FIRE PROTECTION
Engineering
SUMMER 2005
Issue No.27

Fire and the Aging Population

ALSO:

- Corrosion Processes Inside Steel Fire Sprinkler Piping
- A Short Review of Fire Safety in Hospitals
- Use of FDS for Large Open Space Protection
- Historical Survey of Multi-Story Building Collapes Due to Fire

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FIRE PROTECTION Engineering

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letters to the editor

Dear Editor,

While interesting, the article titled "Automatic Fire Sprinklers" (Stacy N. Welch, Spring 2005, pp. 13-15) reaches conclusions, in part, bolstered by implausible findings. As the author writes, "...Scottsdale, Arizona, credits sprinklers for saving 52 lives since its sprinkler ordinance was passed in 1985" and footnotes a publication titled *The Case for Residential Sprinklers* written by the National Fire Sprinkler Association as the source. Just because this claim appears in a report does not make it true.

For many years, Arizona has experienced about 35 residential fire deaths per year, and currently has a population of about 5.2 million persons. Over 20 years, that translates into roughly 700 fire deaths. At present, Scottsdale has a population of about 220,000 persons, or roughly four percent of the state population. If Scottsdale were to experience four percent of the fire deaths in Arizona, it would translate into about 1.4 deaths per year, or 28 deaths over a 20-year period.

For sprinklers to have saved 52 lives over the past two decades, there would have to have been about 80 residential fire deaths in the city since 1985 – roughly 11.5 percent of the state total, or three times the state average rate. Moreover, as the ordinance was not passed until 1985, almost half the stock in Scottsdale is not sprinklered. Thus, the 52 lives saved must come exclusively from the roughly 60,000 units in Scottsdale that are sprinklered. For that to happen, the fire death rate in those houses would, absent sprinklers, have to be astronomical, about 6.5 times the state fire death rate.

Making this claim more implausible is that the housing stock in questions is, by definition, less than 20 years old and median household income in Scottsdale is about 42 percent higher than in the rest of the state. And residential house fire deaths are less frequent among wealthier households living in newer houses.

The debate about fire sprinklers is important. Unfortunately, when suspect data is used, it complicates the debate and makes it more difficult for stakeholders to reach appropriate conclusions. Moreover, disagreements about the efficacy of sprinklers are unlikely to be resolved when highly improbable results are accepted without question.

Sincerely,

Elliot F. Eisenberg, Ph.D.
Housing Policy Economist
National Association of Home Builders

Editor's note: Scottsdale Arizona credits its residential sprinkler ordinance with saving 13 lives from 1986-2001 (see *http://www.ruralmetro.com/services/rmf2001activities.pdf*). The National Fire Sprinkler Association has confirmed that the number 52 appears to be a transcription error between the summary of the Scottsdale report and that of an Operation Life Safety report.

Dear Editor,

The paper by NEMA published in the Spring 2005 issue of *Fire Protection Engineering* misses the point of the alerting requirements for fire alarms. There are exceedingly few fire deaths that occur in compressor rooms. The overwhelming majority of fire deaths in the U.S. occur at home, and a disproportionate fraction of these involves individuals that were asleep. Thus, questions of the audibility of fire alarm signals are irrelevant – we need to know whether the alarm will WAKE the person, not simply if an audiologist can determine that the signal is detectable by an awake, alert individual. A number of researchers in the last few years have published very troubling results, indicating the present-day domestic smoke alarm signals may be ineffective towards waking a substantial fraction of children. If NEMA is going to be helpful towards improving the effectiveness of smoke alarms in reducing fire deaths, then they should focus their efforts on where there are problems, not where there are not.

Sincerely yours,

Vytenis Babrauskas, Ph.D.
President, Fire Science and Technology, Inc.

Author's response

As noted in the first paragraph of Part 2, the effects of hearing loss and other factors are addressed in Part 3 (this issue) of the article. The effects of sleep, drugs, alcohol, and, to some extent, age on the ability for sound to arouse and alert are beyond the scope of the article. However, they are real issues that require attention.

As pointed out in the letter, using sound to arouse sleeping children has been shown to have a lower success rate than with persons of other ages. However, the various failure mechanisms are not yet certain or ranked. These include, but may not be limited to, audibility, frequency content, relative audibility of different frequencies, audible signal pattern, and familiarity. For each mechanism, there may be one or more underlying causes. Sleep and the arousal from sleep are complex restorative and defensive mechanisms that have evolved over millions of years. Thus, technological solutions are still being developed and tested. Possible solutions for arousing and alerting sleeping children include voice, lower-frequency content, alternating-frequency content, tactile signaling, visible signaling, and olfactory signaling.

Experts in the fire alarm and fire protection community have long recognized that fire detection and alarm do not necessarily mean fire protection. They are not active protective measures. Instead, action is required on the part of the individual or a caregiver and is only triggered by an alarm. This is particularly important for younger children, infants, and persons with limited mobility.

The use of compressor room noise data is only for example and applies equally as well to the use of alternate frequencies for alerting hearing-impaired or sleeping persons. Analysis of a room air conditioner would be similar. When researchers consider the effects of frequency on audible arousal and alerting of sleeping children, the concepts and methods described in this three-part series must be used to understand the data.

In addition to life safety, fire detection and alarm systems provide substantial property, mission, environmental, and heritage protection. In many of these applications, the use of frequency analysis and audible signal design can result in substantial cost savings, permitting valuable fire prevention and protection resource dollars to be allocated to other, balanced methods.

Robert Schifiliti, P.E.

viewpoint

Changes in the Heathcare Industry

By Joseph G. Sprague
FAIA, FACHA

The past decade has seen a number of hospitals that are merging, that are networking, that are creating systems as a part of a larger delivery process. A lot of consolidation of services is underway, driven by the notion that there is less money being made available for healthcare. Therefore, facilities are attempting to reduce the cost of delivery through efficiency and effective use of staff and technology. Hospitals are trying to increase margins by either reducing cost or increasing revenue in an effort to improve return on investment.

At the same time, more and more patients are experiencing both acute and chronic diseases. The issue related to increased demand for different clinical service lines has produced niche markets in healthcare, for example, cardiovascular, cancer, ortho-neuro, and child and maternity services. Each of the niche markets is producing opportunities for hospitals to expand their network base while focusing on the market that is the most robust.

The other issue is aging demographics. The baby boomers are just entering the retirement stream and have a substantial consumption attitude that perhaps previous generations haven't had – instant gratification. They are consumers of optional healthcare services to ward off aging in areas like orthopedics, sports medicine, cardiovascular rehab, diet, exercise, preventive medicine, and plastic surgery. They are willing to pay for these services over and beyond what third-party payers cover. A system is evolving that has a need for greater capacity of clinical service lines while, at the same time, has the need to reduce cost and be more efficient in the delivery of healthcare.

Fire Protection Engineering is a very important discipline for a building type that is so highly regulated as healthcare. There are numerous jurisdictions that reference and enforce a myriad of codes and standards focusing on safe environments, primarily safety to life. In looking at building designs, all disciplines, including fire protection engineers, need to have some knowledge of how a health facility works – it is a 24/7 operation, is heavily staffed, and houses many occupancies.

Fire protection engineering professionals need to understand the technology that is utilized in health facilities and the reasons behind some of the requirements. Except in the room of fire origin, healthcare institutions are designed with the concept of a protect-in-place theory. Each aspect of the fire protection engineering design needs to support that concept. Hospitals are not an "everybody out of the building" occupancy. Healthcare occupancies are protecting patients who cannot protect themselves and are rendered quite often incapable of self-preservation. The challenge then is to understand these issues and to work in a partnership with the users, the designers, the regulators, and the caregivers to create options to assist the owner in achieving these goals. Flexibility, adaptability, and options available in the design process should be emphasized.

Healthcare is a continuum of care from personal care, intermediate care, skill care, and acute care. The aging population drives each of those continuums. Patients occupying healthcare occupancies are more acutely ill today. Patients are likely older and quite possibly suffer from more than one malady. They may have, for example, a cardiac problem and they may have fallen and broken their hip, so they have both a heart condition as well as an orthopedic surgical condition. It is clear that the building around these patients needs to support safety, and like any other discipline, engineering is important to that support.

People are living longer and require greater health services as they age. When the population shifts from the baby boomers, another demographic characteristic will predominate. The market moving forward will be a strong growth opportunity because of these trends. Substantial opportunities will occur in the healthcare market that suggest that a continual, substantial boom in hospital and healthcare design and construction is just starting.

Joseph G. Sprague is with HKS Architects.


Life. Safety. Technology.
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SFPE President Dannaway Meets with Congressman Curt Weldon

As part of the activities associated with the 17th Annual National Fire and Emergency Services Dinner held in Washington, DC, SFPE President Sam Dannaway had the opportunity to meet with Congressman Curt Weldon of Pennsylvania. During this meeting, Weldon discussed legislation that will be debated this year in Congress aimed at making the U.S. safer from fire.

In addition to discussing the Fire Act Grant and a bill aimed at providing improved communications for first responders, Weldon explained the importance of passing the Fire Sprinkler Act of 2005. "The benefits of the firesprinkler systems have long been known," said Weldon. "Protecting fire-fighters and our communities, as well as saving lives, is one of our goals in Congress. I am convinced this legislation will provide the mechanism to further protect the fire service."

Weldon is known as an outstanding advocate for the fire service. He is the founder of the Congressional Fire and Emergency Services Caucus. This Caucus is now the largest on Capitol Hill, with over 340 members from both the House and Senate.

■ ■ ■

University of Maryland Receives Major Fire Research Grant

The United States Fire Administration has awarded a one-year, $1.1 million grant to the University of Maryland Center for Fire-fighters Safety Research and Development (CFSRD) to investigate the physiological state of firefighters during training evolutions. The goal of this study is to reduce injuries and fatalities in training. The CFSRD is also conducting research on firefighter location and novel communication strategies. The Maryland Fire and Rescue Institute and the Fire Protection Engineering Department of the A. James Clark School of Engineering are jointly managing CFSRD in partnership with the Small Smart Systems Center, the Human Performance Laboratory, and the MIND Lab.

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September Designated as Campus Fire Safety Month

Federal legislation has been introduced in Congress designating September as Campus Fire Safety Month. This legislation was announced at Campus Fire Safety Summit 2005, an unprecedented gathering of members of Congress and fire safety experts from across the nation on Capitol Hill in Washington, DC, to discuss the issue of campus fire safety. The Summit was co-sponsored by Congresswoman Stephanie Tubbs-Jones (D-Ohio) and the nonprofit Center for Campus Fire Safety.

According to Ed Comeau, director of the Center for Campus Fire Safety, fire safety education is not strongly emphasized and the new legislation could play a vital role in reducing the number of both on- and off-campus fires.

For more information, go to *www.campusfire.org*.

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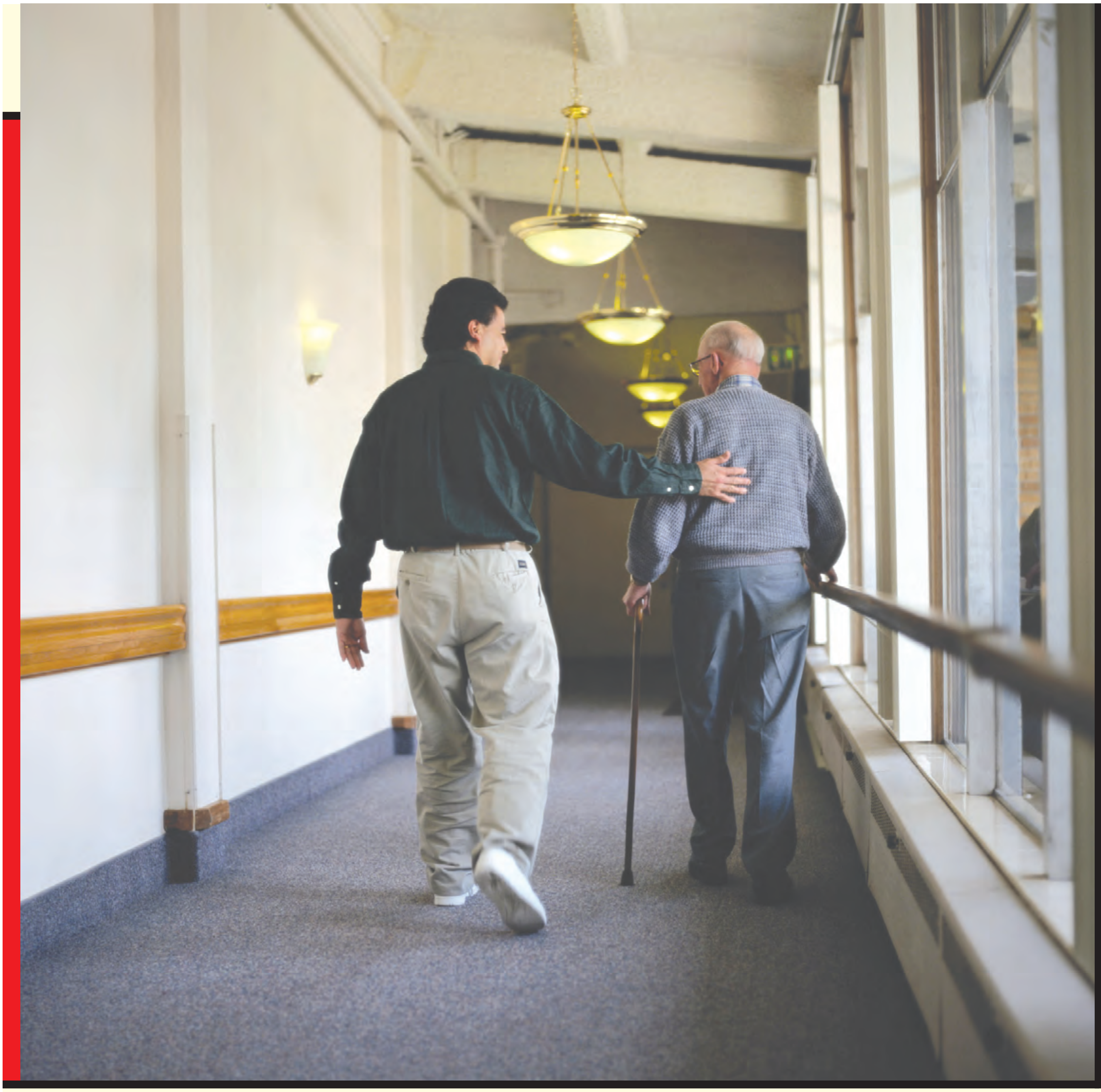
By Marty Ahrens

Fire and the Aging Population

The U.S. population is aging. In 1980, only 11.3 percent of the U.S. resident population was at least 65 years old. By 2000, 12.4 percent had reached that age. The 65 and over age group is projected to increase to 13.0 percent of the population in 2010, and 16.3 percent in 2020.[1] When planning for fire protection, what are the assumptions about the people who are protected and their ability to respond to a fire? Should these assumptions be reevaluated periodically to reflect changes in the population? This article will provide a brief overview of the elevated fire death risk faced by older adults; the functional declines that can accompany aging, making older adults more vulnerable to fire; and the added risk incurred when medical oxygen is used. Fire experience and fire protection statistics are provided for a) nursing homes and residential board and care facilities, and b) healthcare facilities other than nursing homes. Some patient and staff statistics are also discussed. The importance of fire protection and staff training is illustrated by a 1992 nursing home fire in Woburn, Massachusetts.



FIRE DEATH RISKS AMONG OLDER ADULTS

The home fire death rate is higher for older adults than for any other segment of the population, and the rate increases with age. In 1995-1999, the risk of home fire death was 2.2 times as high for those 65 and over as the general population. For those 75 and over, the risk was 3.1 times as high, and for those 85 and over, the risk was 4.5 times as great.[2]

Although the percentage of people 65 and over who smoke is less than half that of people between 18 and 64 years old, 40 percent of the home smoking fire fatalities were at least 65 years of age.[3] Other leading causes of home fire deaths among older adults are heating, cooking, and electrical distribution equipment. Intentionally set fires ranked fifth, but accounted for a much smaller share of the fire deaths for this age group than for those between 18 and 64. Victims of intentional fires and fires started by children playing tend to be younger people.[4]

VULNERABILITIES INCREASE WITH AGE

Normal physiological changes as well as medical conditions that become more common with increasing age result in an older population more likely to have difficulties with hearing, vision, smell, mobility, memory, and decision-making than the general population. Among

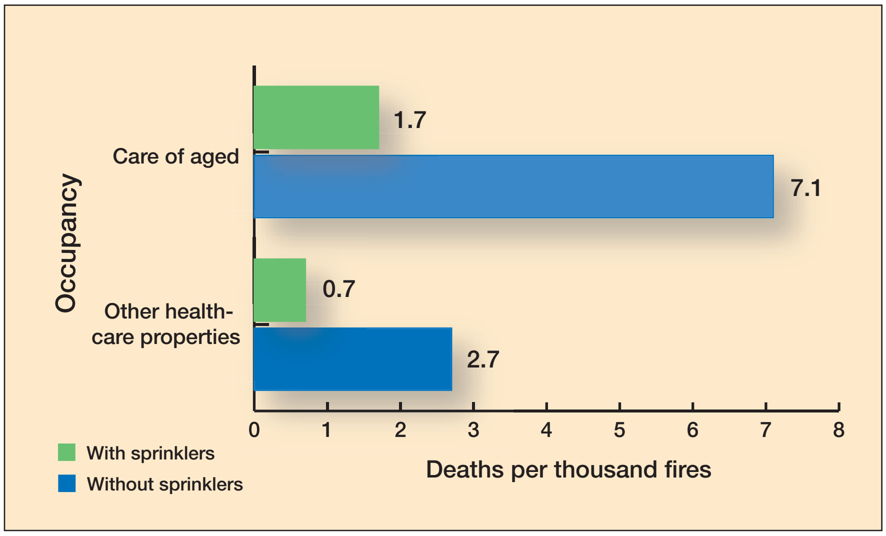


Figure 1. Fire death rates by sprinkler presence: 1989-1998 annual averages.

noninstitutionalized adults, 29.7 percent of those between 65 and 74, and 46.0 percent of those 75 and over report at least a little hearing trouble. Among the 65-74 age group, 14.5 percent report vision trouble, even with corrective lenses, and this increases to 21.1 percent for those at least 75. Mobility also becomes a greater concern with age as 9.4 percent of those 65-74 find it very difficult or impossible to climb up ten steps without resting; the percentage increased to 21.0 percent for those 75 years or older. Among people between 65 and 74, 16.8 percent report that it is very difficult or impossible to stoop, bend, or kneel; the percentage increased to 27.9 percent for those 75 or older.[5] In 2000, 14.2 percent of the noninstitutionalized U.S. residents who were at least 65 years of age had some type of sensory disability, 28.6 percent had a physical disability, and 10.8 percent had a mental disability, including problems with learning, remembering, or concentrating.[6] In 2002, 23.6 percent of those 65-74 lived alone, while 65.1 percent lived with a spouse. For those 75 and older, 39.6 percent lived alone, and 45.1 percent lived with a spouse.[7] Many older adults try to age in place as long as possible.

Dorothy Bruck reviewed the literature on sleep and waking to fire alarms. Among the conclusions of her review are the following:

- 25 percent of those over 60 years may be unlikely to wake to a 55 dBA alarm and 10 percent of those over 70 years may sleep through 75 dBA (due to hearing loss at the higher frequencies in older persons);
- Significant individual differences in arousal thresholds exist; and
- Those under the influence of sleep-inducing medication are unlikely to arouse to 75 dBA (and such medication is in high use among the elderly).[8]

RISKS OF MEDICAL OXYGEN

People with impaired respiratory systems, many of whom are older adults, use medical oxygen at home and in institutions. Products such as furniture, mattresses, and bedding have flammability requirements. Yet these requirements are compromised when medical oxygen is in use. The use of medical oxygen in the home environment is a growing concern for the fire safety community. In a review of fatal fires started by smoking materials reported in 1997 and 1998, NFPA found that 7 percent of the victims were smokers with medical oxygen.[9]

From March 3, 1999, to November 30, 2000, 12 oxygen-therapy fires in Philadelphia caused three deaths and injured seven others. All were caused by smoking materials or the open flame used to light cigarettes.[10] In 2002, medical oxygen was a factor in four Massachusetts fire deaths, all caused by smoking.[11]

The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) identified a number of risk factors for fires occurring when home healthcare patients were using supplemental oxygen. These included living alone, the absence of working smoke alarms, cognitive impairment, a history of smoking while oxygen was in use, and flammable clothing. Recommendations included better staff training, improved communication among providers, involving Ethics Committees in decisions to end services to noncompliant patients, and increasing fire safety with smoke alarms and other practices.[12]

FIRES IN HEALTHCARE OCCUPANCIES

While fire protection engineers are rarely involved in the construction or renovation of people's homes, except for larger apartment or assisted living complexes, fire protection engineering is an important part of most nursing home and hospital design. The vast majority of nursing home patients and a substantial minority of hospital patients are older adults. In these institutional settings, facility staff are responsible for cooking, heating, laundry, and maintenance, as well as overall safety.

Changes in the U.S. Fire Administration's (USFA) National Fire Incident Reporting System (NFIRS) that were first introduced with Version 5.0 in 1999 make many types of trend analysis difficult. Certain occupancy classes have been combined and/or reassigned to different property classes. "Unclassified" and "unknown-type facilities that care for the aged" convert to "nursing homes," as do "facilities with nursing staff that care for the aged." "Facilities that care the aged without nursing staff" convert to "residential board and care." Assisted living facilities are also captured with board and care facilities. Confined cooking and heating fires are more easily documented. The share of cooking fires has grown with the increase of data collected originally in Version 5.0.

FIRES IN NURSING HOMES AND RESIDENTIAL BOARD AND CARE FACILITIES

During the four-year period of 1999-2002, an estimated average of 3,680 structure fires in nursing homes and residential board and care facilities were reported to U.S. fire departments per year. These fires resulted in an annual average of 11 civilian fire deaths, 172 civilian fire injuries, and $12.5 million in direct property damage. Almost half (47%) were caused by cooking equipment or cooking activities, with confined cooking fires accounting for 24 percent of the fires in these properties. Eighteen percent were caused by appliances, tools, or air conditioning, with clothes dryers, the leading appliance, causing 13 percent. Heating equipment caused nine percent of the fires, smoking materials caused seven percent, six percent were caused by electrical distribution equipment, four percent were intentionally set, and yhree percent were caused by open flames, embers, or torches. Half of the fire deaths resulted from fires started by smoking materials.

Not surprisingly, the majority of fires in nursing home or residential board and care fires started in what NFIRS calls "function areas," including 44 percent that started in the kitchen or cooking area, 15 percent that started in laundry rooms, and 12 percent that began in bedrooms or patients' rooms. Five percent originated in equipment areas, and five percent started in structural areas.

FIRES IN HEALTHCARE FACILITIES EXCEPT NURSING HOMES

During the same four-year period, an average of 3,150 structure fires in other healthcare properties were reported per year. These fires caused an annual average of one civilian death, 87 civilian injuries, and $21.3 million in direct property damage. More than one-third (37%) of the fires in these properties were caused by cooking, with confined cooking fires accounting for 14 percent of these fires. Twelve percent were intentionally set. Appliances, tools, or air conditioning were involved in 11 percent of the fires, with dryers, the leading appliance, causing six percent of the incidents. Nine percent of the fires in these facilities were caused by electrical distribution equipment; seven percent were started by smoking materials; other equipment was involved in seven percent; open flames, embers, or torches started another seven percent; and heating equipment was involved in six percent of the ignitions.

Sixty percent of the fires in healthcare properties excluding nursing homes originated in function areas, with one-third starting in the kitchen area, nine percent beginning in bedrooms or patients' rooms, seven percent starting in laundry rooms, and five percent beginning in lavatories, locker rooms, or check rooms. Eight percent began in structural areas, another eight percent began in equipment areas, six percent started in technical processing areas, five percent started in storage areas, four percent began in egress areas, four percent began in assembly or sales areas, and three percent began in service areas.

FIRE DETECTION AND SUPPRESSION

Smoke detection and sprinklers are more common in healthcare properties than in most other occupancies. In 1999-2001, 90-92 percent of healthcare facilities except nursing homes had smoke detection equipment; 93-94 percent of nursing homes and residential board and care facilities were similarly equipped. During that same period, this detection equipment, when present, operated in 89 percent of the reported fires in healthcare properties except nursing homes, and in 89-93 percent of the nursing home and residential board and care fires.[13] In recent years, sprinklers were present in roughly three-quarters of the fires reported in facilities that care for the aged and residential board and care facilities. They were also present in seven out of ten fires in other healthcare facilities. Figure 1 shows that the death rate per 1,000 fires in these occupancies is roughly 75 percent lower when sprinklers are present.[14]

STAFF AND PATIENTS

The nursing home population has been rising, and with the increasing age of the population, it can be expected to grow substantially in coming years. Staffing patterns in nursing homes have also been changing based on the type and location of the facility. In 1995, the 54 percent of nursing homes that were part of chains had an average of 51.5 nursing employees (including registered nurses, licensed practical nurses, aides, and orderlies) per 100 beds, while independent homes had 52.1. By 1999, the chain homes (60%) had 42.8 nursing staff per 100 beds, but independent homes (40%) had 69.5. Nursing homes in metropolitan and nonmetropolitan areas showed a similar divergence with facilities in metropolitan statistical areas going from 52.0 nursing employees per 100 beds in 1995 to 59.5 in 1999, while facilities in nonmetropolitan nursing homes dropped from 51.1 in 1995 to 38.8 in 1999. Staff play a role in any emergency situation in an institutional setting. Are there enough staff to close doors, move patients, etc., in the event of a fire? If staff ratios decline, should fire protection requirements increase? In 1999, 14.6 percent of all nursing home residents used transfer equipment, 61.7 percent used wheelchairs, and 24.4 percent used walkers; 29.0 percent received help in transferring, 32.5 percent received help in walking, and medical oxygen was used by 6.4 percent of the residents. In 1995, only 24.2 percent of the patients received help with transferring, and 29.8 percent received help with walking.[15, 16]

Other aspects of healthcare are also changing. In 1970, the average length of stay in U.S. short-stay hospitals was 7.8 days for all ages, and 12.6 for people 65 and older. Average duration of stay in 2002 was reduced 37 percent to 4.9 days for the total population and reduced 55 percent to 5.8 days for the 65 and over group. In 1970, 20 percent of the discharges and 33 percent of the days of care involved people 65 and over, while in 2002, this age group accounted for 38 percent of the discharges and 45 percent of the days of care. From 1970 to 2001, the number of discharges for the general population increased 12 percent, while discharges for those over 65 increased 112 percent.[17, 18]

What does this have to do with fire protection? The patient population is older. With shorter stays, larger shares of patients are likely to be sicker or in earlier stages of recovery and may, therefore, require more assistance. Nursing staff may have less experience with that particular patient. These factors could increase the time required in any evacuation.

IMPORTANCE OF FIRE PROTECTION AND STAFF TRAINING SEEN IN SERIOUS FIRE

Statistics show the common scenarios. For vulnerable populations in institutional occupancies, it is also important to provide sufficient protection for even unlikely events. A 1992 fire in a 101-bed Woburn, Massachusetts, nursing home shows the wisdom of full fire protection and staff training. A two-story, wood-framed dwelling, originally built in 1905, had been converted to nursing home use. Five additions of lightweight construction had been built around the old core. Fire doors separated the wings which contained rooms. The building was protected by sprinklers and a monitored detection system. The latest renovation (in 1992) was made in close cooperation with the fire department. This cooperation led to several improvements, including a new water main, new hydrants, and a new access road. The facility also had an extensive staff training program in fire safety. On October 30, 1992, a plumber turned on the natural gas, unaware that a one-inch orifice was still open. Investigators estimated that 300-500 cubic feet of natural gas leaked and spread through the building and into concealed spaces within 15 to 20 minutes. After an explosion, staff immediately closed the doors to residents' rooms and started evacuating residents. Heavy smoke and flames from the roof were seen by the first responding apparatus. The fire was controlled by 21 operating sprinklers, barriers blocked its spread, and firefighters extinguished the fire in the concealed spaces. Because the generator was gas-fueled and had been shut off when the gas was shut off, emergency power was unavailable. All 101 residents were evacuated within 15 to 20 minutes. Twenty-three people were injured, with the plumber sustaining the most severe injuries.[19]

The above scenario is not one that would normally be expected in a nursing home. It could easily have turned into a true disaster. It also serves as reminder that properties will be renovated, spaces modified, and new functions added. Facility staff, building features, and the fire department are all part of the fire protection equation. Any changes in these areas should cause the entire equation to be recalculated. ▲

Marty Ahrens is with the National Fire Protection Association.

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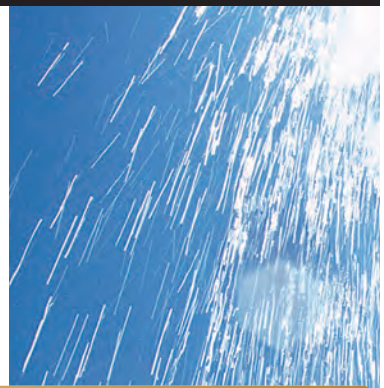

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Corrosion Processes Inside Steel Fire Sprinkler Piping

By Bruce W. Christ, Ph.D.

Sprinkler contractors, facilities managers, and their technical advisors sometimes have to deal with corrosion inside pressurized, water-based, metal fire sprinkler piping systems. Examples of such corrosion are discussed and illustrated in an article published by Clarke in the Winter 2001 issue of *Fire Protection Engineering*.[1] Clarke observed that corrosion causes pinhole leaks as well as insoluble corrosion residue buildup ("obstructive growth") that increases pipe friction losses. Corrosion deterioration was attributed to microorganisms in water, i.e., to microbiologically influenced corrosion (MIC).

Clarke referred to an earlier nationwide (U.S.) survey of pinhole leaks in metal fire sprinkler piping reported by Bsharat in 1998.[2] Bsharat also attributed pinholes and obstructive growth to MIC. Among measures that Bsharat and Clarke described to overcome MIC is chemical treatment of water in fire sprinkler piping with disinfectants (biocides) such as "chlorine, iodine, hydrogen peroxide, and ozone"[2] and "ammonium compounds, organo-sulfur compounds, bromines, carbamates, isothiothiazalone,..."[1] These chemicals destroy bacteria and their habitats, i.e., biofilms. Both Bsharat and Clarke also suggested cleansing obstructive growth inside piping via flushing and rinsing with chemically treated water. Clarke noted that the most critical step in MIC mitigation is selection of a qualified corrosion control consultant.

As Clarke pointed out, the National Fire Codes address MIC with a statement requiring that water supplies be tested and treated if the water is known to have contributed to MIC in fire sprinkler piping.[3]

This article is based on a review of the engineering and scientific literature pertaining to biological and nonbiological metal corrosion processes. The objective of the review was to establish a fundamental understanding of the corrosion of fire sprinkler piping in such facilities as office buildings, hotels, warehouses, shopping centers, and public buildings.

Findings of this review indicate that several metal corrosion processes besides MIC can occur inside pressurized, water-based, metal fire sprinkler piping. For example, Notarianni and Jackson in 1994[4] pointed out that oxygen alone causes harmful corrosion that results in pits and sedimentation. Speller in 1951[5] compared corrosion in hot-water heating systems and automatic fire extinguisher systems due to dissolved gases such as oxygen. The scientific literature of electrochemistry is rich with examples of corrosion processes other than MIC that can deteriorate metals. For example, "oxygen corrosion" is a nonbiological process that can corrode certain metals. Moreover, "acid-oxygen corrosion" is a nonbiological process that can corrode certain metals even faster than oxygen corrosion. This article discusses these and other nonbiological corrosion processes that are spontaneous under the conditions of temperature and pressure that prevail in pressurized, water-based, metal fire sprinkler piping systems.

Nonbiological corrosion processes always generate dissolved metal as the initial corrosion product. Ongoing localized dissolving eventually produces pits and sometimes pinhole leaks. Moreover, dissolved metal (i.e., metal ions) can react speedily with certain chemical species that are dissolved in most waters to produce insoluble corrosion residues such as oxides, hydroxides, and carbonates. These residues produce obstructive growth that adheres to the interior pipe wall and increases pipe friction losses. The increase is especially significant in small-diameter pipe.

As regards MIC, review of the literature of microbiology did not identify any microorganisms that can attack directly an elemental metal or an alloy and cause it to dissolve, i.e., to release metal ions into the water. This point is relevant to corrosion control strategies. For example, the literature indicates that metal ions from some of the nonbiological corrosion processes can serve as nutrients for certain microorganisms. Consequently, microorganisms such as bacteria must compete for metal ions with various chemical species in water that produce insoluble corrosion residues. Because it is not established that microorganisms dominate this competition, MIC is not an assured sole explanation of corrosion deterioration of pressurized, water-based, metal fire sprinkler piping. In fact, physical evidence is needed to make MIC even a partial explanation of such corrosion deterioration. For example, persuasive evidence would be a finding of bacteria that use dissolved pipe metal (metal ions) for nutrients embedded in insoluble corrosion residues and inside pinholes. Scanning electron microscope inspection at magnifications of 10,000 to 20,000 times is a reasonable approach to search for such evidence.

In summary, this article presents many findings of a literature survey about nonbiological and biological corrosion processes that can deteriorate pressurized, water-filled, low-carbon

Figure 1. Rust on low-carbon steel pipe.

steel pipe that is used for fire sprinkler piping.[3] Such pipe is composed of about 98 percent iron. The twofold purpose of this article is to describe several iron-water corrosion processes that can contribute to producing pinhole leaks and obstructive growth in low-carbon steel piping systems, and to suggest several corrosion-control measures.

CORROSION PROCESSES

Corrosion processes involve paired, mutually dependent electrochemical reactions between metal and certain reactive chemical species dissolved in ordinary fresh water.[6, 7, 8, 9] Reactions occur at the metal-water interface and tend to speed up with increasing temperature. Concentrations of individual corrosive chemical species in fresh water charged into fire sprinkler piping systems from public water supplies usually range from 1 to 200 milligrams per liter. For example, the solubility of oxygen in water is about 8 milligrams per liter at 60°F and atmospheric pressure.[10] Spontaneous electric charge transfer occurs at the atomic scale of dimensions during corrosion reactions, e.g., dissolved oxygen receives electrons from iron metal during the process of oxygen corrosion of low-carbon steel pipe.[2] External electrical factors are not likely to play a role in corrosion processes if the piping system is electrically grounded.

Corrosion reactions dissolve ("leach") metal. Following electron transfer, metal particles with positive electrical charge ("ions") are expelled into the water. Wasting of metal one particle at a time produces pits, craters, and sometimes penetrations during time spans ranging from months to years. Corrosion processes tend to localize in crevices and underneath aggregations of insoluble substances.[11] Insoluble substances that might be found inside steel fire sprinkler piping systems include scale from hard water of high carbonate or bicarbonate alkalinity, sediments, chips and filings from drilling and sawing during fabrication, and corrosion residues. Several corrosion processes that can occur inside water-based, metal fire sprinkler piping are described below. Each process can proceed independently of any other, provided the necessary chemical ingredients are available and that physical conditions are suitable. Each corrosion process is described in more detail elsewhere.[12]

1. Oxygen corrosion is due to oxygen dissolved in water reacting with metals.[11] Discussions of oxygen corrosion often use rusting of iron by dissolved oxygen as an example of one of many possible metal-water corrosion processes.[2, 13] Figure 1 illustrates orange-brown rust ("hydrated ferric iron oxide") that forms spontaneously on low-carbon steel pipe and cast-iron fittings exposed to outdoor conditions. Oxygen dissolved in atmospheric moisture fuels such rusting. The electrochemical reactions causing rust formation also can occur inside pressurized, water-based, low-carbon steel fire sprinkler piping if the water contains dissolved oxygen.

2. Acid corrosion is caused by hydrogen ions from dissolved acids reacting with metals.[11] Ordinary fresh water usually is considered acidic when the chemical characteristic, "pH," is below the neutral pH value of 7. However, water chemists consider waters to be acidic

only when pH drops below the "M alkalinity endpoint" of 4.4.[14] This apparent contradiction in the definition of acidic water is due to alkalinity that arises from hydrolysis associated with dissolved bicarbonates and several other chemical species.[15] The pH of most public water supplies charged into fire sprinkler piping systems ranges between 7.3 and 8.4,[14] so it is not likely that acidified water is charged into a piping system. However, concentrations of acidified water can arise spontaneously in certain localities inside a closed piping system via hydrolysis of hydrated metal ions.[11, 16, 17, 18] Localities that favor spontaneous acidification include crevices and regions underneath aggregations of insoluble substances.[11] Trace concentrations of chloride ions and sulfate ions play a role in hydrolysis.[11, 12] Acidified water also can be generated by the metabolism of acid-producing bacteria or sulfate-reducing bacteria living in biofilms that might be growing inside a piping system.[11, 19]

3. Acid-oxygen corrosion occurs in oxygenated acid solutions and is due to an electrochemical reaction in which hydrogen ions and dissolved oxygen team up to waste metal.[20] Acid-oxygen corrosion in iron-water systems usually is a speedier process than either oxygen corrosion or acid corrosion acting alone.

4. Hypochlorite corrosion occurs when certain chlorine-based disinfectants found in most public water supplies react with metal.[14] Concentration of disinfectants usually ranges from 1 to 4 milligrams per liter of "free available chlorine." Chlorine and hypochlorite disinfectants hydrolyze water to produce biocidal hypochlorous acid molecules in acidified water and hypochlorite ions otherwise. Both of these chemical species can corrode low-carbon steel and most other structural metals.

5. Microbiologically Influenced Corrosion (MIC) is another segment of the corrosion world and is traceable to certain microorganisms.[11, 14] For example, bacteria are a category of single-cell microorganisms that frequently participate in biologically mediated corrosion. They live in aggregations of wet, viscous, gelatinous substances called biofilms. Several bacterial species and many millions of these miniscule creatures might thrive communally in a biofilm[19] where chemical and physical conditions are favorable. Biofilms trap organic matter and certain dissolved chemical species that serve as nutrients for bacteria.[11, 15] The metabolic processes of certain bacteria produce waste products such as organic acids that are the source of hydrogen ions that can cause acid corrosion of most metals.[11] Interestingly, bacterial metabolism is understood in terms of electrochemical reactions, as are the foregoing metal-water corrosion processes.[21]

PINHOLE LEAKS

Pinhole leaks usually spray with no forewarning and cause water damage to the surroundings. Figure 2 illustrates a

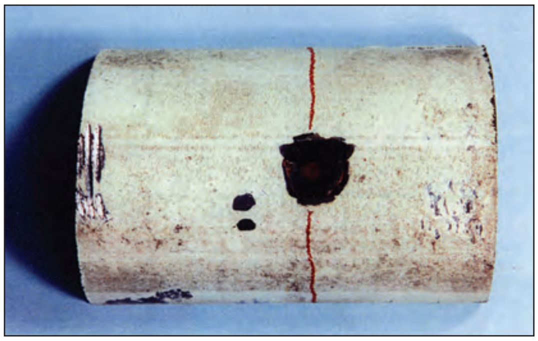

Figure 2. Pinhole leak that sprayed.

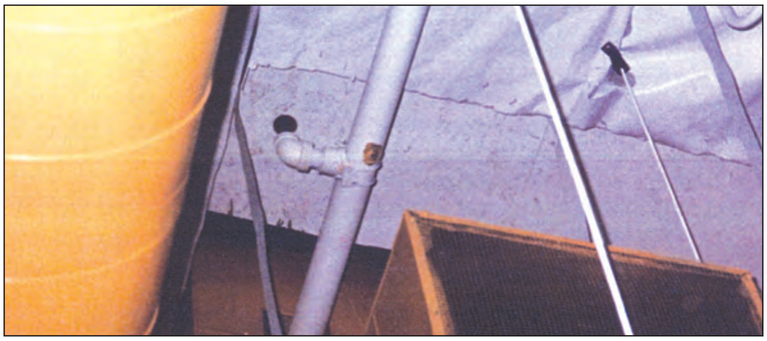

Figure 3. Pinhole leak on verge of spraying.

pinhole leak that sprayed, whereas Figure 3 shows a seeping pinhole leak on the verge of spraying. Remedy usually involves immediately sealing pinhole leaks with temporary encirclement sleeves and replacing degraded sections of piping.

Pinhole leaks are caused by one or more ongoing electrochemical corrosion processes that usually are localized in crevices or underneath aggregations of insoluble substances.[11] A spraying pinhole leak might take several months or several years to develop, depending on pipe wall thickness, ambient temperature, and availability of chemical ingredients for corrosion reactions. Reactions are focused so precisely that the process could be called *chemical drilling*.

Outbreaks of several pinhole leaks nearby one another in an older or a thin-wall piping system sometimes occur when fresh supplies of water are introduced frequently into a completely drained piping system, e.g., during construction to expand or rehabilitate a piping system that has been in service for several years. Introduction of water replenishes the reactive chemical ingredients that dissolve ("leach") metal from the interior pipe wall. Air that is not vented during charging can become trapped and compressed at high elevations. The increased solubility of oxygen in water at typical gage pressures of 50 to 160 pounds per square inch (340 to

1,100 kPa) in a fire sprinkler piping system provides ample dissolved oxygen to fuel oxygen corrosion in such localities. Oxygen corrosion is a likely contributor to the formation of pinhole leaks.

INSOLUBLE CORROSION RESIDUES

Ongoing corrosion reactions cause buildup of insoluble corrosion residues on the interior pipe wall over months and years, gradually increasing pipe friction losses. Residues form when metal ions react spontaneously with certain other dissolved chemical species,

Figure 4. Insoluble corrosion residues.

including oxygen. Figure 4 illustrates dried-out residues in a steel pipe section long after removal from a fire sprinkler piping system. These residues are probably iron compounds, e.g., oxides, hydroxides, and carbonates.[17, 22] Regions where residues have built up on the interior pipe wall can be located, and wall thickness can be measured, by applying non-destructive techniques such as ultrasound to the exterior pipe surface.[23] Residue thickness also can be measured using ultrasound.[24] Residues can be flushed from a piping system using weakly acidified solutions that disrupt and carry away most insoluble aggregations that build up on the interior pipe wall. Cleansing with solutions that neutralize acidity follows such flushing.[25] More detail about the causes of buildup and clearing away of insoluble aggregations appears elsewhere.[12]

The Friction Loss Formula[3] for fire sprinkler piping indicates that frictional resistance increases exponentially with a linear decrease in actual internal diameter. Consequently, the gradual buildup of obstructive growth due to insoluble corrosion residues such as those shown in Figure 4 can increase pipe friction losses. Dramatic increases can occur in small-diameter pipe because pipe friction losses vary inversely with diameter (d), i.e., with $d^{4.87}$. For example, analysis using the Friction Loss Formula shows that pipe friction doubles if internal diameter decreases from 2.00 to 1.75 inches (50 to 44 mm); friction quadruples if internal diameter decreases from 1.00 to 0.75 inches (25 to 19 mm). Although the Friction Loss Formula does not apply accurately to a nonuniform buildup of obstructive growth like that in Figure 4, it is clear that gradual buildup increases pipe friction losses to a value greater than that calculated by designers from the actual internal diameter of uncorroded pipe.

The Friction Loss Formula[3] also indicates that pipe friction losses depend on the surface texture of the interior pipe wall, which is represented quantitatively by the friction loss coefficient, C. Pipe friction losses are proportional to $1/C^{1.85}$. "C" becomes smaller as the surface texture roughens. Consequently, pipe friction losses can increase significantly as obstructive growth due to insoluble corrosion residues gradually build up and roughen the interior pipe wall.

Figure 5 shows wet, black, sulfurous-smelling residues found inside a freshly removed steel pipe section. These residues probably contain the insoluble black oxide of iron, magnetite, which forms when dissolved oxygen is scarce.[15] The sulfurous odor suggests that these residues probably also contain sulfide

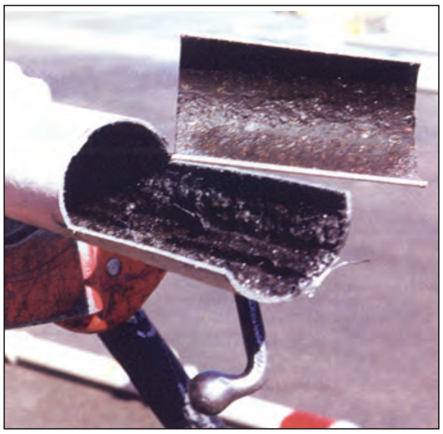

Figure 5. Sulfurous residues.

ions (low pH) or bisulfide ions (high pH). These ions form when sulfate ions present in the water are used by sulfate-reducing bacteria as terminal electron acceptors.[15, 26] The residues in Figure 5 probably contain some insoluble black ferrous iron sulfides that are produced by the reaction between dissolved iron and sulfide ions.

CORROSION-CONTROL MEASURES

The following measures can minimize iron-water corrosion inside pressurized, water-based, low-carbon steel fire sprinkler piping. These measures are discussed more fully elsewhere.[12]

1. Reducing the frequency of filling a piping system and venting trapped air tend to minimize oxygen corrosion.

2. Inspecting a piping system externally using nondestructive evaluation techniques such as ultrasound can locate regions where insoluble substances have built up on the interior pipe wall and also regions where corrosion has reduced pipe wall thickness to unacceptable values.

3. Flushing a piping system with a solution that disrupts and carries away insoluble aggregations and biofilms that build up on the interior pipe wall minimizes underdeposit corrosion that causes pits, craters, and sometimes penetrations. Shaking out chips and filings from drilling and sawing during fabrication also minimizes underdeposit corrosion.

4. Maintaining pH in the range 8.3 to 8.5 so that water cannot become acidified via hydrolysis of hydrated metal ions minimizes acid corrosion.

5. Chemically treating water to minimize chloride and sulfate concentrations minimizes acidification via hydrolysis of hydrated metal ions. Minimizing sulfate concentration also minimizes acidification due to metabolism of sulfate-reducing bacteria.

6. Minimizing organic matter in input water and lubricants on interior pipe surfaces reduces the metabolic activity of bacteria that produce acids upon using organic matter for nutrients, e.g.,

acid-producing bacteria such as *Clostridia* and *Thiobacillus*, as well as sulfate-reducing bacteria.

7. Providing continuous, adherent, nonporous coatings on a metal surface can block electrochemical reactions between corrosive chemical species dissolved in water and metal.

8. Providing a *corrosion allowance*, i.e., more metal thickness than is needed to support structural loads, increases the service time before corrosion causes undesirable consequences.

9. Keeping an operations log provides a database that can help sprinkler contractors, facilities managers, and their technical advisors evaluate corrosion durability and reliability of fire sprinkler piping systems. A log might record renovations and rehabilitations, changes in water chemistry, results of nondestructive inspections, and general maintenance procedures.

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Bruce Christ is with Converse Consultants.

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A Short Review of Fire Safety in Hospitals

By Chip Carson, P.E.

Existing code requirements that apply to hospitals and other healthcare occupancies have evolved over the last century. This article reviews some of the major events that have occurred and that have shaped code requirements applicable to these types of facilities.

The Triangle Shirtwaist fire in 1911 in New York City is one of several fires that have impacted the current level of fire safety in buildings. This fire involved the top three floors of an eight-story building that were used for the manufacturing of women's clothing. 146 people died; 62 of those deaths were due to trapped occupants who jumped from the upper floors. This fire resulted in considerable activity in the development of codes for better egress in buildings, including the development of today's *Life Safety Code*®.[1]

In 1913, a Committee on Safety to Life was appointed by the National Fire Protection Association. The work of this committee is the origin of the *Life Safety Code*®, which was first published in 1927 as the *Building Exits Code*. Prior to 1927, several pamphlets were published addressing exiting issues in specific occupancies, including factories and schools.

The Cocoanut Grove Night Club fire in Boston in 1942 resulted in 492 deaths and again focused attention on the importance of adequate egress in buildings.[2] The development of codes and standards and the improvement of requirements for fire safety have traditionally followed major fires that resulted in the loss of multiple lives or large property loss. In other words, codes have traditionally been reactive instead of proactive.

1948 BUILDING EXITS CODE

The 1948 edition of the *Building Exits Code*[3] had requirements for hospitals, but they were not very extensive. They did include a reference to a total concept, although it was not referred to as a "total concept" as it is in today's *Code*. It stated that safety to life required proper construction, adequate exits, careful housekeeping, protection of fire hazards, and competent trained personnel. The *Code* limited the height of a building to not greater than eight stories, as this was considered the maximum reach of the fire department ladders. Buildings three or more stories had to be of fire-resistive construction and were required to have sprinkler protection if over five stories. A manual fire alarm system and occupant-use hose (Class II Standpipe System) were required. The requirements for interior finish materials were minimal, mostly addressing interior finish in combustible construction. The Steiner Tunnel Test, now known as NFPA 255 (ASTM E-84), classifies interior finish based on its flame spread rating. It was developed by Al Steiner at Underwriters Laboratories Inc. in the 1940s and was adopted by the American Society for Testing and Materials (ASTM) as a tentative standard in 1950.[4] Prior to the development and adoption of this test, there was not a convenient quantifiable method to limit interior finish combustibility.

The requirement for occupant-use hose has changed significantly over the years. The *Life Safety Code*® (2003 edition)[5] only requires standpipes with occupant-use hose in two locations: on either side of regular stages over 1,000 ft.^{2} (93 m^2) in size and all legitimate stages, and in nonsprinklered detention and correctional occupancies over two stories in height. Evacuation of the occupants is the primary concern in today's *Code*, and occupants are no longer expected to fight fires with occupant-use hose lines.

The 1948 *Building Exits Code* did not require smoke barriers in hospitals, and there was no requirement for fire or smoke resistance of the corridor wall construction. There was also no requirement for windows in patient rooms. Travel distance was limited to 100 feet (30 meters) in buildings not protected with sprinklers and 150 feet (45 meters) in buildings with sprinkler protection.

A fire in the 125-bed Saint Andrews hospital in Effingham, Massachusetts, on April 4, 1949, resulted in 74 deaths, including 11 babies in the nursery. The hospital had oilcloth-covered walls, a combustible trash chute, and open stairs.[X] This tragic fire focused attention on fire safety in hospitals.

1958 BUILDING EXITS CODE

By the 1958 edition of the *Building Exits Code* there had been several changes to the requirements for hospitals. The construction requirements were made more restrictive by requiring all buildings to be of fire-resistive construction except one-story buildings of not more than 5,000 ft.^{2} (1500 m^2). Interior finish in corridors, exits, and rooms for mental patients were required to be Class A (flame spread index of 25 or less when tested in accordance with the NFPA 255/ASTM E-84 test). Interior finish in rooms with not more than four patients could be Class B (flame spread index or 75 or less).[6]

Requirements for separating hazardous areas were also included in the 1958 edition. Boiler rooms; basements or attics used for storage; workrooms such as carpentry, paint, and upholstery shops; and central storerooms were to be safeguarded to minimize the hazard to occupants. The appropriate degree of safeguarding was left to the Authority Having Jurisdiction, including separation, sprinklers, or both if the hazard was considered severe. Permitted travel distance was left at 100 feet (30 meters) in buildings without sprinklers and 150 feet (46 meters) in buildings with sprinkler protection.

A fire in the Hartford Hospital on December 8, 1961, resulted in the death of 16 persons, including 7 patients, 5 visitors, and 4 employees. The building had combustible ceiling tile, which materially contributed to the rapid fire spread. There were also combustible concealed spaces above the ceiling. Combustible trash chutes were a contributing factor in the rapid vertical transmission of the fire in the building. The fire reached the 14th floor but fire department ladders could only reach the 8th floor.[Y] The limitations on flame spread introduced in the 1958 code would prohibit the use of low-density cellulose ceiling tile that was a significant factor in the rapid spread of the fire in the Hartford hospital.

CODE REORGANIZATION

In 1963, the Safety to Life committee was reorganized and reduced in size. Subcommittees were established for specific sections of the code. The 1963 edition[7] included several significant additional requirements for hospitals. The "total concept" was expanded to include proper construction, adequate exits, careful housekeeping, and trained staff. This concept was further expanded in subsequent editions.

Provisions for treating combustible draperies, cubicle curtains, and decorative curtains were added. Beds were required to have wheels, although later editions removed this provision. The requirement for wheels on beds was removed because beds had become so large that, with side rails attached, they would often not fit through the patient room doors. Also, the newer beds had considerable electrical equipment and monitoring equipment attached, making movement out of the room difficult. Evacuation would be accomplished by gurneys, wheelchairs, or blanket drags.

Requirements for automatic sprinklers were added based on construction, and the main control valve for the sprinkler system was required to be supervised. The smoke barriers provisions were strengthened, including requiring one-hour fire resistance. This edition did allow the doors in smoke barriers to be held open by fusible links. In the 1967 edition,[8] this provision was changed to allow the doors to be held open if closed automatically by activation of the building sprinklers, automatic fire detection system, or smoke detectors located at the door. Doors to stairs and hazardous areas were not allowed to be held open. Later editions did allow stair doors to be held open by magnetic hold-open devices that would cause the doors to close automatically by activation of smoke detectors located at the doors. This provision also required that if one door in a stair closed, all of the doors in that stair must close. Doors to boiler rooms are still not permitted to be held open.

The 1963 edition[7] also contained significant requirements for the construction of corridor walls. Patient rooms were required to be separated from the corridors by one-hour fire-resistive rated walls, although no separation was required if the hospital was protected with automatic sprinklers. Doors were required to be substantial, such as 1-3/4" (45 mm) thick solid bonded wood core doors, and, where possible, the doors were to latch. The latch requirement was later strengthened following a fire in a nursing home in Norfolk, Virginia, in 1989. In this fire, the nursing staff closed the patient room doors, but many of the doors "bounced" back open, since the latches were roller-type and not positive-latching. The *Code* now requires positive-type latches on corridor doors.[Z]

The protection of hazardous areas was also improved in the 1963 edition. A list of hazardous areas was added, and the walls separating those areas were required to have one-hour fire resistance. In addition, sprinklers were required in all the hazardous areas listed. The list included boiler rooms, laundries, kitchens, repair shops, handicraft shops, laboratories, employee locker rooms, soiled linen rooms, rooms for storage deemed hazardous by Authority Having Jurisdiction, trash collection rooms, and gift shops. Sprinklers were not required in all hazardous areas, and special requirements were included for gift shops and laboratories.

A requirement for separation between new additions and existing buildings was also added. The 1963 code required a two-hour separation unless the entire building was in accordance with the requirements for new construction. This two-hour separation was later changed to require the separation only between new additions and existing portions not conforming to the requirements for existing buildings.

THE LIFE SAFETY CODE

The 1966 edition was a complete revision of the 1963 *Building Exits Code*. The code title was changed from the *Building Exits Code* to the *Code for Life Safety from Fire in Buildings and Structures*. Also, this revision put requirements in more enforceable text with explanations placed in the appendix. New editions were published in 1967[8] and 1970. The *Code* was then put on a three-year revision cycle. By the 1970 edition, the requirements in the *Code* were similar to those in the current edition.

Mr. Richard Stevens, Chief Engineer of the National Fire Protection Association, testified before the U.S. Senate Joint Subcommittee on Long-Term Care in May 1964[9] and cited several fires in healthcare occupancies, including the Hartford Hospital fire and the fire in the Golden Age Nursing Home in New London, Ohio, which killed 63 of the 84 residents. Mr. Stevens noted that from 1953 to 1963, 228 people died in 41 fires in nursing homes. These hearings resulted in revisions of the Social Security Act, which included the *Life Safety Code*® as a condition of eligibility for Medicare and Medicaid reimbursement. The Health Care Financing Administration (HCFA), which now is called Center for Medicaid and Medicare Services (CMS), first started enforcing the *Life Safety Code*® in hospitals and nursing homes receiving federal funding in 1971. The 1967 edition of the *Life Safety Code*® was the first edition enforced by HCFA, followed by the 1973, 1981, 1985, and now the 2000 editions.

The Joint Commission on Accreditation of Healthcare Organizations (JACHO) began surveying hospitals for accreditation with a focus on improving safety and care provided by healthcare organizations. JACHO is an independent, not-for-profit organization that sets standards for and provides accreditation of healthcare organizations. JCAHO uses the *Life Safety Code*® for determining fire safety within a healthcare facility.

Today, both JCAHO and the Center for Medicare and Medicaid Services (CMS) enforce the 2000 edition of the *Life Safety Code*® for hospitals. Of course, the 2003 edition is one more improvement to the level of fire safety in buildings included in earlier *Code* editions. Today's *Code* is a product of lessons learned from many fires over the years involving loss of lives. ▲

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imagination at work

Use of FDS

By Ming He and Yun Jiang

INTRODUCTION

Large open space protection can be very challenging. Some of the challenges are: (1) the distance from a potential fire to the detection points; (2) smoke being diluted in a large volume space; and (3) a large number of occupants may need to be evacuated. The fire protection industry has been searching for optimal solutions to adequately meet building and life safety design objectives. Standards such as NFPA92B[1] have been developed and adopted specifically for large open space applications. However, many large open space applications are usually part of a landmark building involving extensive innovative design features to accomplish visual, energy sustainability, and useability goals. These unique features have not been exhaustively considered in the existing codes and standards.

A fair percentage of buildings exhibit the characteristics of a large open space application. These include atria in office buildings/serviced apartments, hotels, convention and exhibition centers, museums and public libraries, main railway and airport terminals, sport stadiums, halls (municipals, universities, churches, etc.), entertainment and indoor recreation facilities, large warehouse-type structures such as aircraft hangars, hardware/furniture stores, shopping malls, arcades, industrial sites, and so on. When considering the best fire protection solution for such building types, the following aspects must be taken into consideration: 1) the key attributes of the building layout (e.g., ceiling height and interface to outside ambient environment); 2) ventilation (i.e., natural or mechanical), 3) airflow dynamics (i.e., building leakage, air supply and return vents and air handling unit [AHU] operation). Examples of the impact on fire growth and smoke propagation are the possibility of stratification, the extent of

to Assess the Effectiveness of an Air Sampling-Type Detector for

Large Open Space Protection

smoke dilution, and uncertainty of a smoke plume forming.

Beam detectors have often been used in large open space environments mainly due to the fact that many other conventional spot detectors, such as ionization- or photoelectric-type, may not be sensitive enough when mounted at a very high ceiling level. Also, the maintenance of conventional spot detectors is quite difficult when mounted at such high ceiling levels. Over the years, recommendations for beam detector design and installation have been changed to reflect the need for detailed design considerations in order to achieve the level of protection required. As stipulated in BS5839-1[2], additional considerations include smoke plume formation, the need to provide ceiling level detection, etc. This highlights two important issues in regards to the effectiveness of large open space protection using beam detectors. The first issue is how to position the beam detectors when close spacing is required for supplementary detection of a rising smoke plume. The second is how to assess the system design so different fire scenarios, hazards, and locations can be covered.

Today, performance-based building codes have been in use in many countries, such as Australia and the U.S. They provide great incentives for safer and more innovative building designs as well as encourage the application of advanced technology. In contrast to the prescriptive "deemed-to-satisfy" (DTS) approach, the cost of the solution is optimized when the building safety margin is maintained or even enhanced.

Because of the new performance-based approach, many computer tools have been developed so a fire safety system design can be evaluated. Fire Dynamics Simulator[3] (FDS) is one of the leading Compulational Fluid Dynamics (CFD) models. As part of the transition from prescriptive to performance-based designs, it becomes a necessity to be able to quantify the performance of the system in order to assess it against a set of design criteria.

This paper gives an insight into how FDS and other CFD-based computer models can be applied to quantify the performance of air sampling detectors in terms of response time for large open space applications. This article presents a case study of the use of air sampling detectors in a 60m high atrium in Langham Place in Hong Kong.

VERY EARLY WARNING FIRE DETECTION SYSTEMS

In their simplest form, air sampling detection systems continually draw samples of air from the equipment or area requiring protection and assess these samples for the presence of smoke. The detector is a form of nephelometer – an air pollution monitor having high sensitivity, typically hundreds of times higher than conventional smoke detectors. Such high sensitivity can be used to detect the earliest traces of airborne particles or aerosols released due to the overheating of materials. One particular interest is how these systems handle fires in large open spaces or high airflow environments in which the smoke density and heat intensity can be dramatically reduced, preventing many conventional detection technologies from functioning effectively. Many air sampling detectors can actively aggregate lower-density smoke from sampling points to minimize the dilution effect.

As shown in Figure 1, an air sampling detection system is typically implemented as a number of small-bore pipes distributed across a ceiling (above or below) with sampling holes drilled into each pipe at suitable intervals. Air is then continuously drawn into the pipe network via the holes to the centrally located detector using an air pump or aspirator. The density of smoke in the sampled air is compared to a set of predefined smoke thresholds. If the amount of smoke in the sampled air exceeds the set thresholds, alarms are issued accordingly.

The locations of the pipe network and the sampling holes are generally governed by local fire codes and standards such as Australian Standard AS 1670,[4] BS 5839,[2] or NFPA 72.[5] Typically, the pipes and holes are laid out according to a grid pattern that places each hole where a conventional point detector would otherwise be located to meet the prescriptive codes. Placing the sample holes at points where smoke is most likely to travel (i.e., affected by mechanical air conditioning) provides the most effective means of very early warning smoke detection, typically at return air grilles. It is also possible to use these

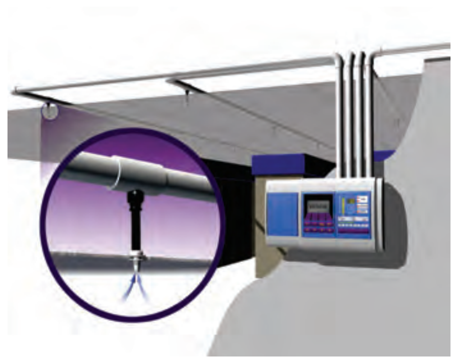


Figure 1. Air sampled through a capillary and sample point.

systems to initiate fire-suppression systems at a much later stage in the fire-development cycle.

An air sampling detection system can detect smoke concentrations as low as 0.005 percent Obscuration/m up to 20 percent Obscuration/m. Obscuration is the effect that smoke has on reducing visibility. Staged alarms and time delays can be used to avoid nuisance alarms.

The provision of staged alarms allows for activation of controlled and escalated responses. For example the "alert" (i.e., the first alarm) condition may be used to call authorized staff to investigate an abnormal condition. Should the smoke condition continue to increase, the "action" (i.e., the second alarm) condition could activate smoke control measures, begin warning sequences via the evacuation system and notify staff members. "Fire 1" (i.e., the third level) alarm indicates that a fire condition is very close or has started. Evacuation alarms are generally sounded at this time. With the provision of a "fire 2" alarm level, suppression systems can be discharged.

MODELING APPROACH

For the design analysis, two types of fire growth rates, "ultra-fast" and "fast," were chosen as "design fires." These two types of fires follow T-square curve and reach 1055kW/m² at 75 and 150 seconds respectively.[5] A Heptane burner with an open section of 1m x 1m (1m²) was used as the fire source in the simulation. The maximum heat release rate was set to 5000kW/m². For the FDS simulation, the minimum grid size was set to 330 mm.

The time delays associated with the air sampling detection system were included in the analysis, including the time for smoke to move from the fire source to the sampling holes **and** the time for smoke to travel from a sampling hole to the detector under a nominal airflow rate of 30 to 60 l/min. To be conservative, the time for smoke to travel from the sampling hole farthest from the detector was used in the analysis.

AIR SAMPLING DETECTION SMOKE OBSCURATION MEASUREMENT AND CALCULATION

FDS can simulate the light extinction coefficient. Bouguer's law has led to the following relation:[6]

$$\frac{I_\lambda}{I_\lambda^0} = e^{-KL} \qquad (1)$$

where:

- I_λ^0 is the intensity of the incident monochromatic light of wavelength λ;
- I_λ is the intensity of the light transmitted through the path length, L, of smoke.
- K is the light extinction coefficient (1/m)

The extinction coefficient, K, can be expressed as the product of an extinction coefficient per unit mass, K_m, and mass concentration of the smoke aerosol, m.

$$K = K_m \times m \qquad (2)$$

Here, K_m is a function of a number of factors, such as the mass size distribution, the ratio of particle diameter to the wavelength of light, particle density, etc. Seader and Einhorn[7] give K_m values of 7.6 m²/g for smoke produced from flaming combustion of wood and plastics, and 4.46 m²/g for pyrolysis smoke products. In FDS, 7.6 m²/g was used for all the combustion phenomena.

Light obscuration, S_x (%) is used to describe the visibility in a smoky enclosure. The definition of the light obscuration is:

$$S_x = 100(1 - \frac{I_\lambda}{I_\lambda^0}) \qquad (3)$$

Obscuration per meter, OB, can be obtained from following equation:

$$OB = \frac{S_x}{L} = 100(1 - e^{-KL}) / L \qquad (4)$$

For an air sampling detection system, the smoke obscuration level measured in a detector's chamber is a function of the smoke concentrations from a number of sampling holes, flow rates, and transport time within the pipe network. The flow rate and transport time from each sampling hole can be calculated by a CFD software named ASPIRE.[8] The smoke concentration profile at any given time at each sampling point is obtained from the FDS fire model. Hence, the smoke obscuration for an air sampling detection system can be calculated as follows:

$$K_{ASD,t} = f(K_{i,j}, F_i, j) \qquad (5)$$

Where:

- i represents a sampling hole
- j represents time step
- F_i is the flow rate ratio contributed from sampling hole i
- $K_{i,j}$ is the smoke concentration at a given time j at sampling hole i
- $K_{ASD,t}$ is the extinction coefficient in the detector's chamber at time t

Finally, the smoke obscuration per meter can be obtained by substituting calculated $K_{ASD,t}$ into the equation (4). The time for this obscuration level to reach a preset value, for example, 0.05%/m, is the response time of an air sampling detection system.

FDS VALIDATION: SMOKE DEVELOPMENT

The FDS simulation was evaluated by comparing predictions to a series of real fire/smoke tests for validation purposes. The fuel materials tested include liquids (i.e., Heptane) and solids (i.e., timber and paper). The enclosure sizes involved in the tests vary from about 80 m² with a ceiling of height 3.6 m (i.e., similar size to a standard test room specified by UL 268 standard[9]) to over 550 m² with a ceiling height of 8 m in a real warehouse. In order to model the early and very early detection abilities that the air sampling detection system possesses, some very small fire sizes were investigated in these environments. The minimum fire size tested and simulated was as low as few hundred watts.

In the smaller enclosure, the simulation results of smoke properties were compared point by point at ceiling height with detector measurements. Figure 2 indicates that the differences between the simulation and detector measurement at each location are within 20 percent for a 3kW Heptane fire. While FDS was developed to simulate industrial scale fires, it has achieved about 20 percent accuracy on gas velocity and temperature prediction.[3]

The simulation results are even better when compared with the measurements taken from a standard pipe network design. In this case, the smoke collected from the above 15 sampling holes was

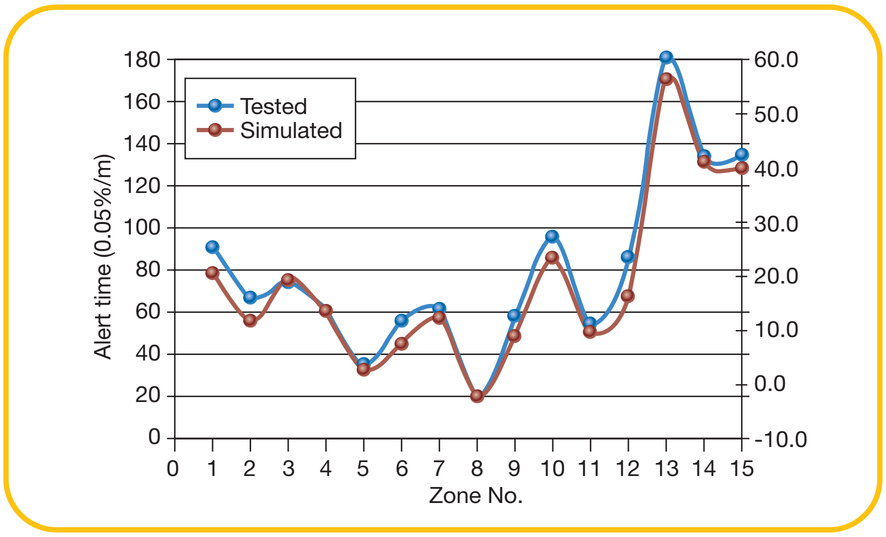


Figure 2. Comparison of response times at 15 points.

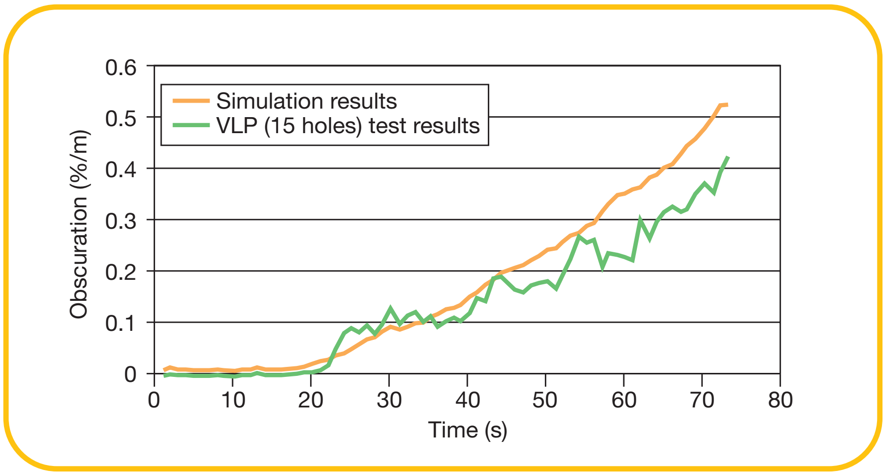


Figure 3. Comparison of smoke levels from simulation and one ASD detector for a 750W fire.

sent into a single air sampling detector. The measured smoke level was then compared to calculated value based on the above computation methodology. Figure 3 shows an example of model validation using a very small fire size.

ATRIUM LAYOUT AND SIMULATION MODEL

To apply FDS simulation to a large open space application, the 60 m high Grand Atrium at the Langham Place complex in Hong Kong was chosen as a case study. The simplified floor plan is shown in Figure 4.

The atrium has a ventilation capacity of two air changes per hour. The total air-supply flow is 23,890 l/sec, distributed by five vent columns, approximately 4,800 l/sec each. The total air-return is 18,000 l/sec. The difference in airflow is assigned to all openings (doors, etc.) evenly.

The purpose of this case study is twofold. First, the simulation results are to be used to verify the air sampling detection system design, especially for those protection zones closer to the air vents. Second, the simulated performance is compared with in-situ hot smoke tests.

SIMULATION AND PERFORMANCE ASSESSMENT

An ultra-fast fire up to 5MW is used to assess the air sampling detection performance according to the initial design, taking into account the possible fire from Christmas trees during the festival season.[10] Using 60 and 90 seconds as benchmarks, the air sampling detection activation and the response time vary when the fire location is changed. A total of four fire locations are selected. These locations are considered as worst-case scenarios in terms of airflow dynamics and the distance from the detector sampling holes.

The simulation results for air sampling detection ports located 4m (13ft) above the atrium floor level for the 5MW fire at different locations are illustrated in Table 1. The response times are all calculated based on the maximum transport time, worst-case scenario. Only results for the zones that activated within 90 seconds are listed. The locations of these protection zones are illustrated in Figure 4.

Note that "7+7" indicates detectors using 2 branches, each with 7 sampling holes. To investigate the effectiveness of ceiling detection and the effect of the upper hot layer stratification, additional simulations for three detection zones installed at the ceiling level were conducted. These simulations involved fire sizes ranging from 500kW to 2MW with fast growth. The stratification condition in the FDS simulation is set at a maximum temperature of 38°C (100°F) at the ceiling (i.e., 60m high) and descending downwards at a gradient of -0.3°C/m (-9.92°F/ft) to ambient temperature of 20°C (68°F). Simulated air sampling detection response times for a 1MW fire are shown in Table 2.

A 2MW liquid fire placed near location I in Figure 4 was simulated for a comparison with the in-situ hot smoke tests. Ethanol was chosen as fuel in the full-scale test. However, a Soot Yield ratio 10 times higher was adopted to simulate a smoke machine used during the test. The simulation results are shown in the following section with test results.

Figure 5 shows a 3D illustration of the stratification effect.

SMOKE TESTS AND PERFORMANCE VERIFICATION

The in-situ tests involved a number of preliminary "mock-up" tests and a final formal fire test. The final test was carried out in accordance with Section 2.1 of the Hot Smoke Test procedure detailed in Australian Standard AS 4391-1999.[11] The fire source consisted of six A1-size fuel trays containing denatured

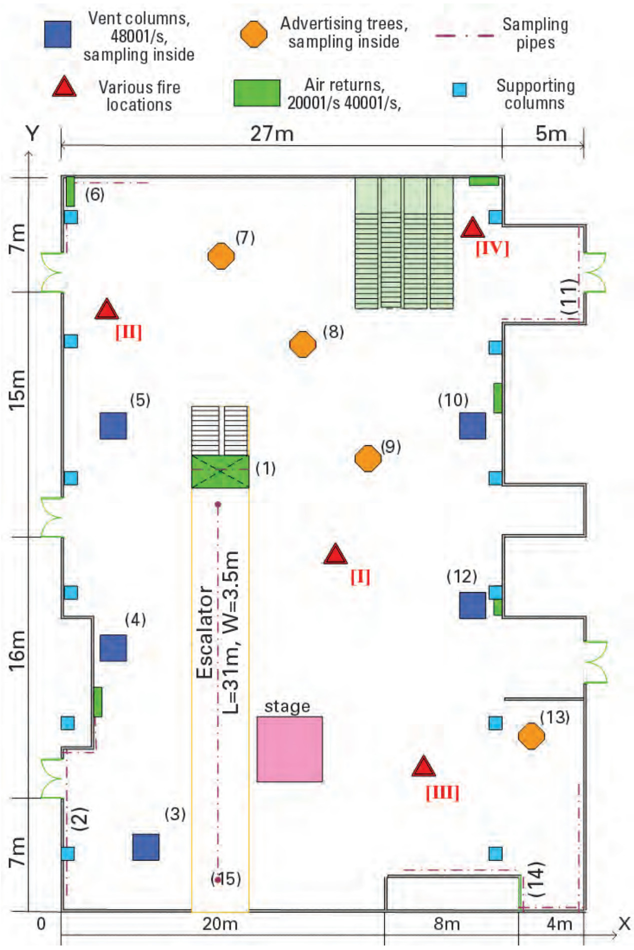
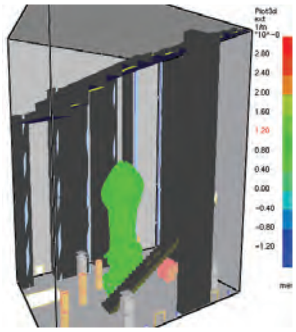


Figure 4. Protection zones on the bottom part of the atrium.


(a) At 20 seconds

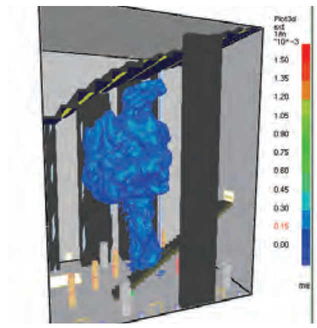

(b) At 50 seconds

Figure 5. 3D smoke contour from a 1 MW fire.

Fire location	I			II		III		IV
Fire zone (Design No)	Zone 1 (1)	Zone 2 (15)	Zone 14 (9)	Zone 4 (6)	Zone 12 (7)	Zone 6 (14)	Zone 15 (13)	Zone 5 (11)
No. of sampling holes	18	16	8	7+7	8	7+7	8	7+7
Tst (max) (sec)	5	50	9	20	9	20	9	20
Tsp (sec)	25	33	32	5	47	55	42	52
Trt - Alert (sec)	30	83	41	25	56	75	51	72
Trt - Action (sec)	35	84	43	26	57	77	52	74

Table 1. Air Sampling Detector response time "alert" (0.05%/m) and "action" (0.1%/m), 5MW ultra-fast growth fire.

Stratification	No			Yes		
Sampling zone	Zone S1	Zone S2	Zone S3	Zone S1	Zone S2	ZoneS3
Location in the domain	Lower ceiling	Middle ceiling	Higher ceiling	Lower ceiling	Middle ceiling	Higher ceiling
No. of sampling holes	27	26	30	27	26	30
Trt - Alert (sec)	94	62	82	98	67	>110
Trt - Action (sec)	95	63	83	99	68	>110

Table 2. Air Sampling Detector response time "alert" (0.05%/m) and "action" (0.1%/m), 1MW fast growth fire.

industrial-grade methylated spirit (Grade 95). The fuel trays were placed in a metal rig.

Since the selected fuel results in a clean combustion without visible smoke, a smoke generator was used.

From previous testing experience, a liquid fire configured as above normally has a growth rate that is close to ultra-fast T-square curve and even has a faster burning rate at the initial stage. Therefore, this 2MW testing fire was simulated as an ultra-fast fire.

Figure 6 shows the simulated smoke profile for the first activated air sampling detector installed to cover the middle ceiling area.

It was recorded from the fire test that this air sampling detector activated in just over 60 seconds after the ignition had occurred. This agreed very well with the simulation results.

A comparison of the upper hot layer height from the simulation and actual testing[12] for a 2 MW liquid fire is also performed. Figure 7 illustrates a comparison of the simulated upper hot layer height against the one from the testing.

During the test, it was observed that such fire configuration did not give a smoke plume stratifying at the outer edges at middle-level of the atrium. This result is also evident in simulation as shown in Figure 8.

DISCUSSION

Sampling Point Placement

From simulated 1 to 5MW fires, the smoke reaches the ceiling quite quickly, even at the 60 m high ceiling. Therefore, ceiling detection is adequate and recommended for this project.

Extra care should be taken when ventilation columns are used as sampling pipe locations. This is because the flow rate of fresh air blown out through these ventilation columns is relatively high (4800 l/sec in this case). The airflow is nearly horizontal at the height of six meters. These may prevent the smoke from reaching the ventilation columns at the early stage of the fire development, especially when the fire starts at a distance far away from the columns.

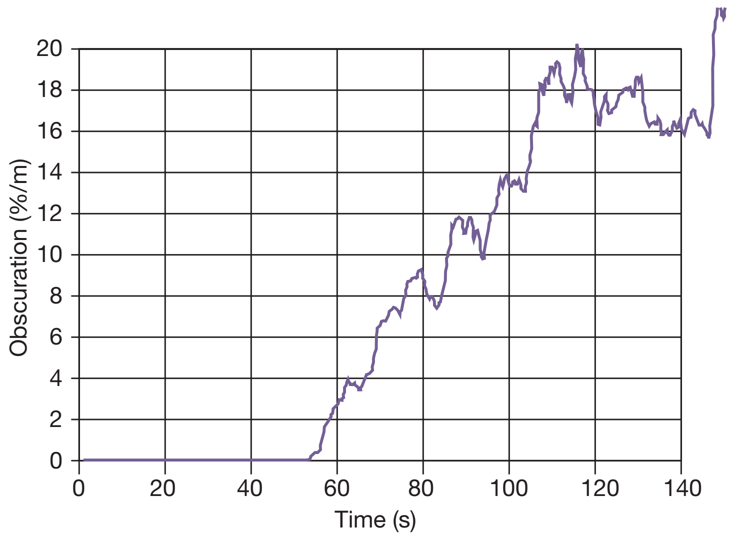
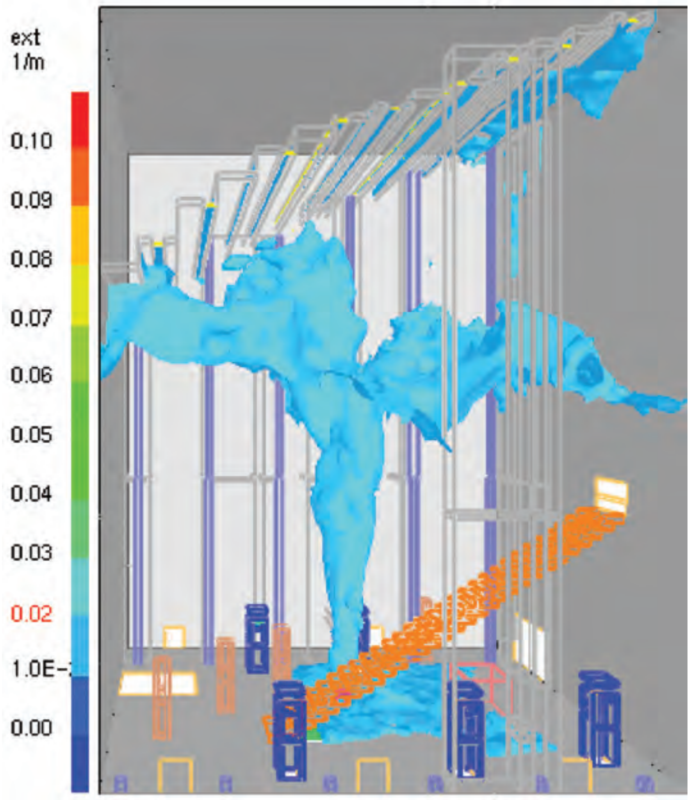


Figure 6. Smoke profile simulated for ASD detector for the 2MW ultra-fast fire.



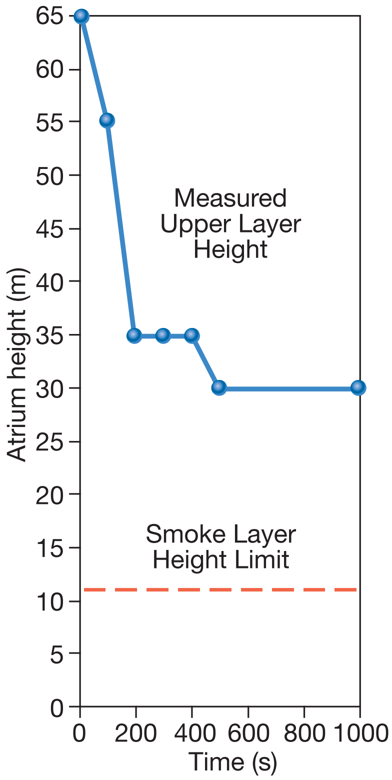


Figure 7. Comparison of simulated and tested upper hot layer height.

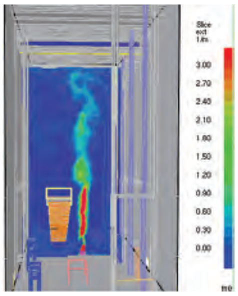


Figure 8. Smoke from an ultra-fast fire reaching to ceiling without stratifying.

For other vertical columns, such as advertising trees, where there is no strong air movement at the upper section, sampling holes should be placed as far up as practically possible. In certain cases, smaller spacing may be considered to maximize the overall system detection performance.

Additional Requirements

It may be necessary to position the sampling pipe near the return air area to further reduce the response time. For example, detector number 11 as shown on Figure 4 was the only detector with the response time longer than 60 seconds for all investigated fire locations. If the pipe network in Zone 5 as shown in Figure 4, which is protected by detector number 11, were repositioned to be closer to the return air area, the response time for "alert" and "action" alarms would be shortened from 72 sec and 74 sec to 28 sec and 29 sec, respectively. ▲

Ming He and Yun Jiang are with Vision Systems Ltd.

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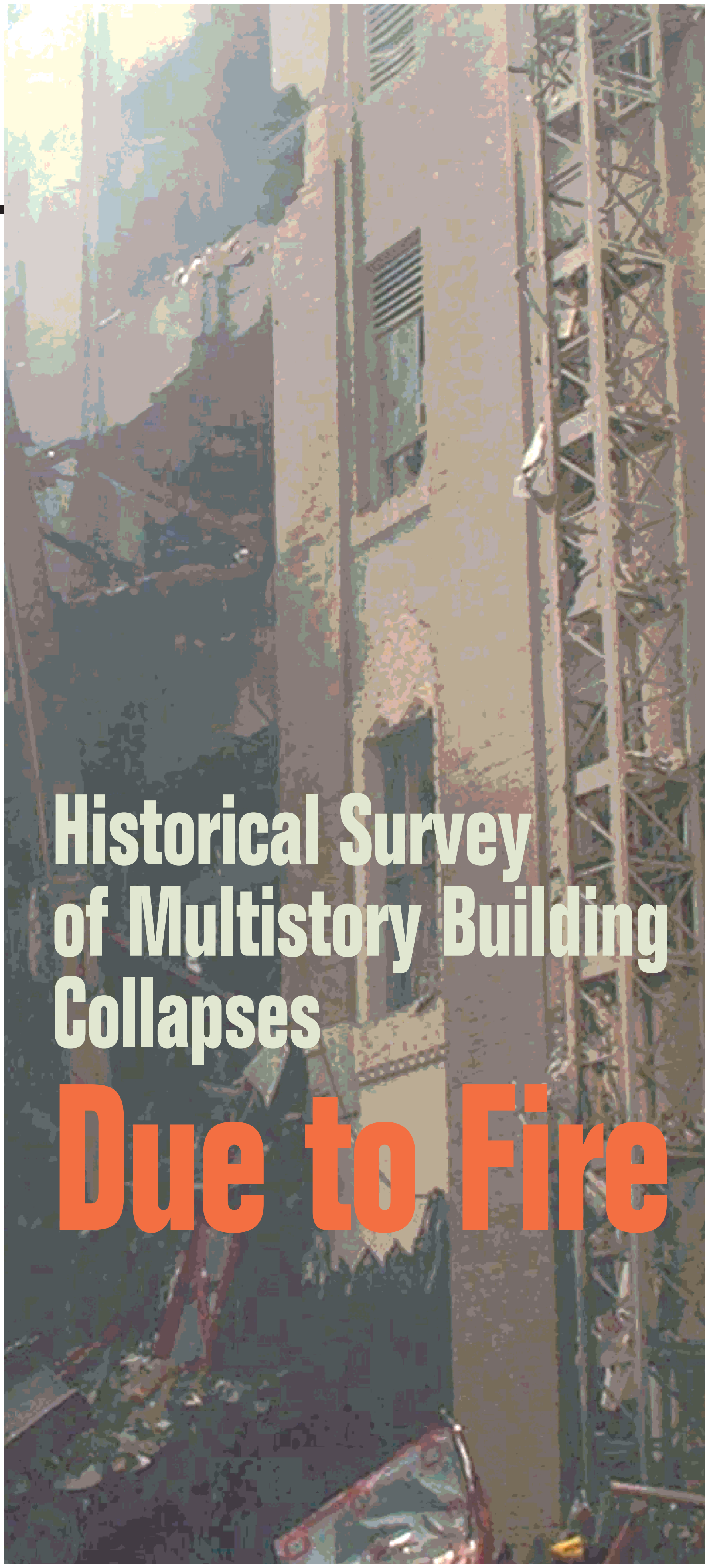

Photo courtesy of Paul Doherty

Historical Survey of Multistory Building Collapses Due to Fire

By Jesse Beitel and Nestor Iwankiw, Ph.D., P.E.

INTRODUCTION

There have been, and remain to be, continuing concerns about the adequacy of structural fire protection in the wake of the 9/11 tragedies. As significant as these events were, they were also clearly not representative of the normal accidental impact of fire on building structures. To assess the extent and nature of structural collapses due to fire in taller buildings, a review of existing information about fire incidents resulting in structural collapse was collected and reviewed.

The survey was international in scope and included building collapses due to fire in structures with four or more stories that had occurred during the 1970-2002 time frame of the survey. Both total and partial collapses were included in the survey. Since no database exists that systematically identifies building collapses due to fire (including the NFIRS system), the survey was necessarily exploratory. The survey methodology included a review of both news sources and technical literature, as well as interviews with a wide range of individuals

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knowledgeable in structural fire protection. Twenty-two fires were identified that caused either partial or total collapse of a multistory structure. The adequacy and code compliance of the original structural and fire-resistant design of the identified buildings were beyond the scope of the project and were not assessed. While the number of fire events may appear low (average of one/year), these fire events are high-consequence occurrences with respect to loss of life, injuries, and economic costs.

This survey of structural building collapses due to fire causes was sponsored in 2002 by the National Institute of Standards and Technology (NIST) as part of a larger project. The complete report is available from NIST.[1]

SURVEY RESULTS

For the purposes of this NIST survey, multistory buildings were defined as those having four or more stories. Nonbuilding structures, such as tunnels, bridges, observation or transmission towers, were not included. Either partial or total failure of the structural framing, members, and/or connections was considered to have constituted a collapse, and it was necessary for a fire to have been the direct cause of this failure.

A total of 22 such cases were identified through 2002 after extensive searches of the literature, news, and other contacts, with the Sept. 11 disasters in New York and Washington, DC, counting as five of these incidents [World Trade Center (WTC) 1, 2, 5, and 7, and the Pentagon]. The cases occurred not only in the U.S. and North America, but also internationally. This NIST survey data demonstrated that buildings of all types of construction and occupancies, in the U.S., North America, and abroad, are susceptible to fires, particularly older buildings and those that may be undergoing construction, renovations, or repairs. The total fatalities were dominated by the Sept. 11 WTC disasters, which were unique in that they were precipitated by terrorist attacks that substantially damaged the buildings' structural framing and destroyed their fire protection systems prior to the fires.

The NIST survey of 22 fire-induced building collapses from 1970-2002[1] identified a variety of conditions, materials, locations, and buildings. Fifteen cases were from the U.S., two from Canada, and five from Europe, Russia, and South America. The numbers of fire collapse events can be categorized by building material as follows:

- Concrete: 7 (1 in Pentagon 9-11 event)
- Structural steel: 6 (4 in 9-11 WTC events)
- Brick/Masonry: 5
- Wood: 2
- Unknown: 2

Three of the these events were from the 1970s, another three from the 1980s, four from the 1990s, and 12 in 2000 and beyond. This temporal distribution is skewed towards more recent occurrences, as expected, both due to the magnitude of the WTC (counted as four events) and Pentagon (one event) disasters of 9-11 and the news media searches.

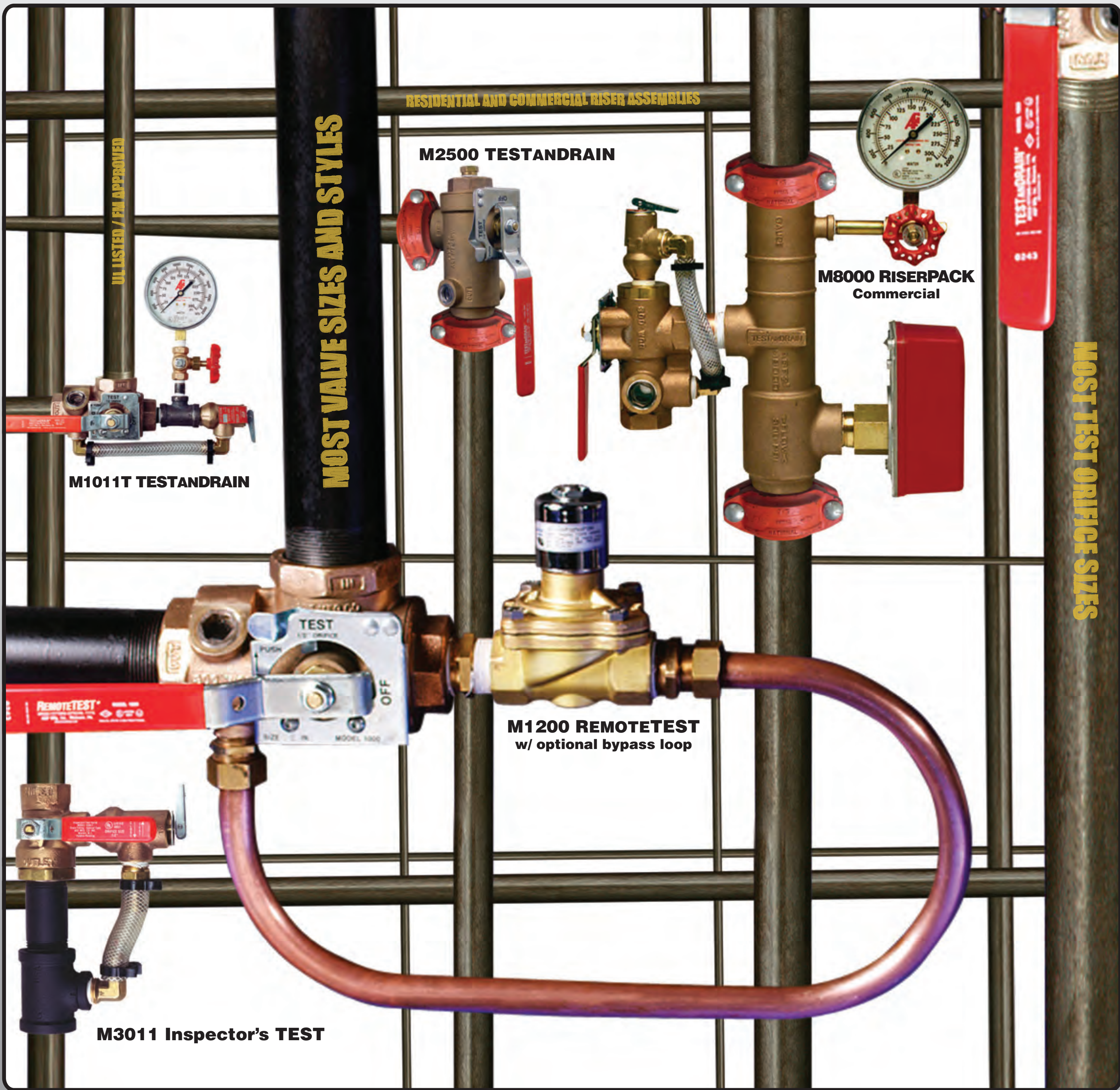
The collapse distribution by building story height was as follows:

- 4-8 stories: 13
- 9-20: 3
- 21 or more: 6

Almost 60 percent of the cases are in the 4-8 stories range, with the remainder affecting much taller buildings. Six collapses occurred in buildings over 20 stories, and three of these were the WTC steel-framed buildings (1, 2, and 7).

At least four of these fire collapses had occurred during construction or renovations of some kind, when the usual expected architectural, structural, and fire protection functions were still incomplete or temporarily disrupted, and/or potential new fire sources were introduced, such as electrical and gas line repairs, welding, and the presence of other flammable supplies and/or equipment. Partial collapses (14 events) were the most frequent occurrences, and the WTC disasters (listed as four separate events, with three full collapses) dominated the full collapse event total of eight cases. Office and residential were the primary types of occupancy in these 22 buildings, as would be expected in multistory construction, with the occupancy distribution being as follows:

- Office: 9
- Residential: 8
- Commercial: 3
- Combined commercial/residential: 2



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The 9-11 events are quite thoroughly documented in the FEMA 403[2] and ASCE-SEI Pentagon Reports,[3] with further NIST investigations on the WTC ongoing, and will not be further covered herein. Rather, some other interesting and more obscure cases of fire-induced collapses will be described.

Two large department store fires in Athens, Greece, in 1980 are documented in the paper by Kyriakos Papaioannoa, 1986.[4] These fires began at 3 a.m. on Dec. 19, 1980, with arson being suspected as the cause. The Katrantzos Sport Department Store was an 8-story reinforced concrete building. Its fire started at the 7th floor and rapidly spread throughout the building, due to lack of vertical or horizontal compartmentation and the absence of sprinklers. Collected evidence indicated that the fire temperatures reached 1000°C over the 2- to 3-hour fire duration, and the firefighters concentrated on containing the fire spread to the adjacent buildings. Upon termination of these fires, it was discovered that a major part of the 5th to 8th floors had collapsed. Various other floor and column failures throughout the Katrantzos Building were also observed (see Figure 1). The cause of these failures was considered to be restraint of the differential thermal expansion of the structure that overloaded its specific elements or connections.

Figure 1. Katrantzos Department Building in Athens, Greece, after 1980 fire.

On May 21, 1987, Sao Paulo had one of the biggest fires in Brazil, which precipitated a substantial partial collapse of the central core of the tall CESP Building 2.[5] This was a 21-story office building, headquarters of the Sao Paulo Power Company (CESP), after whom the building was named. Buildings 1 and 2 of this office complex were both of reinforced concrete framing, with ribbed slab floors. These two buildings had several unique internal features and contents. Both buildings still retained their original wood forms used for pouring the concrete floor slabs, which were never removed. Low-height plywood partition walls were also used in the interiors. Approximately two hours after the beginning of the fire in CESP 2, its structural core area throughout the full building height collapsed. This collapse was attributed to the thermal expansion of the horizontal concrete T-beam frames under the elevated fire temperatures, which led to the fracture of the vertical framing elements and their connections in the middle of the building, and the consequent progressive loss of gravity load-carrying capacity (see Figure 2).

Figure 2. CESP 2 core collapse in São Paulo, Brazil.

A fire-initiated full collapse of a textile factory occurred in Alexandria, Egypt, on July 19, 2000.[6] This 6-story building was built of reinforced concrete, and its fire started at about 9 a.m. in the storage room at the ground floor. Fire extinguishers were nonfunctional, and the fire spread quickly before the firefighters could arrive. An electrical short-circuit accelerated the fire spread. At about 6 p.m., nine hours after the start of the fire, when the blaze seemingly was under control and subsiding, the building suddenly collapsed, killing 27 people. Figure 3 shows a photograph of this collapse.

Figure 3. Collapsed textile factory in Alexandria, Egypt.

CONCLUSIONS

Past experience and this 2002 NIST collapse survey confirm that fires, and the related damage, deaths, casualties, and any collapses, are essentially rare and random events, whose effects depend highly on the time, nature, and circumstances of the fire occurrence. Thus, fires represent a hazard to all building types, materials, and occupancies. Likewise, the added fire-fighting difficulty in all taller buildings must be recognized, given the longer times needed to escape or access the higher floors. Many of the past major fires in tall buildings fortunately occurred in the evenings or weekends, when the office buildings were almost vacant, thereby, minimizing their potential dangers to human life. Automatic sprinkler systems are a very effective means to suppress a fire, but if the system is being repaired, or is nonexistent or nonfunctional for other reasons, the threat of fire growth increases.

Another important finding of this study was the lack of readily available, and well-documented, information on partial or total structural collapse due to fire. Unless the fire event was significant for other reasons, e.g., loss of life, very little information was available. It is recommended that a centralized database be developed, whereby structural damage and collapse can be investigated and systematically reported in the future. The current lack of systematic information on fire-induced collapses seriously limits the profession's understanding of the scope and nature of the real structural fire protection problem. ▲

Jesse Beitel and Nestor Iwankiw are with Hughes Associates, Inc.

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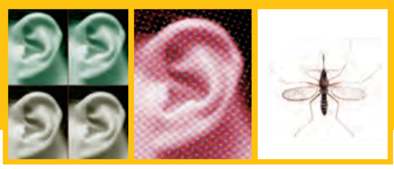

Part 3

The Mosquito and the Picket Fence –

A Modern-Day Fire Alarm Fable About

Broadband versus Narrowband Signaling

Parts 1 and 2 of this article in the Winter and Spring, 2005 issues showed that sound is generally composed of many frequencies, and that as long as one of the alarm signal's frequency bands (pickets) is taller than the corresponding noise picket, the signal can be heard, even if the total broadband sound pressure level of the noise is greater than the total broad band sound pressure level of the signal. How one sound can penetrate another and the effects of masking were presented. This final article in this series introduces the signal-noise requirements of the National Fire Alarm Code (NFPA 72) and other factors, including the effects of distance, hearing loss and hearing protection. This article concludes with a summary of the advantages and disadvantages of narrowband signaling.

NARROWBAND FIRE ALARM SIGNAL GOALS

The requirements for narrowband audible signal levels in NFPA 72 and ISO 7731 differ from those for broadband signaling. Where the noise and the alarm have been measured using an octave-band meter, the sound pressure level of the audible alarm tone must exceed the masked threshold in one or more octave-bands by at least 10 dB in the octave-band under consideration. For 1/3 octave-band analysis, the sound pressure level of the audible alarm tone must exceed the masked threshold in one or more 1/3 octave-bands by at least 13 dB in the band under consideration.

These goals are for exceeding peak measurements of noise. There is no requirement for measuring and exceeding a time-averaged sound pressure level as there is for broadband signaling.

LOCATION, LOCATION, LOCATION

The farther one moves from a sound source, the less loud it will be. Basic design practice is to analyze or estimate the ambient noise and then select and place alarm appliances to overcome that background noise. The picket fence analogy is useful here again – see Figure 1. It is possible to hide a larger object that is farther way with a smaller object close by. Similarly, when one is at a certain location and the noise is at a certain level, there is a distance at which an alarm signal will be clearly heard, and there is a distance at which it will not be heard.

Also, for set levels of noise and alarm and for a set distance between their sources, there is a point where one can be so close to the noise that it will mask the alarm. See Figure 2. For example, a noise source may be found to produce 95 dB at 3 meters. This could be at a particular frequency band or it could be an integrated, A-weighted measurement. Similarly, a fire alarm horn might be rated 100 dB at 3 meters and located 5 meters behind the noise source. How far from the noise source would one have to be to be able to hear the alarm?

The equations for sound at some distance are:[1, 2]

$$L_{P2} = L_{P1} - 20\log_{10}\left(\frac{r_2}{r_1}\right) \text{ dB} \quad \text{and}$$

$$L_p = L_W - 20\left(\log_{10} r\right) - 11 \text{ dB}$$

where L_W is the sound power of the source.

Figure 3 shows the sound pressure level plotted for both the noise and the alarm in the above example. The distance scale is the distance from the noise source – the alarm is an additional 5 meters farther away. The plots cross at approximately 6.4 meters, where the sound pressure level from both is about 88 dB. For locations closer, the noise overpowers the alarm, even though the location is also closer to the alarm. This analysis is idealized in that it assumes "free field" conditions – no reverberation and no differential absorption of sound by surfaces.

HEARING LOSS AND HEARING PROTECTION

So far, the analysis has assumed that listeners have "normal" hearing. What is normal? The internationally accepted definition of a decibel of sound pressure level uses $2x10^{-5}$ Pa (Pascals) as the threshold of human hearing.[2]

$$L_P = 20 \ \log_{10}\left(\frac{P}{2x10^{-5}}\right) \text{ dB}$$

However, the threshold of hearing varies with frequency and varies statistically among otologically normal persons – those with normal hearing structures.[3] The reference threshold at different frequencies is determined by testing an adequately large group of otologically normal persons in the age range of 18 to 25 years, inclusive. The ISO 389-7 data show that an average person actually hears slightly better than the reference threshold of $2x10^{-5}$ Pa at frequencies between approximately 1,250 Hz and 6,000 Hz, depending on conditions. Outside of that range – lower and higher frequencies – a higher threshold exists.

The sensitivity of human hearing decreases (threshold increases) with age, more for sound at high frequencies than at low frequencies. Also, the magnitude of this effect varies among individuals. ISO 7029 provides statistics regarding the hearing threshold for populations of various ages.[4] The data for a frequency of 3,000 Hz (common for modern fire alarm appliances) show that approximately half of the male population will experience a 20 dB hearing loss by age 60, 13 dB for females. Ten percent will have a hearing loss of approximately 42 dB for males and 30 dB for females at 3,000 Hz. At 500 Hz, the hearing loss is only 6 dB for half the population of both males and females.

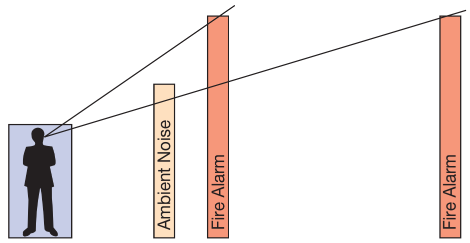

Figure 1. Effect of distance between sound sources.

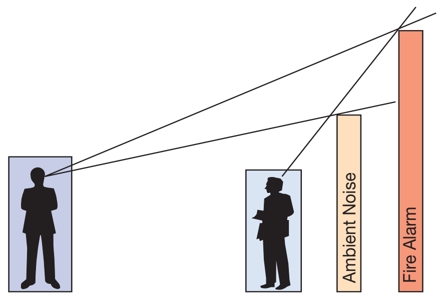

Figure 2. Effect of proximity to sound source.

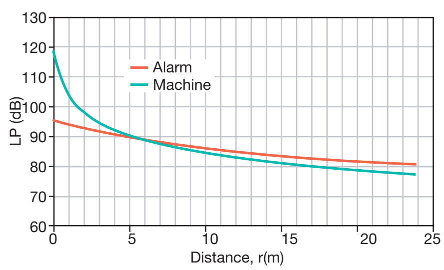

Figure 3. Sound pressure level vs. distance.

Frequency, Hz	125	250	500	1000	2000	3150	4000	6000	8000
Mean Attenuation, dB	22.1	27.9	34.9	35.8	37.3	41.4	42.3	41.6	41.2
Std. Deviation	2.9	2.8	3.4	2.0	2.5	2.7	2.8	3.1	3.7

Table 1. Performance data for hearing protection.

In addition to the normal statistical variation of hearing threshold with age and frequency, artificial hearing loss caused by hearing protection may be a consideration in determining the audibility of an alarm signal. Manufacturers of hearing protection provide data such as that shown in Table 1.

ALARM SIGNAL DESIGN

Presently, codes and standards do not require consideration of hearing loss or hearing protection in the design of an audible alarm signal. Also, there are no requirements for the frequency content of the alarm signal. The goals previously cited for broadband and for narrowband signaling are for "normal" hearing persons. Most codes require the use of strobes for alerting persons with hearing impairments and for alerting persons in high-noise environments. There are proposals to require audible fire alarm signals to contain a 200 to 700 Hz component.[5]

System designers may choose to include one or more low-frequency components in the alarm signal to target a percentage of persons with age-dependent hearing loss. Similarly, in spaces where hearing protection is worn, the signal can be designed to penetrate the protection at one or more frequency bands. This is accomplished by simply increasing the alarm sound pressure level at the desired frequencies by the expected loss or threshold of hearing at those frequencies. For example, to penetrate the hearing protection device specified in Table 1, the octave-band signal-to-noise ratio of 10 dB required by NFPA 72 would have to be increased to about 45 dB for a 500 Hz signal (10 dB + 34.9 dB).

Caution is required to ensure that the maximum sound level does not exceed the maximum permitted level of 120 dBA.[3] Note that the maximum of 120 dBA in NFPA 72 (2002) differs from other codes and standards that often cite 110 dBA.[6] For workers who may be exposed to high sound levels over the course of a 40-year employment history, Occupational Health and Safety Administration (OSHA) has established a maximum permitted dose before a hearing conservation program must be implemented.[7] A worker exposed to 120 dBA for 7.5 minutes a day for 40 years might be in danger of suffering a hearing impairment. The OSHA regulation includes an equation to calculate a dose for situations where a person is exposed to different sound levels for different periods of time. The maximum permitted by the regulation is an 8-hour equivalent dose of 85 dBA. Thus, in spaces where hearing protection is required, attempts to overcome the effects of that protection with an alarm signal may result in signals that are dangerously loud if a person were to be exposed without the hearing protection in place.

Most modern audible fire alarm appliances operate at about 3,000 Hz – right where age-dependent hearing loss has a marked effect. There are several possible reasons. One is that physical size to produce that wavelength is smaller than that generally required to produce lower frequencies – though this is not an absolute requirement or limitation. Another is that the appliances themselves are more electrically efficient than older appliances, which operated down closer to 1,000 Hz. This is particularly important for battery-operated smoke alarms.

Another possible reason for the shift to higher-frequency appliances is component reliability. Anecdotal evidence suggests that the older mechanical bells and horns that operated at lower frequencies have a higher failure rate compared to modern electronic sounders.

Systems that use speakers, as opposed to direct current sounders (horns, bells, chimes, etc.), can be designed to reproduce any recorded frequency alarm signal. It would be easy for designers of such systems to include lower-frequency content in the signal.

Where specific frequency content is a stated goal, measurement and verification of compliance become, more complex than a simple broadband design. It becomes necessary to use a meter with octave- or 1/3 octave-band filters to verify that the signal-to-noise ratio is met or exceeded at the desired frequency band. It may be possible to simplify the testing and verification. For example, it might be possible to measure the signal using a simple broadband dBA meter. A product listing may verify that the appliance produces a 77 dBA signal with an 80 dB component at Hz measured at three meters. At some other distance, if the measured signal is 50 dBA, the 500 Hz component would be expected to be reduced by approximately the same amount: 80-(77-50)=53 dB. The problem with this estimation is that different materials reflect, absorb, and transmit frequencies differently. Thus, it would only be valid near the appliance or in free-field conditions. It may be possible for research to establish a method for estimating the relative attenuation for common household construction and furnishings.

The concept of narrowband analysis and signaling explains why one can hear a mosquito and an alarm signal in noisy environments. The possibility exists for signals to operate with only one narrow frequency band that might be the least effective for an aging population. That possibility already exists even when measurements are made using the dBA scale on a meter. However, narrowband analysis and signaling provide a viable and effective way to design signals for the penetration of specific noise content and for the alerting of persons with hearing deficiencies.

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Editor's Note – About This Article

This is a continuing series of articles that is supported by the National Electrical Manufacturer's Association (NEMA), Signaling Protection and Communications Section, and is intended to provide fire alarm industry-related information to members of the fire protection engineering profession.

SFPE Resources

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Join your colleagues at the 2005 Annual Meeting and Professional Development Conference at the Hyatt Regency La Jolla in San Diego, CA. The Annual Meeting will include a technical program, a report on Society activities and finances, as well as the SFPE Picnic. This will be followed by the Awards and Honors Banquet, and by four days of educational events, including nine seminars, a symposium on Advances in Fire Suppression Technologies, and an expanded Technology Showcase.

The week features several NEW seminars: Advanced Fire Dynamics Simulator and Smokeview, Smoke Control, Structural Fire Protection, and Dust Explosion. Returning are the always-popular seminars on sprinkler design, human behavior, principles of fire protection engineering, and how to study for the FPE/P.E. exam.

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Abstracts are solicited for paper presentations at the conference, which will be held June 14-16, 2006, in Tokyo. Abstract submission requirements can be found at *www.sfpe.org*.

The deadline is July 30, 2005.

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Student Fire Academies – An Immersive Seminar
University of Colorado/Boulder
Boulder, Colorado
Info: www.campusfire.org

November 8-10, 2005
Campus Fire Forum 7
Tempe, Arizona
Info: www.campusfire.org

September 13-15, 2005
Technical Conference on the Federal Building and Fire Safety Investigation of the World Trade Center Disaster
National Institute of Standards and Technology
Gaithersburg, Maryland
Info: www.wtc.nist.gov

September 18-23, 2005
8th International Symposium on Fire Safety Science
Beijing, China
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September 28-30, 2005
International Water Mist Conference
Berlin, Germany
Info: www.iwma.net

September 28-30, 2005
3rd International Conference on Pedestrian and Evacuation Dynamics
Vienna University of Technology
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Fourth Mediterranean Combustion Symposium
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SFPE Annual Meeting and Professional Development Conference
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Info: grupos.unican.es/GIDAI

November 2-4, 2005
Fire Safety – Sea Road Rail International Conference
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Info: www.rocarm.com/FSAS05CFP.htm

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October 17-21, 2005

Hyatt Regency La Jolla in San Diego, CA

MONDAY October 17	TUESDAY October 18	WEDNESDAY October 19	THURSDAY October 20	FRIDAY October 21
SFPE Annual Meeting and Picnic	Symposium on Advances in Fire Suppression Technologies: Developing and Engineering New Fire Suppression Solutions to Protect People, Environment, and Property		***New!*** Smoke Control: Session I – Fundamentals and Pressurization Systems	***New!*** Smoke Control: Session II – Design Fires, Atrium Control, and Tenability Systems
	Principles of Fire Protection Engineering			
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	Human Behavior in Fire		How to Study for the FPE/P.E. Exam	
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Awards and Honors Reception and Banquet	Showcase Welcome Reception	F.P.E. Alumni Reception		

KELTRON CORPORATION

Case Study

George Mason University

A Fire Protection System for the Present and the Future

With over 160 buildings on three campuses, George Mason University (GMU) serves more than 28,000 students, presenting a continuous challenge to the university's fire safety officials and staff.

In addition to GMU's arsenal of heavily enforced fire safety regulations and extensive array of fire protection devices, all buildings are monitored at a central dispatch station on the Fairfax campus using a Keltron LS 7000 life safety event management system.

When searching for a solution to upgrade GMU's fire alarm monitoring system, "we were particularly interested in facilitating communications to ensure the fastest response to alarms," says Fred Wharton, director of fire safety programs at GMU.

GMU relies on state funding and tuition to pay expenses. Since cost is always a factor in procuring new equipment, the GMU team decided to implement system upgrades systematically. "This required the new system to interface with a smorgasbord of existing fire alarm control panels and digital dialers, and to accept signals using the existing infrastructure," notes Steve Bryson, lead fire alarm technician at GMU. The Keltron LS 7000 system provides a wide range of features including:

- Connects existing fire alarm control panels on three campuses to a central receiving station, using the existing campus telephone system.
- Complies with UL guidelines and requirements.
- Receives information from diverse fire alarm control panels.
- Provides an easy-to-use graphic user interface with comprehensive data to enable fast, accurate dispatch.
- Enables remote location programming via the GMU LAN so as not to disrupt the activity in the dispatch center.
- Transmits event information to an offsite printer.
- Provides comprehensive history to generate standard format reports.
- Provides a pathway for upgrades, future expansion, and building systems integration.

"We looked at a number of solutions from different companies and none except Keltron's met all of our requirements," says Bryson.

WHEELOCK, INC.

Case Study

State-of-the-Art Veterinary Hospital Secures Premises with Wheelock Multifunctional Facility

When Red Bank Veterinary Hospital, Tinton Falls, NJ, broke ground for the construction of its 58,000-sq.-ft., state-of-the-art medical facility, many structural challenges accompanied the design and construction.

Security World, Inc., Long Branch, NJ, was selected to install, maintain, and upgrade the security and life safety communications network.

"There were numerous issues involved," says Bob Napoli, president of Security World. "Since animals react adversely to sirens, a conventional system utilizing strobe horns would be counterproductive. We also needed to exceed minimal safety standards while maintaining a level of cost."

To meet both criteria, Napoli selected the SAFEPATH® system from Wheelock, Inc., Long Branch, NJ. The system, which combines fire alarm and public address functions, met the key criteria for functionality and cost-effectiveness.

"SAFEPATH® met the hospital's needs for far less than what it would've cost to install separate fire alarm and public address systems," says Napoli. "Plus, the system was easy to install, is readily expandable, and requires minimal maintenance."

The SAFEPATH® system offers the flexibility to deliver prerecorded tones and/or announcements from an on-board microphone or remote microphone station in addition to general paging and voice evacuation messaging. The system combines on-board 24 VDC power for strobes with either 40 or 80 watts of supervised audio or supervised line level output with an 8-tone generator that can be used as an inquiry or preannouncement tone. Two discrete outputs ensure that prerecorded messages can be broadcast over multiple zones simultaneously with mic override capability.

Additionally, NAC circuits automatically respond when the associated audio output circuit is activated. All module inputs and outputs are supervised with on-board circuitry, while the module's circuits are monitored by status relays and LEDs for remote trouble reporting.

"We've already begun to upgrade the system with multiple messaging options designed to address an array of emergencies," says Napoli. "As the facility continues to grow, we can expand the system along with it."

GAMEWELL

Case **Study**

Fire Protection System at Hard Rock Hotel & Casino Is Sure Bet for Maximum Safety

Gamewell
A Honeywell Company
12 Clintonville Road
Northford, CT 06472
203/484-7161
www.gamewell.com

One thing you won't have to gamble on at the Seminole Hard Rock Hotel & Casino Tampa is safety. That's because the entire Hard Rock complex – the 90,000-sq.-ft. casino, 12-story hotel, restaurants, and all back-house operations – feature fire protection systems from Gamewell.

The system was provided and installed by Integrated Systems of Florida, Inc. (ISOF), which became involved in the project as a subcontractor to Terry's Electric, a large, Florida-based electrical contractor. Terry's had been enlisted by the project's primary developer, Perini Suitt.

The installation was a two-phase, fast-track project. In Phase I, 50 percent of the casino and 70 percent of the back-house operations were built from the ground up with ISOF concurrently beginning the installation. Planning and provisions were then made to double the casino while it remained in full operation. In Phase II, 100 percent of the casino and the balance of the back-house operations, along with the 250-room hotel, were brought on line.

At the heart of the system is a Gamewell Identi-Flex 650, a fully featured fire alarm control panel (FACP) that can be configured to monitor and control both analog intelligent addressable devices and conventional hardwire zones, providing the maximum application flexibility and up to 2,016 analog-addressable points. The system also uses the Gamewell Voice (GV) Multiplexed Evacuation System Fire Command Center to provide automatic response to life safety emergencies.

Through the Gamewell GV, fire department authorities can take command of evacuation, relocation procedures, and emergencies from a single fire command center. Furthermore, building management and fire brigades can monitor and control emergency responses even before the professionals arrive.

All of these features and benefits give the Seminole Hard Rock Hotel & Casino Tampa a fire protection system that's a sure bet.

NOTIFIER®

Case **Study**

NOTIFIER's Superior Fire Detection Technology Protects Sony's New Headquarters

NOTIFIER®
12 Clintonville Road
Northford, CT 06472-1653
203/484-7161
www.notifier.com

The Sony Corporation has become synonymous with consumer electronic innovation, and Sony looks for the same technological superiority in its facilities. When investigating fire detection systems for its new, sophisticated, 80,000-square-foot Mexico City headquarters, Carlos Aguilar, Sony Security Manager, put advanced technology as a top priority. Aguilar, who is responsible for the safety and security of all 300+ employees in the new facility, wanted a fire alarm system with strong early-detection capabilities.

After speaking with experts from various security and fire protection associations who offered strong testimonials about NOTIFIER, the world's leading manufacturer of engineered fire alarm systems and part of Honeywell's Life Safety Group, Aguilar turned to Carlos Monroy, president of Conpel S.A. de CV, the local NOTIFIER Engineered Systems Distributor. Together with NOTIFIER, Monroy customized a system that would ensure Sony's specific emergency procedures were followed using the NFS-3030 intelligent Fire Alarm Control Panel, one of NOTIFIER's ONYX™ Series products. Ideal for medium- to large-scale applications, the NFS-3030's modular design can be configured to meet virtually any facility's fire detection and emergency evacuation requirements.

Aguilar was firmly convinced that the most important feature of the NFS-3030 is its early-warning capability through ONYX Intelligent Sensing algorithms. In his opinion, only the NOTIFIER system would provide enough warning in the event of a fire to initiate all of the company's emergency procedures.

Ultimately, the NOTIFIER system blended seamlessly with Sony's business philosophy: to offer the best products to its customers while providing the best working conditions for its employees.

THE RELIABLE AUTOMATIC SPRINKLER

Case Study

The Model DDX Valve by Reliable

The Reliable Automatic Sprinkler Co., Inc.
525 North MacQuesten Parkway
Mount Vernon, NY 10552
800/431-1588
www.reliablesprinkler.com

The Reliable Automatic Sprinkler Company introduces a new deluge valve, the Model DDX, for use as the primary water control valve in deluge, preaction (both single and double interlock), and Reliable's low-pressure dry systems. The DDX is available in 4-in. and 6-in. sizes, with 2-, 3-, and 8-in. versions to come.

The DDX is UL-Listed and FM-Approved for application in these various system types as detailed in Reliable's data sheets. Developed with the latest advances in design technology, the ductile iron valve body is:

- Compact – Takeout dimension for the 4-in. valve is 14 in.; takeout dimension for the 6-in. valve is 16 in.
- Lightweight – The 4-in. valve weighs 64 lbs.; the 6-in. valve weighs 95 lbs.
- Strong – 250 psi working pressure.

The Model DDX is a hydraulically operated differential-type valve. An intermediate chamber is designed into the valve body, eliminating the check valve previously required for other brands and Reliable's Model BX Preaction and LDX Dry Pipe Valve Systems.

Other design features include a single main drain valve, grooved inlet and outlet connections, external reset by rotation of a comfortable hand-fitting knob, and a drop-in seat-and-clapper assembly for future maintenance. The Model DDX Valve requires no priming water for any of its applications. The low-pressure dry system may be hydrostatically tested with the clapper in the closed position.

The trim is designed to be compact and simple, resulting in faster installation, with the valve and trim piping requiring less space. Each complete trim set may be ordered in either a preassembled segmented kit or a loose package. It is also available completely assembled trim to valve, with or without a butterfly control valve. To simplify ordering of the complete trim packages, one part number will provide you with all the trim components necessary for a complete installation.

AGF MANUFACTURING INC.

Case Study

The Pennsylvania State University Selects
AGF Model 1200 REMOTETEST TESTANDRAIN Valve for Sprinkler Retrofits

AGF Manufacturing Inc.
100 Quaker Lane
Malvern, PA 19355
610/240-4900
www.testandrain.com

The January 2000 Seton Hall fire put sprinkler retrofit plans at colleges and universities nationwide into high gear. Administrators – becoming aware of the life safety benefits that sprinklers provide – began including them in most new construction and scheduled residence hall rebuilds. After January 2000, the installation of sprinklers became the driving force for residence hall retrofits.

While these initiatives have created safer environments, they have also posed a challenge for safety administrators: how to provide regularly scheduled system readiness testing for more buildings with limited staff already working at capacity. The solution for The Pennsylvania State University has been to include the AGF Model 1200 REMOTETEST TESTANDRAIN Valve in its sprinkler retrofits.

The first installation was for a five-building dorm complex with 50 individual inspector's test-and-drain valve locations. To provide a precaution against tampering, the test valves were located in locked closets with locked handles.

Now the process of testing goes quickly, taking one person a fraction of the time originally slated for the testing process (two people over several days). The AGF REMOTETEST Valves can be operated in numerous ways, including through the Fire Control Panel (FCP). The University, however, opted to use one auxiliary panel located next to the FCP to control the 50 valves.

The UL-Listed/FM-Approved Model 1200 REMOTETEST meets all NFPA 13 and 25 testing requirements by performing conventional system testing from a single remote location. REMOTETEST has allowed the University to do more frequent testing – with existing staff – than would be possible with standard manual-only test-and-drain valves.

Based on this success, the AGF Model 1200 REMOTETEST Valve has become part of the University's sprinkler specification. They are installed in more than 20 residence halls and are being included in the new Food Science Building Complex and historic McAllister Hall, with more sprinkled buildings being planned each year.

They Learned Fire Prevention at WPI

Advanced Distance Learning Network
Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609
508/831-5220
www.wpi.edu/+ADLN

More than 350 graduates of Worcester Polytechnic Institute's (WPI's) Fire Protection Engineering program are contributing to the broad field of fire prevention and safety worldwide. They educate and train fire safety professionals, provide technical assistance for firefighters, review new construction projects and building design plans, work with developers to assure code compliance, investigate fires, and analyze fire research. Whatever the field of expertise, each graduate aims to make the world a safer place.

Paul Donga

Fire Protection Supervisor, Boston Fire Department's Fire Prevention Division's Plan Review and Acceptance Testing Unit

Paul discovered WPI's FPE program while working for Boston's Building Department. "I wanted to get into the fire code compliance review area, but my background was in electrical engineering," he says. He landed a fire-related job and then entered the FPE program. "I got exactly what I went for at WPI: tools for analysis," says Paul. He uses these tools daily while reviewing building plans and overseeing acceptance testing.

Kenneth Miller

Assistant Fire Protection Engineer, Las Vegas Fire Department

Ken is satisfied with the progress he's helped facilitate in Las Vegas. "There have been documented cases where buildings I've approved have spared many lives and in which the fire sprinkler systems have helped extinguish dozens of fires," he says. "Minimizing life and property loss are the best things you can do with your knowledge."

David Sheppard

Senior Fire Research Engineer, Fire Research Laboratory, Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF), Ammendale, MD

Dave works in a huge laboratory where materials and fluids are regularly set afire so scientists can study their fire- and smoke-related properties. The place is big enough to fit cars, buses, and even reconstructed buildings for studies. Dave serves as a scientific supporter for arson investigations, trainer, and fire researcher.

Excerpted from an article by Eileen McCluskey.

Products/Literature

Pressure-Rated CPVC Fitting Compound

BlazeMaster® CPVC now offers a commercially available CPVC fitting compound with a pressure rating as listed by Plastics Pipe Institute (PPI). The listing represents PPI's recommended hydrostatic design basis (HDB) rating for thermoplastic piping materials or pipe. To be listed, a material must undergo thousands of hours of testing while surviving specific temperatures and elevated pressures unique to the desired HDB rating.

www.blazemaster.com
—BlazeMaster® CPVC

Releasing Panel

Potter Electric Signal Company introduces the new PFC-4410RC Releasing Panel. This water- or chemical-based extinguishing system includes four Class B programmable initiating zones, four programmable Class B outputs, and 20 preconfigured programs. Available with a single- or dual-hazard panel, it is also compatible with 3,500 feet of Protectowire per zone. The same panel may be used to control water or chemical discharge.

www.pottersignal.com
—Potter Electric Signal Co.

Combination Fire/Smoke Damper

Ruskin announces the all-new FSD60 series of high-performance combination fire/smoke dampers. Applications using the roll-formed "60" blade design include front access for fire-rated shafts, which are now required by the International Building Code, grille access, vertical blade, Class I and Class II leakage, tunnel corridor, 11/2 and 3-hr. rated, two-position or modulating control, and out-of-the-floor or wall structures. Single-piece blade design makes it ideal for high-velocity, high-pressure systems. UL-approved for 3,000 fpm duct velocities.

www.ruskin.com
—Ruskin Mfg.

Outdoor Speaker/Speaker Strobe

The new SP201K outdoor speaker and SP2R1224MCK outdoor speaker strobe are UL-listed for temperatures from -40°F to 151°F. Suitable for use in wet locations, the speakers feature either 25 or 70.7 V RMS operation at 1/4, 1/2, 2, and 4 watts. The outdoor speaker strobe has field-selectable candela selections of 15, 15/75, 30, 75, and 110 cd. The strobe can be operated at 12 volts for the 15 and 15/75 selections.

www.systemsensor.com
—System Sensor

Portable Roll Grooving Tool

Victaulic introduces the VE-106 Vic Groove-N-Go portable roll-grooving tool with a self-contained power drive. Lightweight and easy to move around the job site, it streamlines the grooved mechanical joining process. The VE-106 comes equipped with roll sets to groove lightwall and Schedule 40 carbon steel pipe ranging in size from 1-1/4 in. to 6 in. Optional roll sets are available for copper, lightwall stainless steel, and end-seal pipe.

www.victaulic.com
—Victaulic

Non-Magnetic Fire Extinguisher

The ANSUL® CLEANGUARD® Non-Magnetic Fire Extinguisher is a Halon 1211-replacement portable fire extinguisher for use in hazard areas that require reliable, safe, and portable nonmagnetic fire suppression in hazard applications such as MRI facilities, delivery and operating rooms, and labs. Aside from being safe when dispensed around people, CLEANGUARD will not damage critical electronic medical devices. It requires minimal to no clean-up and can be safely stored.

www.tycofireandsecurity.com
—Tyco Fire & Security

CORPORATE 100

4100U Network Fire Alarm System

SimplexGrinnell offers the Simplex® 4100U Fire Detection and Alarm Platform – a high-end, next-generation network system that combines fire protection and information management with lower costs of installation, maintenance, and ownership. Features include expanded point capacity, fast alarm response, state-of-the-art digital voice communications, advanced built-in diagnostics, dual operating software, Internet connectivity, and more.

www.simplexgrinnell.com
—SimplexGrinnell

CORPORATE 100

Emergency Evacuation System

The new, expandable E3 Emergency Evacuation System offers emergency mass notification and evacuation capabilities in addition to basic fire protection. Highly versatile, the E3 can be configured from a small analog panel to a networked broadband voice and audio solution. A peer-to-peer network operating at 625K Baud, the E3 can be arranged as Style 4 or Style 7 using two conductor unshielded wire or fiber cables. The network riser includes paging, firefighter telephones, and input/output capabilities.

www.firecontrolinstruments.com
—Fire Control Instruments

BRAINTEASER

Add punctuation marks so that the following consists of complete sentences and is grammatically correct:

Mary had had I had had had had had had had the teacher's approval

Solution to last issue's brainteaser

In a game of poker, a player is five cards. What is the probability of a player being dealt a "straight flush," i.e., five sequential cards of the same suit?

In each suit, there are 10 possible straight flushes (A, 2, 3, 4, 5; 2, 3, 4, 5, 6; ...; 10, J, Q, K, A). Since there are four suits in a deck of cards, there are 40 possible straight flushes.

There are $\frac{52!}{(52-5)!\times 5!} = 2{,}598{,}960$ possible five-card hands in a deck of 52 cards. Therefore, the possibility of being dealt a "straight flush" is $40/2{,}598{,}960 = 1.92 \times 10^{-6}$ or one in 519,792.

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Changes to U.S.-Based Engineering License Model to Be Considered

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

Previous editions of this column have reported on changes that were being considered to the U.S.-based engineering license model. However, it is becoming increasingly likely that changes will be implemented in the not-too-distant future.

The National Council of Examiners for Engineering and Surveying (NCEES) is an association of licensing boards representing all states and territories in the U.S. Unlike many other countries where engineering licensure occurs on a national basis, engineering licenses in the U.S. are granted by individual states and territories. The NCEES oversees the development and administration of professional engineering examinations on behalf of licensing boards. The Society of Fire Protection Engineers develops the principles and practices of fire protection engineering examination under the auspices of NCEES.

In 2001, the NCEES began considering changes to the licensure model that it recommends to licensing boards. These changes were prompted by two primary concerns:

• NCEES is concerned that advances in engineering technology, coupled with reductions in engineering credit hours required to earn a bachelor's degree in engineering, make a bachelor's degree, in itself, inadequate for protection of public health, safety, and welfare. Specifically, as engineering technology has grown more complex, undergraduate engineering programs have reduced the total number of credits required for graduation while also adding requirements for general studies and humanities courses. NCEES notes that, in the early 1900s, the educational requirements for an engineer exceeded those to become a doctor, lawyer, pharmacist, architect, or accountant. However, the educational requirements to become an engineer now are less than the requirements of those other professions.

• The percentage of engineers who seek professional licensure is low. Across all engineering fields, only approximately 20 percent of all engineers seek professional licensure. Indeed, licensure is only required for engineers who offer services directly to the public. Engineers who work for many types of employers, such as government or industry, do not need to obtain an engineering license. NCEES is concerned that, because many engineers are not required to become licensed, there is no uniform way to assess their competence.

There are two major components to the new licensure model:

• Require 30 postgraduate credits of upper-level undergraduate- or graduate-level course work in professional practice or technical topic areas. This would be in addition to the present licensure requirements for a bachelor's degree from an accredited engineering program, a minimum of four years' experience, and passing the fundamentals of engineering and principles and practices of engineering exams. (Although the specific requirements vary between licensing boards, and some states permit additional years of experience as a substitute for some of the existing requirements.)

• Add additional classifications of engineering licenses. Once an engineer receives a bachelor's degree, he or she would earn the title "graduate engineer." After passing the fundamentals of engineering examination (which would be waived for an engineer who had earned a Ph.D.), the engineer would earn the title "associate engineer." Following four years of experience (three with a Master's degree and two with a Ph.D.), an engineer would earn the title "chartered engineer," a title that would be under the jurisdiction of the licensing board. Only after an engineer met the above requirements, completed 30 credits of post-graduate coursework, and completed a principles and practices of engineering exam would an engineer be licensed as a professional engineer and permitted to offer services directly to the public. NCEES is also considering adding a requirement to take an as-yet-to-be-defined "professional practice examination" as well.

Given that these proposals will be formally acted upon at the NCEES annual meeting this summer, they have a greater likelihood of being realized than other proposals that they have considered. If the NCEES modifies its licensure model, the requirements would need to be adopted by licensing boards to take effect. Formal action by NCEES on these proposals will be reported in a future issue of *Fire Protection Engineering* magazine.

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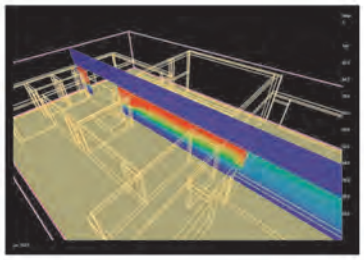

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