getting the people out is the first part of the battle, and the firefighter might be present long after initial evacuation. Lessons of the past must not be forgotten because a model demonstrates that the minimum required egress time is provided. There is almost no part of building fire safety that can be altered without some impact, good or bad, on the firefighter in the building.

When all is said and done, engineers should put themselves in the shoes of a person that was not at all part of the planning and design meetings and needs to make decisions under great stress.

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What Users Want Fire Model Developers to Address

By J.K. Richardson, P.Eng.,
L.R. Richardson, J.R. Mehaffey, Ph.D.,
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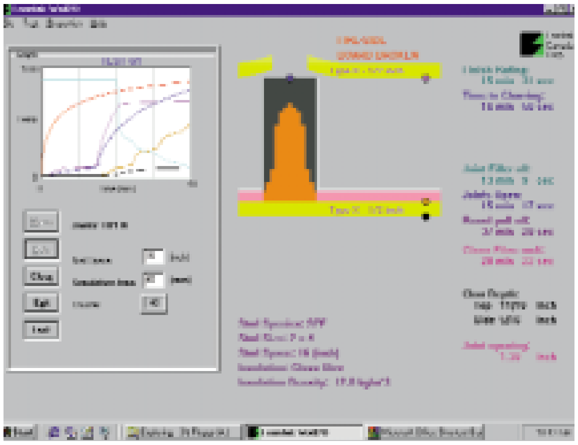
There is a growing trend in fire protection design towards the use of computer models to determine the effects of fire in various scenarios. The appeal of such models is obvious – a properly validated and calibrated model can reduce the need for costly experimental tests, can be a tool in making design decisions, and can be used by investigators to reconstruct fire scenarios. Since developing a computer model requires a sizable investment of resources, it is in the interest of model developers to consider the needs of the model's potential users throughout the development process. This article discusses some of the issues that potential model users consider important for the release of a new computer model, based on a survey by Forintek Canada Corporation (FCC). A primary issue being investigated was the acceptability of fire models for regulatory approval. The results obtained are considered to have broader relevance to models besides the one considered in the survey.

Forintek has been developing computer-based models for the past decade. This article presents an overview of the results of a study that



WALL2D Results

FCC commissioned to investigate the expectations of a target group of potential users of FCC's WALL2D model. WALL2D is a 2-dimensional computer model for predicting heat transfer through nonload-bearing wood-stud walls protected by gypsum board. Using this model results in the assessment of fire-resistance of such assemblies. The opinions of a group of potential model users were gathered through a series of in-person and telephone interviews. That group included:

- consultants – fire safety engineers and architects,
- regulatory officials – building and fire,
- fire researchers,
- codes and standards developers,
- insurance inspectors,
- university professors who could use or teach fire models, and
- representatives of professional societies that might review models.

The group of 13 potential users was balanced between subjects who were recent graduates and more experienced practitioners, frequent users of models and inexperienced users, Canada-and U.S.A.-based subjects, and subjects with a variety of educational backgrounds (technical college degree, baccalaureate degree, or graduate degree). No attempt was made to select individuals with a prior knowledge of FCC, the wood industry, or fire modeling in general. Considerable effort was expended to ensure that the selected users provided as great a diversity of backgrounds as possible.

The potential users were asked about:

- the degree of acceptance they thought the model would have in the user community,
- how they thought WALL2D needed to be validated in order to be a useful tool, and
- how they expected such a model to be documented.

Assuming that the group identified above constitutes the most likely users of models such as WALL2D, then the results of FCC's interview project provide a good indication of the expectations that the user community has of fire models in general. Designers of all types of fire models can benefit from the conclusions of this project.

FAMILIARITY WITH AND ACCEPTANCE OF FIRE MODELS

The interview results revealed that there is a moderately high degree of awareness in the potential user community of the use of models of fire phenomena: sixty-nine percent of the subjects interviewed had some experience using fire models. Some used simple algorithms from handbooks, while others used more complex computer programs to model phenomena like smoke movement or people movement. Fewer interviewees had used modeling techniques to calculate fire resistance, but there was frequent agreement that fire-resistance models are needed. While there is a demand for such models, developers must bear in mind that nearly a third of the potential users (and half of the regulators) had no experience using fire models for any purpose. If fire modeling is to achieve widespread use, developers will have to educate target users who may be unfamiliar with modeling techniques. Without an understanding of the data and calculations on which a model is based or of how to use the model correctly, users who have not been educated about the model may be reluctant to trust results that appear to have been produced from a "black box". An investment in educating potential users is likely to be worthwhile; however, since the evidence shows that fire models in general and fire resistance models in particular, are likely to find acceptance in the target user community. Ninety-two percent of the potential users interviewed believed that fire models are useful, and 77% believed that fire-resistance models are useful.

It was felt that FCC's WALL2D model would be especially useful if it incorporated the ability to measure the fire resistance of assemblies with a greater variety of wall membrane materials. This comment reminds developers of fire models that any model is more useful if it allows users to set the parameters to represent the conditions of a fire scenario, rather than having these parameters hard-coded.

VALIDATION OF FIRE MODELS

A second set of questions in the FCC project was used to determine what level and type of validation was necessary for users to accept the results of WALL2D's modeling as sufficiently representative of fire conditions in actual wall assemblies. At the time of the project, the theory underlying WALL2D had been discussed in papers published in peer-reviewed journals. Such journals also published comparisons between the results provided by WALL2D and the results of full-scale fire-resistance tests. Sixty-two percent of the interviewees found that level of validation to be acceptable, while 30%, a sizable number, felt that further validation was necessary. Furthermore, 75% of the regulators who were interviewed were unwilling to consider the model sufficiently validated. Many of the interviewees recommended that the model be reviewed and approved by some third-party agency, which could be a certification agency or professional society. Others wished to learn more details about the calculations and modeling techniques underlying the computer program. Another suggested that the model should be discussed in trade journals as well as peer-reviewed journals so that more potential users could learn about it.

These comments by the target users echo the remarks made above – that users must be educated about the "inner workings" of a model before they will be willing to accept it. Evaluation or certification of a model by an independent agency will clearly help to increase users' level of trust in the results of the model.

A majority (54%) of the target users wanted to see further comparisons between WALL2D's results and experimental results. Again, this finding underscores the user expectation that a model accurately represent real-life conditions. The greater reluctance of regulators to accept WALL2D at its then-current level of validation emphasized the need for model developers to communicate with regulators (through the media mentioned above, as well as through demonstrations and educational seminars) about the theory, results, and appropriate use of the model. If regulators do not accept a model, the model's usefulness is limited for all other users. Developers might therefore be better served by overpublicizing their efforts than by underpublicizing.

DOCUMENTATION OF FIRE MODELS

Potential users of WALL2D were asked whether they preferred the model's documentation in electronic or printed form. It was originally intended that either form of documentation would consist simply of a user manual describing how to use the computer program. The interviews revealed, however, that users thought it important that more technical information be documented as well, such as the validation information, the theoretical basis of the model, and guidance about the appropriate use of the model, including its limitations. Most (69%) of those interviewed were of the opinion that this information, as well as the how-to user manual, should be available as a printed document, not just electronically.

This finding illustrates users' reluctance to trust online help systems, probably because of their experience with nonintuitive and downright unhelpful "help" attached to other programs. Model developers are likely to find more sympathy for documentation in book form than online. The interviewees' comments about what must be included in the documentation also reveal a trend that was hinted at in their previous answers. Their answers thus far indicate that target users are entirely willing to use computer models of fire phenomena, as long as they can understand how and why the model works.

FUTURE FIRE MODELING EFFORTS

The varied responses of the target users to the interview questions about the future directions of model development all echoed the same theme – the more parameters that can be set by the user, the more useful a model is. For WALL2D, a model representing heat transfer through walls, users wanted to be able to set parameters for such variables as wall size, covering material, stud material, insulation material, fastener spacing, and the effects of doors or other openings, among others. Clearly, the message for developers of any kind of fire model is that the more scenarios a program can model accurately, the more value it has to the user.

The results of WALL2D model interviews can be generalized for developers of other fire models. The two recurring themes were education and adaptability. Users want to be educated so that they can understand how a model works, why it is a representative model of real-life scenarios, and how it is used correctly and appropriately, in order for them to feel confident about and rely on the results to help make decisions. Furthermore, for any model to be of value to its users, it must be adaptable to a variety of scenarios, rather than hard-coded to a given set of parameters. Model developers who bear these two goals in mind throughout the development process are likely to find that their models achieve much successful use.

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A RISK-BASED FIRE-ENGINEERED ALTERNATIVE SOLUTION FOR

Nursing Homes

A CASE STUDY IN NEW ZEALAND

By Tony Parkes, and Carol Caldwell, P.E.

New Zealand's building code allows for performance-based fire engineering designs. However, performance-based designs that are submitted are evaluated on their relative merits when compared to the prescriptive code requirements. These prescriptive requirements are designated to be the minimum risk acceptable by the public. Therefore, a performance-based design should show that it provides a level of risk that is equal to or better than the prescriptive requirements. The performance-based design presented in this case study uses the reliability and performance of sprinklers and smoke detectors installed throughout the building in place of the prescriptive code requirement for self-closers and fire doors to the rooms. It should be noted that the prescriptive code requires sprinklers and smoke detectors to be installed throughout the building *as well as* self-closers and fire doors to bedrooms.

The performance-based design provided the fire safety features of the building to meet the requirements of the New Zealand building code. The acceptance criteria of a performance-based design is outlined in the New Zealand Building Act, which states:

After considering an application for building consent, the territorial authority shall grant the consent if it is satisfied on reasonable grounds that the provisions of the building code would be met if the building work was properly completed in accordance with the plans and specifications submitted with the application.

Although this case study provides less than the prescriptive code requirements, the Territorial Authority was satisfied on reasonable grounds. It accepted the performance-based design based upon the performance of residential sprinklers and the excellent past history of sprinklers in New Zealand.

There are many fire issues involved with the design of nursing homes. Often the occupants may have physical or mental problems that prevent them from freely egressing from the building in the event of fire. It is often best to provide for staged evacuation into another part of the building instead of a complete evacuation of the building. This case study addresses these issues and the performance-based fire engineered approach that was developed.

DESIGN PHILOSOPHY

A performance-based design has been developed that considers all the fire protection features of the building: active systems, passive system and administrative procedures. Additionally, the performance of sprinkler systems in New Zealand is used to justify the performance-based design.

The fire report is submitted as a performance-based design fire report. It is submitted to permit the installation of nonfire-rated patient room doors without self-closures. The performance-based design allows the fire safety features of the building to meet the requirements of the New Zealand building code. The primary objectives of the code are[1]:

- Protect occupant life safety
- Protect neighboring property
- Provide for some safety for fire-fighters
- Protect the environment

With the installed fire safety features in this building, these objectives have been achieved, as well as showing that the level of risk provided is equal to or better than the prescriptive requirements.

In general, the prescriptive requirements of means of escape features, door widths, and interior finish requirements of the *New Zealand Building Code Handbook and Approved Documents*[1] are followed.

PRESCRIPTIVE REQUIREMENTS

Nursing homes are classified as an SC purpose group, sleeping care. The prescriptive documents in New Zealand do not differentiate between nursing home and hospital care. Typically, the occupants in the nursing home are ambulant; they move to a different level of care facility when they are no longer so. However, both facilities are SC purpose groups.

The prescriptive requirements for the nursing homes vary according to the number of sleeping occupants. For up to five occupants in a single-story home, there are only requirements for manual pull stations. For six to 20 occupants, smoke detectors are required. Beyond 20 occupants, sprinklers are required with at least smoke detectors in the bedrooms. Smoke detectors are required throughout the facility in addition to sprinklers when the occupant load exceeds 40.

In addition to the requirements for smoke detectors or sprinklers, there are also requirements for fire separations. The fire separation requirements apply regardless of the other installed fire protection features. Interpretation of the *New Zealand Building Code Handbook and Approved Documents*[1] requires the occupant rooms to be fire separated from the rest of the building. This requires all sleeping rooms to be separated by 30- or 15-minute fire-resistant construction; this includes the walls and doors. This would require that a fire door fitted with a self-closer be provided. The difficulty arises in that fire doors with self-closers are not practical for the occupants of these spaces. It is difficult for the occupants in this facility, SC purpose group, to open the door to escape from their rooms. It also tends to isolate the occupants behind a shut door, which is counterproductive to getting them involved in activities.

FIRE PROTECTION FEATURES

The building is to have a sprinkler and smoke detection system installed throughout. The building will be protected with quick-response sprinklers (not residential), and the bedrooms, with residential sprinklers. Standard-response sprinklers will be used in the attic space. Any sprinkler operation will activate the strobes and audible alarms in the building.

A smoke detection system will be provided throughout the building. Optical smoke detectors will be used. Separate strobe lights and low level sounders are to be provided throughout all areas of the building. The strobe and low-level sounders are to be wired so that each can be used independently. The capability for muting the low-level sounders is to be provided at the main/remote fire alarm panel.

Emergency lighting is required throughout the facility. It is to last for 120 minutes.

Fire/Smoke Separations. The building will be divided into two fire cells. The fire separations are to be 30 minutes. The doors at these locations are required to be a 30-minute fire doors and shall be fitted with self-closing devices.

The fire and smoke stop doors are to be held open on an approved hold-open device. The hold-open devices will be connected to the smoke detection system. On activation of the smoke detector adjacent to the doors, the hold open devices will release the doors and allow the automatic closers to close them.

System Operation. When a smoke detector, sprinkler system, or manual pull station is activated, the low-level sounders and strobes alarm throughout the building. If it is a sprinkler or manual pull station, the signal is sent to the New Zealand Fire Service. The zone in alarm is displayed on the main/remote fire alarm panels in the building. The capability for muting the low-level sounders is provided at the main/remote fire alarm panels. Staff respond to determine the cause and relocate occupants to the other side of fire or smoke separations. If there is a need to fully evacuate the building, a switch will be provided at the main/remote fire alarm panels to allow for operation of the sounders for full evacuation.

COMPLIANCE WITH NEW ZEALAND BUILDING CODE

New Zealand Building Code Clause. New Zealand building code performance criteria C3.3.2 states:

> *Fire separations shall be provided within buildings to avoid the spread of fire and smoke to:*

a) Other fire cells,
b) Spaces intended for sleeping,
c) Household units within the same building or adjacent buildings.

The building meets the performance criteria by the fact that “sleeping spaces” are provided with fire separations. There are two separate fire cells in the nursing home containing sleeping spaces. Hence the “sleeping spaces” are fire separated. With the installed smoke detectors for early warning of fire and residential sprinklers installed in the bedrooms, the occupants of the bedrooms are not expected to be exposed to untenable conditions.

COMPARATIVE RISK-BASED PERFORMANCE SOLUTION

We now turn to items that deviate from the *New Zealand Building Code Handbook and Approved Documents*[1]. They relate to the degree of fire separation between bedrooms, the installation of nonfire-rated patient room doors without self-closers, and the location of emergency lighting. Staff operation and system operation are discussed to provide the scenario of what happens in the event of a fire. Additionally, information on the benefits of residential sprinklers and information on the past history and reliability of sprinkler systems in residential-type occupancies is provided.

This performance-based design compares the implied risk of failure of a sprinkler system to that of the requirement of the BIA Acceptable Solutions. Is the AHJ *reasonably satisfied* that the risk to life safety of the occupants is not lessened with a solution based upon the performance of sprinkler systems in New Zealand? This question addressed by the AHJ relates to the risks associated with each fire protection measure and whether or not it can be implied that they are equal to one another. One must also not forget that, with the installation of sprinklers in these facilities, the use of passive fire measures is not thrown out the window, but that more emphasis is placed upon the performance of an active fire-suppression system and the good level of staff training.

Although the risks associated with the performance-based design are somewhat implied, the risk of the performance of the sprinkler system and a good level of staff training show that what is provided is nothing less than what is expected by the public, i.e., the minimum risk acceptable.

When a smoke detector or manual pull station goes into alarm, this activates the strobes and low-level audible devices in the building of alarm. Only the strobes will activate in the other building. It also indicates the zone of the alarm on the main/remote fire alarm panel. The staff on duty responds to determine the cause of the alarm.

When the sprinkler system activates, basically the same sequence as that taking place during smoke detector activation occurs. The only difference is that the sprinkler system is one zone for the building. The sprinklers and manual pull stations are connected to the New Zealand Fire Service.

In the event there is a fire in a bedroom, staff will evacuate the occupant from that room and close the door. This is included as part of staff training. The facility has staff in attendance 24 hours a day, every day. There will be at least two staff on duty in the building at all times.

Emergency Lighting. According to the *New Zealand Building Code Handbook and Approved Documents*[1], emergency lighting is required throughout the facility. It must be available for 120 minutes. The emergency lighting is provided to assist in evacuating occupants. Since the doors to the rest home bedrooms are not on self-closers, the door can be left open to allow light from the corridor to enter the bedroom. That light is sufficient to assist occupants from their beds in the event they need to evacuate.

There is also the problem of the emergency lights coming on when evacuation from the facility is not necessary, which is most often apt to be the situation. If the emergency lighting is installed in the bedrooms and is on when evacuation is not required, it prevents the occupants from sleeping.

Considering this, it is believed to be appropriate to not provide emergency lighting in the rest home bedrooms.

Residential Sprinklers. Residential sprinklers are to be installed in the bedrooms. Residential sprinklers have passed special testing requirements in order to be called “residential sprinklers.” For sprinklers to be classified as residential, standard testing must be undertaken to show that a sprinkler meets certain performance criteria before it may be marketed. The acceptance requirements for residential sprinklers are based on the temperatures in the surrounding environment. After sprinkler activation, the acceptance requirements of the space protected by residential sprinklers are:[3]

- The maximum temperature 76.2 mm (3 in) below the ceiling shall not exceed 316 °C (600 °F).
- The maximum temperature 1.6 m (5.25 ft) above the floor shall not exceed 93 °C (200 °F).
- The temperature 1.6 m (5.25 ft) above the floor shall not exceed 54 °C (130 °F) for more than any continuous two-minute period.
- The maximum ceiling temperature 6.35 mm (0.25 in) behind the finished ceiling surface shall not exceed 260 °C (500 °F).

The first three requirements are directly relevant to the life safety of the occupants in the rooms. The residential sprinklers must meet these performance requirements. Considering this information and actual fire experience, it is reasonable to expect that the bedroom occupant will survive in the event of a flaming fire in the bedroom. If the occupant of the bedroom can survive the fire, it is reasonable to state that tenable conditions will be maintained in the adjacent corridor. With the presence of the smoke detectors in the bedroom units, it is expected that the occupants will be alerted to the presence of a fire before the sprinklers are activated.

Past Experience with Sprinkler Systems. The effectiveness of sprinkler systems in residential-type buildings at preserving life when an occupant is in the same room as the fire has been well documented by H.W. Marryatt in his book, *Fire: A Century of Automatic Sprinkler Protection in Australia and New Zealand.*[2]

As noted in the book, "An important question raised by the fire fatalities in the USA in 1985 is whether sprinkler operation in a single-room fire, as in a hotel or hospital, would be fast enough to prevent the asphyxiation of an occupant smoking in bed for example." The author goes on to evaluate the fatalities in 79 single-room fires. There were only two: one person whose clothes were on fire and who ran from the room, and one whose bedding ignited. These were all standard response sprinklers, not quick-response.

The statistics show that in 389 documented fires in which sprinkler systems in residential buildings activated, there have been only three fatalities. The majority of the these residential sprinkler systems have been provided with standard-response sprinklers, not residential sprinklers that use a quick-response activating element. The fatalities occurred when the occupant was intimate with the fire origin:

- An elderly woman dropped a cigarette onto the rubber-upholstered chair on which she was sitting.
- An elderly woman sustained fatal burns when her bedding caught fire when the overhead fluorescent lights burst and hot metal ignited her bed covers.
- A young woman in a mental hospital ignited her clothing while smoking and suffered fatal burns.

In each of the described fatality scenarios, the standard-response sprinklers activated and prevented danger to other occupants of the buildings. In all other documented fires where residential-type sprinkler systems were installed, the sprinklers activated and either suppressed the fire or controlled it until the fire service was able to intervene. The documented situations show residential sprinkler systems are capable of saving the lives of occupants directly exposed to the fire. In some cases, the sprinkler system has saved the lives of occupants who have deliberately started fires in their room. With the advent of residential sprinklers, the performance of a sprinkler system in the rest home occupancies is increased.

With the installed sprinkler system, it is reasonable to expect that the bedroom occupant will survive in the event of a flaming fire in the bedroom. If the occupant of the bedroom can survive the fire, then it is reasonable to state that tenable conditions will be maintained in the adjacent corridor. Therefore, a fire in the room would not cause conditions to become untenable in an adjacent space if the door were left open.

ACCEPTABLE LEVEL OF RISK

The reliability and performance of sprinkler systems in New Zealand has been shown to be high. According to Marryatt:[2]

> *It is reasonable to claim that the percentage of fires recorded is high enough, and the number of occupancies in which fires were recorded wide enough, to enable valid conclusions to be drawn regarding the effectiveness of automatic sprinkler protection. The "fires controlled" percentage of 99.46% is remarkable...*

However this reliability of 99.46% only addressed those buildings in which the sprinklers did operate. It does not include those failures due to shutdowns, etc. In this case a reliability of 95%-98% is more applicable. The reliability of sprinklers in New Zealand is higher than other countries, due to the sprinkler systems being wet pipe systems and significant monitoring and servicing. Due to the reliability of sprinkler systems in New Zealand, their performance, compared to passive fire protection, is considered to be greater. It is recognized that, with the installation of a sprinkler system, the spread of fire and smoke is limited better than with barriers.

This performance-based design shows that, although more emphasis is placed upon the performance of the sprinkler system, it is a reasonable acceptable level of risk and provides a level of life safety to the occupants that is reasonably equivalent to that of the BIA-Acceptable solutions.

MAINTENANCE AND SHUTDOWNS

As mentioned, the reliability of sprinkler systems only addressed those buildings in which the sprinklers did operate. It did not include those failures due to shutdowns, etc. The issue of shutdown or maintenance is addressed by the Building Act, however. Shutdowns or significant maintenance involving the sprinkler systems (or for that matter any major fire protection system) in a building would mean that the building no longer meets the New Zealand building code. The building Warrant of Fitness and registered evacuation scheme would be void. During these periods, the responsibility is placed upon the owner to report to the AHJ and the New Zealand Fire Service, who may ask for interim requirements. For example, this could result in the placement of additional safety features, such as extra staff. Currently, this is not being done to any large extent. However, attention to the compliance of the fire protection systems is increasing, with co-ordination between the AHJ and Fire Service becoming a requirement.

CONCLUSION

The fire report submitted shows that, with the proposed fire protection features, the objectives of the New Zealand building code have been achieved. The Territorial Authority is *satisfied on reasonable grounds* that the installation of smoke detectors in the bedrooms and sprinklers provides an acceptable level of risk to meet the performance criteria of the New Zealand building code in lieu of fire separations between bedrooms and fire-rated patient room doors with self-closures.

Tony Parkes, and Carol Caldwell, P.E., are with Caldwell Consulting Ltd.

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LARGE EDDY SIMULATIONS OF FIRES

FROM CONCEPTS TO COMPUTATIONS

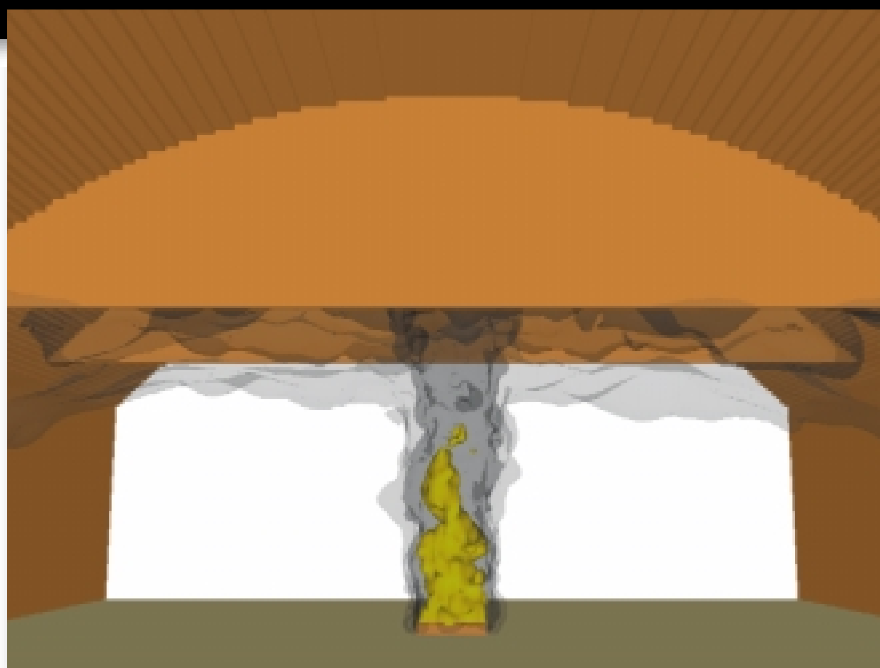

Figure 1 – Simulation of a Fire in a Hangar.

By Howard R. Baum, Ph.D.

The idea that the dynamics of a fire might be studied using digital computers probably dates back to the beginnings of the computer age. The concept that a fire requires the mixing of a combustible gas with enough air at elevated temperatures is well known to anyone involved with fire. Graduate students enrolled in courses in fluid mechanics, heat transfer, and combustion have been taught the equations that need to be solved for at least as long as computers have been around. What is the problem? The difficulties revolve about three issues:

• First, there are an enormous number of possible fire scenarios to consider.

• Second, we do not have either the physical insight or the computing power (even if we had the insight) to perform all the necessary calculations for most fire scenarios.

• Finally, since the "fuel" in most fires was never intended as such, the data needed to characterize both the fuel and the fire environment may not be available.

In order to make progress, the questions that are asked have to be greatly simplified. To begin with, instead of seeking a methodology that can be applied to all fire problems, we begin by looking at a few scenarios that seem to be most amenable to analysis. Hopefully, the methods developed to study these "simple" problems can be generalized over time so that more complex scenarios can be analyzed. Second, we must learn to live with idealized descriptions of fires and approximate solutions to our idealized equations. These idealized descriptions have to be based on the kind of incomplete knowledge of fire scenarios that is characteristic of real fires. Finally, the methods should be capable of systematic improvement. Thus, as our physical insight and computing power grow more powerful, the methods of analysis can grow with them.

The "Large Eddy Simulation" (LES) technique developed at NIST over a nearly two-decade period is our attempt to carry out the conceptual program outlined above. The phrase refers to the description of turbulent mixing of the gaseous fuel and combustion products with the local atmosphere surrounding the fire. This process, which determines the burning rate in most fires and controls the spread of smoke and hot gases, is extremely difficult to predict accurately. This is true not only in fire research, but in almost all phenomena involving turbulent fluid motion. The basic idea behind the use of the LES

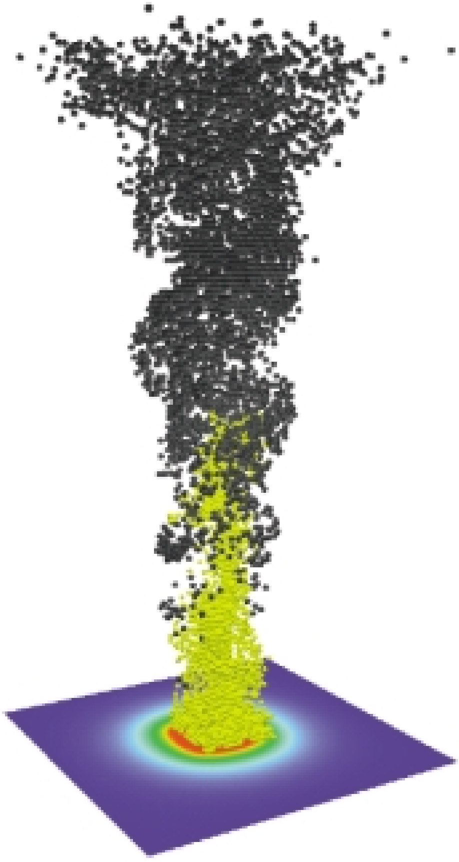

Figure 2 – Thermal Elements in a Fire Plume Simulation.

technique is that the eddies accounting for most of the mixing are large enough to be calculated with reasonable accuracy from the equations of fluid mechanics. The hope (which must ultimately be justified by appeal to experiments) is that small-scale eddy motion can either be crudely accounted for or ignored. The equations describing the transport of mass, momentum, and energy by the fire-induced flows must be simplified so that they can be efficiently solved for the fire scenarios of actual interest.

The general equations of fluid mechanics describe a rich variety of physical processes, many of which have nothing to do with fires. Retaining this generality would lead to an enormously complex computational task that would shed very little additional insight on fire dynamics. The simplified equations, developed by Rehm and Baum,[1] have been widely adopted by the larger combustion research community, where they are referred to as the "low Mach number" combustion equations. They describe the low-speed motion of a gas driven by chemical heat release and buoyancy forces. The low Mach number equations are solved on the computer by dividing the physical space where the fire is to be simulated into a large number of rectangular cells. In each cell, the "state of motion," i.e., the gas velocity, temperature, etc., is assumed to be uniform, changing only with time. The computer then computes a large number of snapshots of the state of motion as it changes with time. **Figure 1** shows one such snapshot of a hangar fire simulation.

Clearly, the accuracy with which the fire dynamics can be simulated depends on the number of cells that can be incorporated into the simulation. This number is ultimately limited by the computing power available to the user. Present-day computers limit the number of such cells to at most a few million. This means that the ratio of largest to smallest eddy length scales that can be resolved by the computation (the "dynamic range" of the simulation) is roughly 100 ~ 200. Unfortunately, the range of length scales that need to be accounted for, if all relevant fire processes are to be simulated, is roughly 104 ~ 105. Much of the discrepancy is due to the fact that the combustion processes that release the energy take place at length scales of 1 mm or less.

FIRE PLUMES

The idea that different physical phenomena occur at different length and time scales is central to an understanding of fire phenomena and to the compromises that must be made in attempting to simulate them. The most important example is an isolated fire plume in a large, well-ventilated enclosure (see Figure 1).[2,3] The fire plume is the "pump" that entrains fresh air and mixes it with the gasified fuel emerging from the burning object. It then propels the combustion products through the rest of the enclosure. The eddies that dominate the mixing have diameters that are roughly comparable to the local diameter of the fire plume. Thus, in the above simulations, the cells have to be small enough so that many (a 12x12 array, in this case) are used to describe the state of motion across the surface of the fuel bed. Since the simulation also needs to include the remainder of the hangar as well, even the 3-million-cell simulation shown in Figure

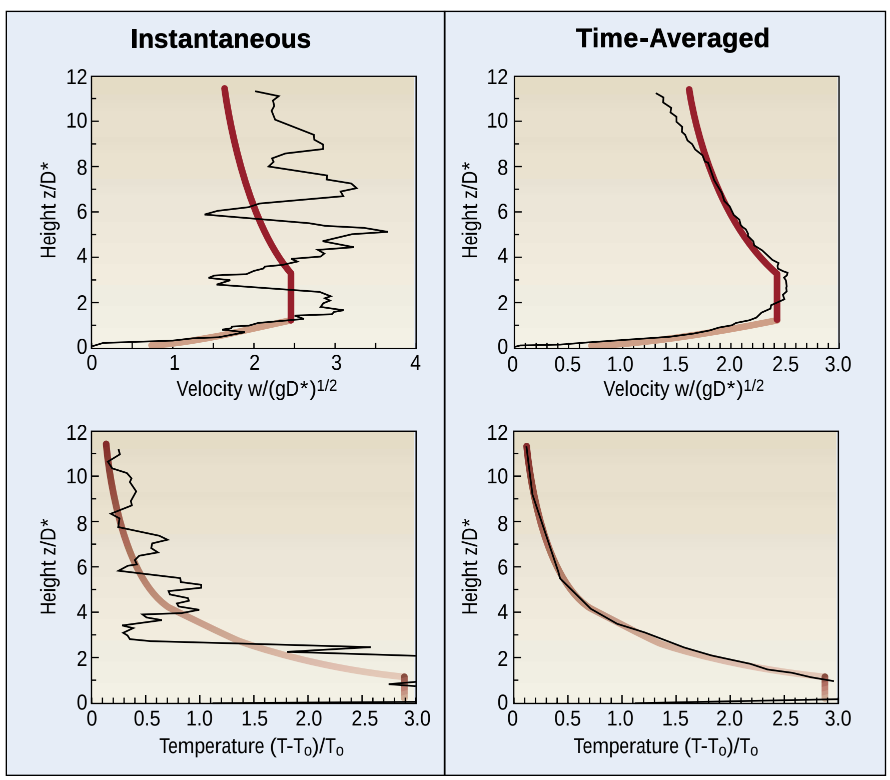

Figure 3 – Vertical Centerline Temperature and Velocity Profiles.

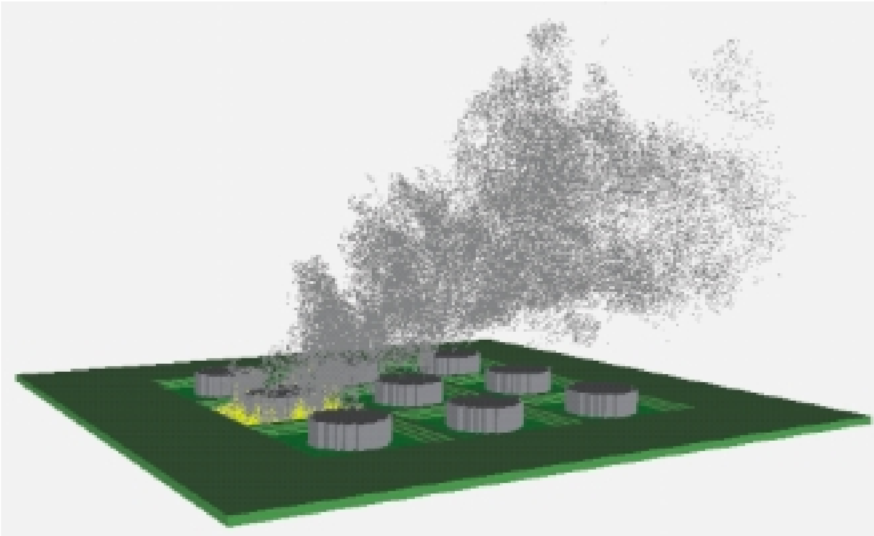

Figure 4 – Simulation of an Oil Spill Fire.

1 cannot cope with the combustion processes without additional modeling effort.

Physical processes like combustion that occur on scales much smaller than the individual cell size are often called "sub-grid scale" phenomena. For our purposes, the most important of these are the release of energy into the gas, the emission of thermal radiation, and the generation of soot together with other combustion products. These phenomena are represented by introducing the concept of a "thermal element."[4] This can be thought of as a small parcel of gasified fuel interacting with its environment. The concept is illustrated in **Figure 2**.

Each element is carried along by the large-scale flow calculated as outlined. As long as the fire is well ventilated, it burns at a rate determined by the amount of fuel represented by the parcel and a lifetime determined by the overall size of the fire. The lifetime of the burning element is determined from experimental correlations of flame height developed by McCaffrey.[5] A prescribed fraction of the fuel is converted to soot as it burns. Each element also emits a prescribed fraction of the chemical energy released by combustion as thermal radiation. This fraction is typically about 35 percent of the total. The soot generated by the fire can act as an absorber of the radiant energy. Thus, if the fire generates large amounts of soot, the transport of radiant energy through the gas must be calculated in detail.[6] Even in the absence of significant absorption of radiant energy by the products of combustion, the radiant heat transfer to boundaries is an important component of the total heat transfer to any solid surface.

Figure 2 shows a snapshot of the elements used to simulate an isolated fire plume in the absence of any boundaries. Time averages of the output of this kind of simulation must be produced in order to make quantitative comparison with most experimental data. Indeed, the fact that the results of the simulation can be averaged in a routine way while the equations of fluid mechanics cannot is the basis of the whole approach presented here.

On the left of **Figure 3** are the instantaneous vertical centerline velocity and temperature profiles. The oscillations are primarily due to the large toroidal eddies generated at regular intervals at the base of the fire, which then rise asymmetrically. Note that the flow is not even remotely axially symmetric, and the centerline is defined only by the geometry of the pool at the base of the plume. The right side of **Figure 3** shows the corresponding time averaged quantities (solid lines) and McCaffrey's centerline correlations. The time averaged flow is symmetric and in excellent agreement with the correlations. The only deviations are at the bottom of the plume, where the thermal elements are turned on instantaneously without any preheat as they leave the pool surface, and at the top, where the computational "hood" exerts some upstream influence on the plume.

OUTDOOR FIRES

Large outdoor fires can be conveniently divided into two categories based on the fuel source. Wildland fires are characterized by a relatively low heat release rate per unit area of ground covered by fuel, but a very large area over which the fire can spread. Indeed, the description of the fire spread process is an essential part of any successful simulation of such an event. Industrial fires, in contrast, are usually much more highly localized but intense emitters of heat, smoke, and other combustion products. This is particularly true if the fuel is a petroleum-based substance, with a high energy density and sooting potential. This latter type of fire is the object of study here.

The hazards associated with such fires occur on two widely separated length scales. Near the fire, over distances comparable to the flame length, the radiant energy flux can be sufficiently high to threaten both the structural integrity of neighboring buildings and the physical safety of firefighters and plant personnel. At much greater distances, typically several times the plume stabilization height in the atmosphere, the smoke and gaseous products generated by the fire can reach the ground in concentrations that may be unacceptable for environmental reasons. The far-field hazard has been studied extensively by NIST researchers.[7,8] This work has led to the development of the computer code ALOFT[9], which is available from NIST.

Consider the near-field hazard associated with the flame radiation. The scenario chosen is a fire surrounding an oil storage tank adjacent to several neighboring tanks. This scenario is chosen both for its intrinsic importance and because it illustrates the ingredients needed to generate a realistic simulation of such an event. The heat release generated by a fire on this scale can reach several gigawatts if the entire pool surface is exposed and burning. Such fires interact strongly with the local topography (both natural and man made) and the vertical distribution of wind and temperature in the atmosphere. Moreover, the phenomena are inherently time dependent and involve

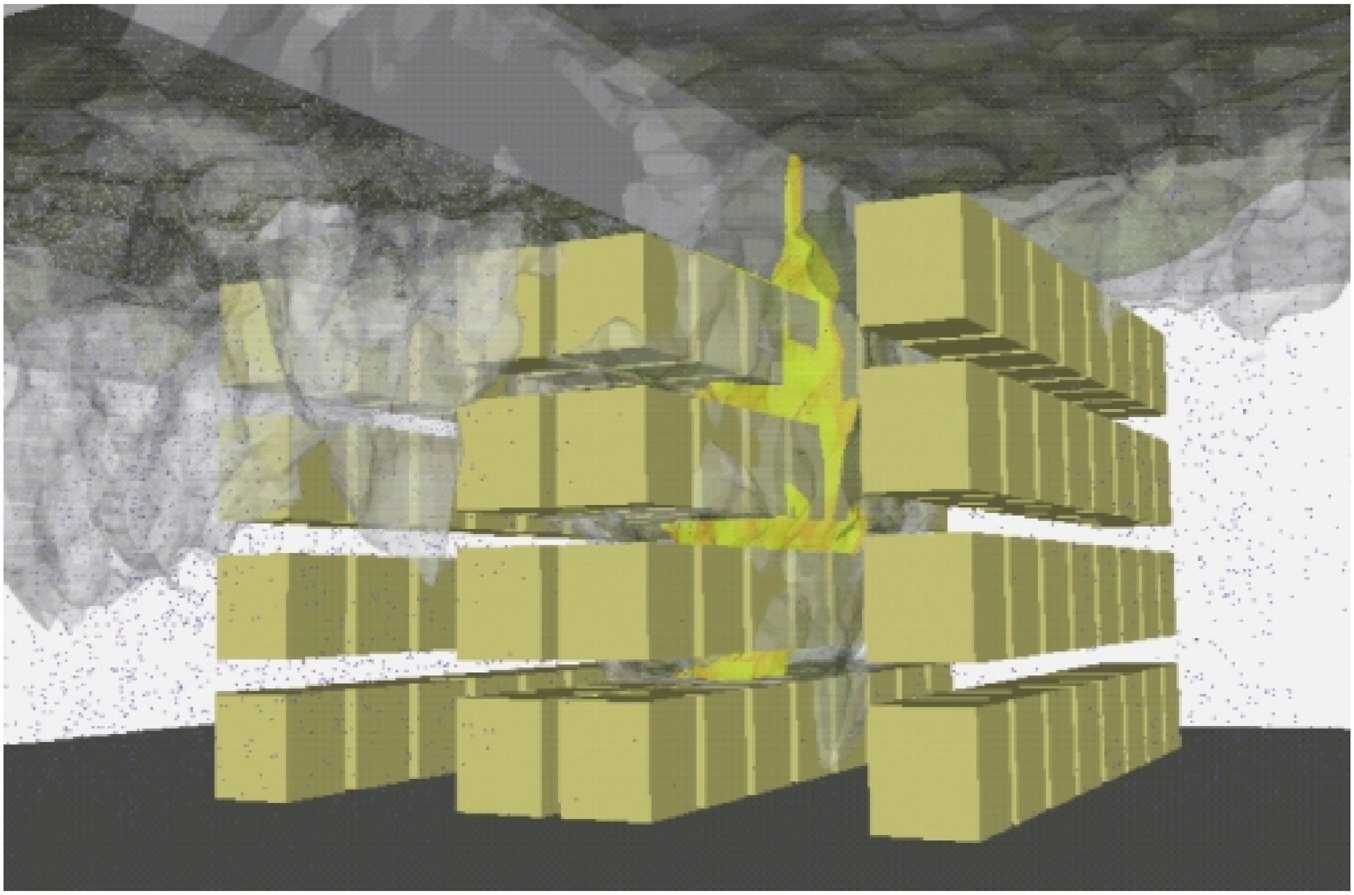

Figure 5 – Simulation of a Cartoned Plastic Commodity Fire Test.

a wide temperature range. Thus, the simplifications employed in ALOFT and its generalizations cannot be used in the present analysis. Indeed, the "low Mach number" combustion equations need to be modified to account for the stratification of the atmosphere.

Figure 4 shows a simulation of a fire resulting from an oil spill trapped in the containment trench surrounding one of the tanks. The diameter of each tank is 84 m (270 ft), the height 27 m (89 ft). Each tank is depressed below ground level and surrounded by a containment trench of depth 9 m (30 ft). The geometry was modeled on the oil storage facility of the Japan National Oil Corporation at Tomokomai, Japan. No attempt was made to represent the entire facility, which contains over 80 tanks. The volume of space represented is a cube 768 m (2,520 ft) on a side. This was filled with a 128x128x128 array of cells 6 m (20 ft) on a side in the horizontal and ranging from 3 m (10 ft) near the ground to 12 m (39 ft) at the top in the vertical direction. A wind profile that increased from 6 m/s (13 mph) near the tank top to 12 m/s (27 mph) at 768 m (2,520 ft) that is representative of the atmospheric mean wind profile near the ground was chosen. The ambient temperature was taken to be constant. This is a very stable atmosphere, typical of winter conditions in northern climates. The spilled oil in the trench was assumed to burn with a heat release rate of 1,000 kW/m^2, for a total heat release rate of 12.1 GW. Each element was assumed to emit 35 percent of its energy as thermal radiation, and 12 percent of the fuel was converted to soot.

The brightly colored elements in **Figure 4** are burning, releasing energy into the gas and the radiation field. Thus, the composite burning elements represent the instantaneous flame structure at the resolution limit of the simulation. The darkly colored elements are burnt out. They represent the smoke and gaseous combustion products that absorb the radiant energy from the flames. It is important to understand how much of the emitted radiant energy is reabsorbed by the surrounding smoke. The magnitude of this smoke shielding can be realized by computing the radiative flux to the surrounding tanks. A test calculation was performed in which no thermal radiation was absorbed by the smoke. Comparison of the two results showed that the effective radiative fraction reaching the surface is about 6 percent. Thus, 29 percent of the original 35 percent was reabsorbed by the soot. This is consistent with measurements made by Koseki.[10] To explore this further, a separate simulation of a vertical plume in the absence of any wind was performed. The convective energy flux at several heights above the fire bed was calculated. The energy flux was consistently approximately 94 percent of the total heat release rate in the fire. This means that of the original 35 percent released as thermal radiation, 29 percent was reabsorbed, confirming the earlier result.[11]

INDUSTRIAL FIRE CONTROL

Up to this point, the emphasis has been on studying fires as natural phenomena. Recently, the LES techniques have begun to be used to study the effects of human intervention to control the damage caused by fires. The

International Fire Sprinkler, Smoke and Heat Vent, Draft Curtain Fire Test Project, organized by the National Fire Protection Research Foundation, brought together a group of industrial sponsors to support and plan a series of large-scale tests to study the interaction of sprinklers, roof vents, and draft curtains of the type found in large warehouses, manufacturing facilities, and warehouse-like retail stores. The tests were designed to address relatively large, open-area buildings with flat ceilings, sprinkler systems, and roof venting, with and without draft curtains. The most elaborate tests involved a series of five-high rack storage commodity burns.

In parallel with the large-scale tests, a program was conducted at NIST to develop a computer model based on the LES methodology, the Industrial Fire Simulator (IFS), that incorporated the physical phenomena needed to describe the experiments. A series of bench-scale experiments was conducted at NIST to develop necessary input data for the model. These experiments generated data describing the burning rate and flame spread behavior of the cartoned plastic commodity, thermal response parameters and spray pattern of the sprinkler, and the effect of the water spray on the commodity selected for the tests.

Simulations were first compared with heptane spray burner tests, where they were shown to be in good quantitative agreement with measured sprinkler activation times and near-ceiling gas temperature rise. The sprinkler activation times were predicted to within 15 percent of the experimental values for the first ring of sprinklers surrounding the fire and 25 percent for the second. The gas temperatures near the ceiling were predicted to within 15 percent. Next, simulations were performed and compared with the unsprinklered calorimetry burns of the cartoned plastic commodity. The heat release rates were predicted to within about 20 percent. Simulations of the five cartoned plastic commodity fire tests were then performed. A snapshot from one of the simulations is shown in **Figure 5**. The goal of these simulations was to be able to differentiate between those experiments that activated a large number of sprinklers and those that did not. This goal has been met. The model was also used to provide valuable insight into what occurred in the experiments and what would have occurred for various changes of test parameters.[12,13]

There are plans to continue the development of the IFS model in the future. Much more work is needed to verify the additional models used to account for the flame spread, the interaction of the spray with fuel surfaces, and the various heat transfer mechanisms. However, the results obtained to date are certainly encouraging. The simulations yield information that is difficult, if not impossible, to obtain any other way. Moreover, it is possible to test the various assumptions and models individually against experiments designed to yield much more precise information than can be obtained from large-scale tests. Thus, the knowledge gained from a limited number of large-scale tests could be systematically extended by coupling this information to the results of computer simulations. While this goal has yet to be realized, it lies in the near future.

The author would like to acknowledge the contributions of many people at NIST, including Dr. Ronald Rehm, Dr. Kevin McGrattan, Dr. William Mell, and William Walton, as well as the guidance of the late Prof. Howard W. Emmons.

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- Designing or recommending materials/equipment such as structural components protection, fire detection equipment, alarm systems, extinguishing devices and systems, and advising on location, handling, installation, and maintenance.
- Consulting with customers to define needs and/or issues and gathering information determine the scope of work.
- Conducting meetings with fire and building officials to discuss upcoming and existing projects and answering any questions that may arise.
- Advising customers on alternate methods or recommending specific solutions to solve problems that may arise.
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Enjoy a competitive salary, medical/dental benefits, profit sharing, 401(k), and company stock purchase plan. (EOE) Send your résumé to: HR Department, TVA Fire & Life Safety, Inc.
2820 Camino del Rio South, Suite 200
San Diego, CA 92108
Fax: 619.296.5656 E-mail: Ndoolittle@tvafiresafety.com

Fire Protection Engineers

Harrington Group, Inc., has 2 immediate openings for Fire Protection Engineers in the Atlanta area: Senior Fire Protection/PLC Engineer and Fire Protection Engineer.

For full details on these job openings, please visit our Web site at www.hgi-fire.com or submit your résumé via e-mail or fax to:
Ms. Patsy Sweeney Psweeney@hgi-fire.com
Fax: 770.564.3509 Phone: 770.564.3505

Harrington Group is a full-service fire protection engineering design and consulting firm. Founded in 1986, Harrington Group has consistently provided a high level of quality and value to clients throughout the United States, Canada, South America, and Germany.

Should you be interested in us? YES! If:

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- You are honest and hard-working.
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- You want to participate in the financial aspects of your company – like owners do.
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Check us out and discover what makes Harrington Group such an excellent career opportunity.

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Fire Protection Engineers

Arup Fire has immediate openings for Fire Protection Engineers in New York. Successful candidates will play a very active role in developing the practice in the USA and will work closely with many of the world's leading architects and building owners developing innovative design solutions for a wide range of building, industrial, and transport projects.

Candidates should possess a Fire Protection Engineering degree, approximately five years of experience, and preferably an FPE – PE. Risk management, industrial fire engineering, and computer modeling skills will be highly regarded.

Similar opportunities available in London, Leeds, Dublin, Hong Kong, and Australia, with opportunities available in Boston, San Francisco, and Los Angeles in the near future.

Arup Fire offers competitive salaries and benefit packages. Please submit résumé and salary history to:
Chris Marrion, PE
Arup Fire
Ove Arup & Partners
155 Avenue of the Americas
New York, NY 10013
Telephone: +1.212.896.3269
Fax: +1.212.229.1986
E-mail: chris.marrion@arup.com

ARUP

EQUAL OPPORTUNITY EMPLOYER

Fire Protection Engineers

National fire protection consulting firm with career growth opportunities has immediate need for entry level and senior level Fire Protection Engineers in their Chicago office. Opportunities also available in San Francisco, San Diego, Los Angeles, Dallas, Las Vegas, Miami, and Washington DC.

Competitive salary/benefits package. EOE/M/F

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Schirmer Engineering Corporation
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Deerfield, IL 60015-4997
Fax: 847.272.2365

SCHIRMER ENGINEERING CORPORATION

Fire Protection Engineers

Founded in 1973, Code Consultants, Inc. (CCI), is a nationally recognized fire protection engineering firm providing professional consulting and design services to developers, owners, architects, and other significant clients throughout the United States. With a staff of 55, CCI is a dynamic, growing firm that has an unmatched reputation for developing innovative fire protection and life safety solutions, code compliance guidance, and cost-effective designs which are equally well received by clients and governing officials. CCI's projects include some of the nation's largest shopping malls, retail stores, stadiums and arenas, hospitals, convention centers, detention/correctional facilities, transportation (air and rail) facilities, warehouses, and theaters for the performing arts, to name a few.

The firm is seeking degreed Fire Protection Engineers and other degreed individuals with a high level of experience applying Model Codes and NFPA standards to service clients and projects throughout the country.

These positions offer a unique income opportunity, including participation in CCI's lucrative performance incentive program. The position requires residency in the St. Louis area.

Code Consultants, Inc.
1804 Borman Circle Drive
St. Louis, MO 63146
314.991.2633

CODE CONSULTANTS, INC.

Fire Protection Engineers

Koffel Associates, Inc., is a fire protection engineering and code consulting firm with offices in Connecticut, Maryland, and Tennessee that provides services internationally. Positions are available at the following levels:

Senior Fire Protection Engineer
Registered Fire Protection Engineer
Fire Protection Engineers (BS or MS in FPE)
Fire Protection Engineering Technician (AutoCAD experience, NICET, or technology degree desirable)

Responsibilities may include:

- Fire protection engineering and life safety surveys
- Design and analysis of fire protection systems including automatic sprinklers, clean agent, fire alarm and detection, water supply, and smoke management systems
- Code consultation with architects, engineers, developers, and owners during design and construction
- Post-fire analysis and investigation
- Computer fire modeling
- Fire risk and hazard assessments
- Codes and standards development

Koffel Associates, Inc., personnel actively participate in the activities of professional engineering organizations and the codes and standards writing organizations. The firm offers a competitive salary and benefits package including conducting its own in-house professional development conference for all employees.

The F.P. Connection

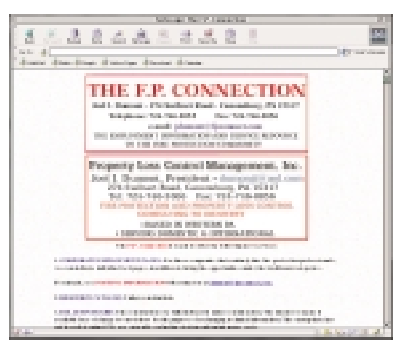
An electronic, full-service fire protection resource Web site.

The FP Connection offers posting of employment opportunities and résumés of fire protection professionals. If, as a fire protection service provider or equipment manufacturer, your Web site is difficult to locate using search engines and key words, let us post your banner and provide a direct link for use by our visitors who may require your services.

Please visit us at www.fpconnect.com or call 724.746.8855.

For posting information, e-mail jdumont@fpconnect.com

Fax: 724.746.8856



Literature Review

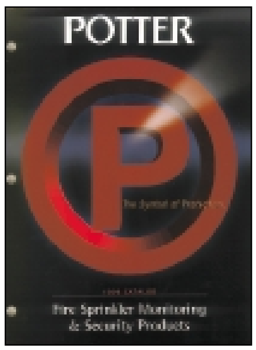
Central's "Combustible Concealed" Space Sprinkler

The new **Central Combustible Concealed CC1*** sprinkler technology allows the use of CPVC pipe to be installed in a combustible concealed space, with the benefit of a superior sprinkler protection for this type of occupancy. Now, based on the unique spray pattern and design characteristics of the CC1* sprinklers, the option to use CPVC in these areas is now available.

—Central Sprinkler

Circle 1 on reader service card

Sprinkler Monitoring



Potter Electric Signal Co., the leader in fire sprinkler monitoring products, offers a wide range of literature for distributors and their customers. The catalog highlights the main product line including datasheet information. The company CD-ROM displays all products with specifications and technical information. Training manuals are also available. *Contact Potter at 800.325.3936 or www.pottersignal.com.*

—Potter Electric Signal Co.

Circle 2 on reader service card

Firecycle III

Firecycle III is the only fire protection system with the ability to turn itself off. Its intelligent design provides fire suppression when you need it and avoids needless water damage to valuable assets when you don't. If you're protecting priceless fine art, artifacts, documents, computer components, or anything else that can be damaged by excessive water, contact us for more information on our UL-listed and FM-approved systems.

—The Viking Corporation

Circle 3 on reader service card

Free CD-ROM

Free CD-ROM about **The RJA Group, Inc.**, consultants in life safety, fire protection, and security. Services include engineering consulting, master plan development, system design, and construction management, as well as technical knowledge transfer programs in audio and video formats, on-site training seminars, and a speakers' bureau.

Call 888.831.4RJA or visit the RJA Web site at www.rjagroup.com.

—The RJA Group, Inc.

Circle 4 on reader service card

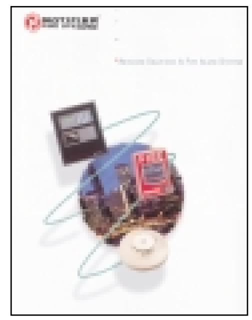
Linear Heat- & Fire-Detection Systems

A new color brochure from **The Protectowire Company** describes how linear heat- and fire-detection systems can warn of fire or overheating conditions in a variety of applications, such as refrigerated warehouses, conveyors, cable trays, transformers, power distribution equipment, cooling towers, pipelines, fuel storage tanks, tunnels and mines, aircraft hangars, historic landmarks, and a wide range of other applications.

— The Protectowire Co., Inc.

Circle 5 on reader service card

Fire Alarm Systems

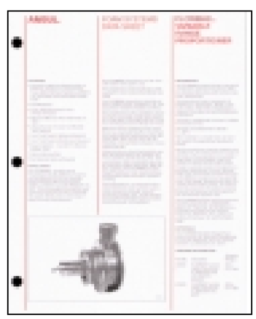


For over 50 years, **NOTIFIER** has taken a leadership position in the fire alarm industry. Today, we are the largest manufacturer of engineered fire alarm systems, with over 400 distributors worldwide and regional support operations on every continent helping to ensure we provide flexibility and options your business needs.

—NOTIFIER Fire Systems

Circle 6 on reader service card

FLOWMAX™ Variable Range

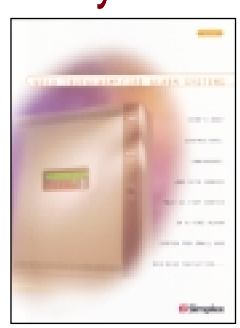


When designing a foam-water sprinkler system, fast response is required even when only one or two heads are flowing. The new FLOWMAX™ Variable Range Proportioner accurately proportions as low as 20 gpm and as high as 2,500 gpm. See **Ansul** for the FLOWMAX™ proportioner and our complete line of foam concentrates and system components.

—Ansul Incorporated

Circle 7 on reader service card

4010 TrueAlarm® Fire Alarm Systems



Simplex offers the 4010 TrueAlarm® Fire Alarm System – a product with the functionality, flexibility, and price that engineers, contractors, and building owners want in an addressable system for small- and mid-sized applications. The 4010 provides ease of installation; reduced cost of maintenance, testing, and service; virtual eliminiation of nuisance alarms; and up to 250 addressable points.

—Simplex

Circle 8 on reader service card

Chemguard, Inc.

As a supplier of foam concentrate solutions and dry chemical compositions, **Chemguard, Inc.,** has established itself as a recognized worldwide leader in the industry and as a reliable partner. Engineered foam concentrate proportioning systems have almost completed our product line of pressure-proportioning tanks and pump-proportioning systems; in-line, balanced-pressure-proportioning systems; mobile units; and high-expansion foam systems.

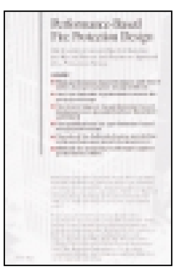
—Chemguard, Inc.
Circle 9 on reader service card

Master Controls Systems

Master Controls Systems, Inc., is the complete fire pump controller company offering NFPA 20, UL-listed, and FM-approved fire pump controllers in all sizes. We offer controllers from 5 to 4000 hp at 200-600 volts and from 20 to 1900 hp at 2300-7200 volts. We also offer diesel fire pump controllers and accessory items. Five-year warranties are standard on our EC-series controllers and paperless pressure and alarm recorders.

—Master Controls Systems, Inc
Circle 10 on reader service card

Performance-Based Design Training



Free brochure on "The Basics of Performance-Based Design," an audio tape program from **Protection Knowledge Concepts, Inc.** (PKC). Focuses on the fundamental performance-based design process and includes a fold-out wall chart. Developed by fire protection engineers at Rolf Jensen & Associates, Inc. Specially priced to SFPE members at $59. *Call 888.831.4RJA or visit the PKC Web site at www.rjagroup.com.*

—Protection Knowledge Concepts, Inc.
Circle 11 on reader service card

Gem Tops The Charts

Gem's new electronic Fire Protection Products CD. From the desktop to the job site, it's one CD you'll never grow tired of playing.

For more information or to order your free copy of Gem's electronic Fire Protection Products CD, contact Gem Sprinkler at 888.610.6101. And be sure to visit our Web site at www.gemsprinkler.com.

—Gem Sprinkler Company
Circle 12 on reader service card

BlazeMaster® Fire Sprinkler System

Now in even more applications, BlazeMaster® 2000™ Fire Sprinkler Systems from **BFGoodrich** offer superior, lasting performance in fire protection, corrosion resistance, low flame spread, and low smoke characteristics. BlazeMaster® CPVC can be used to protect ordinary hazard rooms (not exceeding 400 sq. ft.) in otherwise light hazard occupancies and in sprinklered combustible concealed open wood truss construction when the space is pro tected by a Central Sprinkler model CC1 sprinkler head.

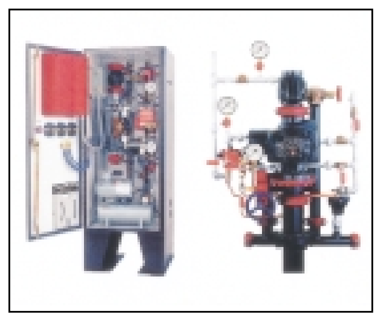
BlazeMaster® pipe and fittings also provide for easier installations with stronger, more durable qualities than metal fire sprinkler systems. And BlazeMaster® CPVC is immune to Microbiologically Influenced Corrosion (MIC).

Contact BlazeMaster® Fire Sprinkler Systems at 888.234.2436 or visit us at www.blazemaster.com.

—BFGoodrich
Circle 13 on reader service card

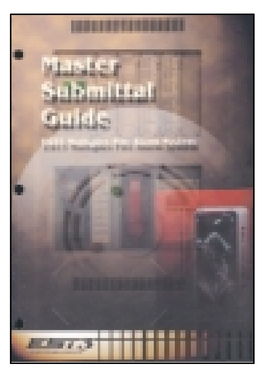
LDX-Lo-Pressure Dry System

LDX-Lo-Pressure Dry System (125 psi water needs a minimum of 15 psi air). It offers opportunities to reduce compressor size requirements and eliminates the need for accelerators. FM-approved, UL, cUL-Listed! Also, Reliable's PrePaK is the simplest pre-action system available with 7 to 10 psi air pressure range for either single/double interlock.
Call 800.431.1588.



—Reliable Automatic Sprinkler
Circle 14 on reader service card

Master Submittal Guide



EST is proud to offer the industry's most complete line of life safety equipment on the market today. Audible and visual devices, multiple element detectors, control panels from 1 zone to the largest network systems round out our offering. Keep costs down and quality up with innovative products from EST.

—Edwards Systems Technology
Circle 15 on reader service card

SFPE Resources

SFPE SEMINARS-

A Continuing Education Opportunity - contact SFPE at education@sfpe.org for more information

SEMINAR	DATE/LOCATION	COST	CEU CREDITS
Smoke Management for Atria and Other Large Spaces Provides design information for smoke management systems for atria, shopping malls, sports arenas and other large spaces including smoke exhaust, natural venting and smoke filling. Illustrates design and analysis techniques including design fires, systems response, example calculations and case studies. Includes information on tenability, commissioning and acceptance testing of systems and examples.	September 15, Dallas, TX October 6, Baltimore, MD	$295	0.6 CEU's
Changes to NFPA 72 and 13 Provides highlights of all the important changes made to these codes along with useful information as to how to incorporate the changes in fire alarm and sprinkler system designs. Topics include new requirements for fire alarm system certification, how to use the performance-based requirements found in the residential chapter of the Fire Alarm Code, expansion of NFPA 13 to include NFPA 24, 231 and 231C requirements as well as the rationale behind the changes.	October 6, Baltimore, MD October 16, Phoenix, AZ	$295	0.8 CEU's
Fire Alarm Systems Design This seminar is intended to help fire protection engineering practitioners from a variety of backgrounds to effectively design fire alarm systems. Advanced fire alarm system design techniques are presented and practitioners are given an opportunity to test those techniques on real world examples. The seminar will address equipment selection, system design, specification writing and development of inspection, maintenance and training programs.	October 2-3, Baltimore, MD	$395	1.6 CEU's
Introduction to Sprinkler Design for Engineers This two-day seminar provides an overview of the elements of sprinkler design that should be undertaken by engineers. Topics include the development of design concepts, hazard classifications, coordination with other professionals, sprinkler system performance criteria, design documentation and specification writing, evaluation of water supply and pump sizing, and professional issues including the impact of the engineer on the bidding process.	April 27-28, Orlando, FL May 24-25, Seattle, WA September 6-7, New York, NY October 4-5, Baltimore, MD November 1-2, Nashville, TN	$395	1.6 CEU's

SFPE Guide to Performance-based Analysis and Design of Buildings Now Available

Performance-based design is the wave of the future. Make sure you're prepared with the field's definitive guide.

This engineering guide, developed by the SFPE Task Group on Performance-based Analysis and Design outlines a process for carrying out these designs, and is essential for anyone who will apply, approve, or be affected by performance-based codes and standards!

Not just engineers, but AHJs, architects, building code officials, fire code developers, building owners, fire officials, legislators and many others will learn from the Guide's detailed review of the entire performance-based analysis and design process. It's both a starting point and a comprehensive reference!

Chapters cover such topics as:

- Defining your project scope and identifying goals
- Specifying stakeholders and design objectives
- Developing performance criteria
- Creating design fire scenarios and trial designs
- Evaluating trial designs
- Documentation and specifications

Equip yourself for the coming era of performance-based codes with this unique guide!

Non-Member Price: $52.00

Contact SFPE at publications@sfpe.org for more information.

BRAIN TEASER

The demand for a fire protection system is 0.0576 m^3/s. For this same system, the design area divided by the density is 1,000,000 $m \times s$. What is the system density and design area?

Solution to last issue's Brain Teaser

A lottery draws six numbered balls (without replacement) from a set numbered 1 to 35. A ticket costs $1.00, and prizes are as follows:

Match any three numbers - $1
Match any four numbers - $50
Match any five numbers - $1000
Match all six numbers - $1,000,000

What is the "value" of a $1.00 ticket? In other words, what return could be expected on the $1.00 investment?

The chance of matching three, four, five and six numbers are as follows:

Three - $20^2 \times (^3/_{35} \times {}^2/_{34} \times {}^1/_{33} \times {}^{29}/_{32} \times {}^{28}/_{31} \times {}^{27}/_{30}) = 0.045$

Four - $15^2 \times (^4/_{35} \times {}^3/_{34} \times {}^2/_{33} \times {}^1/_{32} \times {}^{29}/_{31} \times {}^{28}/_{30}) = 0.0038$

Five - $6^2 \times (^5/_{35} \times {}^4/_{34} \times {}^3/_{33} \times {}^2/_{32} \times {}^1/_{31} \times {}^{29}/_{30}) = 0.00011$

Six - $(^6/_{35} \times {}^5/_{34} \times {}^4/_{33} \times {}^3/_{32} \times {}^2/_{31} \times {}^1/_{30}) = 6.1 \times 10^{-7}$

Therefore, the expected return on a $1.00 ticket is:

$$(0.045 \times \$1) + (0.0038 \times \$50) + (0.00011 \times \$1000) + (6.1 \times 10^{-7} \times \$1000000) = \$0.96$$

Thanks to Jane Lataille, P.E., for providing these brain-teasers.

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.

ADT, Inc.
Arup Fire
Automatic Fire Alarm Association
Bourgeois & Associates, Inc.
Central Sprinkler Corp.
The Code Consortium, Inc.
Code Consultants, Inc.
Copper Development Association
Draka USA
Duke Engineering and Services
Edwards Systems Technology
Factory Mutual Research Corp.
Fike Corporation
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James W. Nolan Company (emeritus)
Joslyn Clark Controls, Inc.
Koffel Associates, Inc.
Marsh Risk Consulting
MountainStar Enterprises
National Electrical Manufacturers Association
National Fire Protection Association
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Poole Fire Protection Engineering, Inc.
The Protectowire Co., Inc.
The Reliable Automatic Sprinkler Co., Inc.
Reliable Fire Equipment Company
Risk Technologies, LLC
Rolf Jensen & Associates
Safeway, Inc.
Schirmer Engineering Corporation
Siemens, Cerberus Division
Simplex Time Recorder Company
S.S. Dannaway Associates, Inc.
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TVA Fire and Lifesafety, Inc.
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Vision Systems, Inc.
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Index of Advertisers

America Burning – Recommissioned

The United States Fire Administration has convened a new "America Burning" panel to examine the fire problem in the United States from the perspective of the fire service and fire prevention community. However, since both the fire service and fire protection engineering are important professional groups that provide protection of the built environment, the recommendations of this panel will likely be important to us.

SFPE has provided comments to this new Commission on two occasions: in live testimony and in written response to a query. Preparing remarks and comments for the new "America Burning" panel caused me to take stock in some of the recent achievements made by SFPE.

America Burning was a landmark document that focused attention on the fire problem in the United States. The document contained 90 recommendations aimed at reducing the fire burden. The *America Burning* report made three recommendations that directly pertain to SFPE:

Recommendation #41 from **America Burning *stated:*** "The Commission urges the Society of Fire Protection Engineers to draft model courses for architects and engineers in the field of fire protection engineering."

The Society of Fire Protection Engineers has an active educational program for our members and allied professionals. The courses cover such topics as performance-based design, smoke management, sprinkler design, and computer fire modeling. Additionally, we are expanding our educational activities as more countries develop performance-based building and fire codes. Recognizing that the widespread acceptance of performance-based codes hinges on the knowledge of performance-based design by Authorities Having Jurisdiction, we plan to target several new courses towards the enforcement community.

To that end, the Society of Fire Protection Engineers has recently entered into agreements with the National Fire Academy (part of the U.S. Fire Administration) and the International Code Council to develop courses on performance-based design for the enforcement community. These courses will provide an overview of the performance-based design process and the science supporting performance-based design.

Recommendation #36 stated: "The Commission urges the National Bureau of Standards (now the National Institute of Standards & Technology) to assess current progress in fire research and define the areas in need of further investigation. Further, the Bureau should recommend a program for translating research results into a systematic body of engineering principles and, ultimately, into guidelines useful to code writers and building designers."

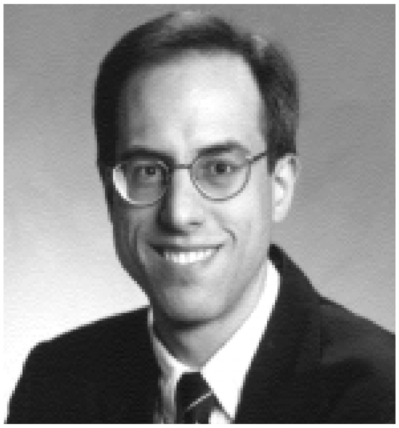
As noted in last issue's column, the Society of Fire Protection Engineers recently hosted a workshop to develop a research agenda for fire protection engineering. The final report identifies research most needed by the fire protection engineering community to improve life safety, reduce fire-related costs, and improve environmental protection.

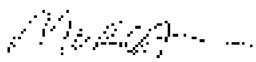
The second half of recommendation #36 forms the mission of SFPE's technical program. We have developed design guides that transfer research into practice in the areas of thermal radiation from pool fires and skin burns from thermal radiation. Design guides are under development in several other areas including human behavior in fire, design basis fires, and room of origin fire hazards. Each of these guides will move a significant body of mature research results into mainstream engineering practice.

Recommendation # 37 stated: "The Commission recommends that the National Bureau of Standards, in cooperation with the National Fire Protection Association and other appropriate organizations, support research to develop guidelines for a systems approach to fire safety in buildings."

The Society of Fire Protection Engineers recently completed *The SFPE Engineering Guide to Fire Protection Analysis and Design of Buildings*. It is the first performance-based design guide published in the United States. Performance-based design is a complete systems approach to fire protection design, which considers the effectiveness of the total building fire protection system in meeting fire protection objectives.

Both *America Burning* and the publication of performance-based codes were seminal events that brought with them opportunities in the fire protection community. While the Society of Fire Protection Engineers will continue to advance the science and practice of fire protection engineering, we will also look to capitalize on opportunities for rapid progress.





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