

# FIRE PROTECTION Engineering

SPRING 2004

Issue No.22

## ASSEMBLY PROPERTY FIRES

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Deaths occurring during fires in public assembly spaces are tragic, however, "major" fires are not typical of assembly property fires, which tend to have a very low risk of death in most years. This article presents up-to-date statistics about fires in eating/drinking places, religious/funeral properties, amusements places, libraries/museums, theatres/studios, and passenger terminals, and discusses the characteristics of assembly fires.

*John R. Hall, Jr., Ph.D.*

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*Joseph B. Zicherman, Ph.D.*

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This article explores the functional similarities and differences of emergency and nonemergency systems and discusses how and why the systems might be combined.

*National Electrical Manufacturer's Association*

*Cover photo by SuperStock*

Online versions of all articles can be accessed at [www.sfpe.org](http://www.sfpe.org).

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Dear Editor,

Because of the great costs involved, more than 95% of all lawsuits are settled before trial. Dr. Schroeder's article regarding the Fire Protection Engineer's responsibilities in preparing a response to a lawsuit clearly describes the pretrial efforts and the value of well-prepared deposition testimony in reaching a satisfactory settlement. However, pretrial deposition testimony, while it may be very searching in its scope, is not subject to cross-examination. If a case does go to trial, a major difference is that expert's testimony will be subject to cross-examination. If not prepared for it, this can be a very hazardous situation for the expert.

Hazard #1 is failure to recognize that the opposing attorney is an adversary, out to discredit the expert's testimony and destroy his or her credibility as an expert witness. This is also known as impeachment. This adversarial situation is a basic part of the U.S. judicial system and is intended to ensure factual truth. All such proceedings are, of course, included in the trial record and may appear in various reporting services accounts of the case. In replying to cross-examination questions, the expert should answer the question, and only the question, in the briefest possible manner. The expert should never volunteer any additional information.

Hazard #2 is the lawyer who plays the odds. Knowing that most cases settle without trial, some lawyers will attempt to save the expense of hiring an expert until it becomes clear that no settlement is possible. Only then, with the attorney's back to the wall, are the services of a qualified expert requested. Obviously, having little or no factual information available and limited access to what is on the record puts the expert in a difficult situation. In any situation like this, the best choice is usually to decline the case rather than work with a person whose judgment is already suspect.

Hazard #3 is the attorney who doesn't know what he or she doesn't know. In this situation, the technical details need to be explained to the lawyer so that, come testimony time, the proper questions can be asked and in the proper sequence. It is the process of preparing the lawyer, although they may prefer to call it preparing the expert. Either way, it is part of the process of preparation and should be carried out very thoroughly. Expe-

rienced trial lawyers maintain that the three keys to successful litigation are preparation, preparation, and preparation.

Hazard #4 is the fee question. During cross-examination, one of the standard questions opposing counsel will ask relates to how much the expert is being paid for his or her testimony. This implies that the expert's testimony is being bought and is purposely asked in a manner intended to be embarrassing. A reasonable reply is that the expert is being paid for his or her time, not his or her testimony. Another way to avoid this hazard is for the expert to have his or her own lawyer preempt the question by asking it during direct examination. A dependent hazard is that the expert's client loses the case, blames the expert's efforts for the outcome, and refuses to pay.

Any technical expert should remember that their primary function is to convince the decision-makers that his or her point of view is the correct one. The expert must be a credible witness. Experts are simply wasting every one's time if others don't believe them. In that regard, testifying as an expert is something of a selling job, making a believer of the prospect. Experts must have the facts, know that they are correct, and remember that honesty is not only the best but also the only policy.

Thomas A. Hunter, P.E. Ph.D.  
*Principal Consultant*  
*Forensic Engineering Consultants, Inc.*

Dear Editor,

The series entitled "Cry Wolf Syndrome" addressed the concern that those who are bugged by false or nuisance alarms are less likely to respond.

The article on the NEMA perspective was well written as usual, but I think they have missed a crucial issue.

A critical component (mostly missing these days) for fire alarms, real or nuisance, is that those responding to these alarms need to be told what happened. And it needs to be done immediately rather than weeks or months later.

Intuition is the process of learning cause and effect. If you have to evacuate a space and later return to the space without explanation, your assumption will be that there was a

false alarm, regardless of the facts. This response is neither unusual nor unexpected.

Assuming that it was not preplanned (evacuation drill), then if the evacuees are told:

- there was a trashcan fire (real fire), or
- there was a puff of dust from cleaning the lint out of the laundry (nuisance), or
- the ambulance had to take someone away (other emergency), or
- whatever it was, then the future response is much more positive because a learning process has taken place, and intuition is properly developed.

These types of improvements occur in many fields. For example, if you go to the motor vehicles department, then you will see where you are in the queue, giving you much more confidence (after an hour's wait!) that you haven't been forgotten.

Walter W. Jones, Ph.D.

Response

Dr. Jones makes a very good point. In the first part of this article, published in the Fall 2003 issue, it was pointed out that, "In order to reduce the Cry Wolf syndrome associated with fire alarm systems, it is necessary to decrease the ratio of false-to-real alerts. Assuming it is not desirable to increase the number of real alerts, it becomes necessary to decrease the number of false alerts. A second way to minimize the Cry Wolf syndrome is to reduce the impact of false alerts so that they are not perceived as being bad."

In the Summer 2003 article titled "Messaging and Communication Strategies for Fire Alarm Systems," this point was also discussed: "In addition to reducing false and nuisance alarms, there are other ways to increase system accuracy and occupant confidence. One way is to always follow-up any unwanted alarm by communicating to the occupants the reason for the alarm and, if possible, what is being done to prevent further occurrences," and "If every unwanted alarm is followed up with a voice message, the perceived system error is reduced from 100% to 50%."

Robert Schiffliti, P.E.  
*R.P. Schiffliti Associates, Inc.*  
*Author, NEMA Supplement to Fire Protection Engineering*

# Life Safety in Large Assembly Occupancies

**By Jake Pauls**

In the few years following the disasters of September 11, 2001, safety professionals, government authorities, the mass media and the public, among others, have questioned the degree to which buildings are safe and perceived to be safe. With the nightclub disasters of February 2003 the questioning grew. Yet as bad as these disasters were, they may pale in comparison to the potential scale of life loss in a large assembly occupancy.

An occupancy of 15,000 people within a single space of an assembly building is not large relative to the estimated occupancy of the two World Trade Center towers an hour or two before their final destruction. Assembly buildings such as large enclosed stadia can easily hold 75,000 people. But unlike in a typical high-rise building, a great deal of awareness of a particular situation can be communicated instantaneously to almost everyone in a large stadium. The very sightlines that make the building work for an entertainment event can also make almost all occupants vulnerable simultaneously to a real or perceived danger.

Sometimes an emergency condition in an assembly occupancy is treated by spectators as a non-threatening bonus on top of the event they paid to see. One of the classic examples of this behavior was the spectators' response to a fire in a grandstand at a Kentucky Derby; they stayed to watch. The fire in the Bradford, England, soccer grandstand was another example of this but the outcome was disastrous for many caught by the rapid fire growth. But some events, such as the sudden onset

of a severe weather condition for an outdoor place of assembly or the progressive failure of a roof for an enclosed stadium could trigger urgent desires to move out of a seating area. An example of this occurred – fortunately shortly before a major-occupancy event – when an unusual snow load on the Pontiac Silverdome in Michigan caused successive failure of membrane roof panels and destruction of seat sections under tons of crushing snow.

But rapid escape is not an option for which such large assembly buildings are typically designed, constructed or managed. Should they be? Alternatively, what prevention and mitigation measures should be used to assure, as benign, an evacuation time of many minutes or even the unavailability of another place to evacuate to? What form should such prevention and mitigation measures take—facility design, construction, management, etc?

These were the central questions raised in 1983 when the author submitted all of the public proposals for what became the 1986 edition of NFPA 102 including one that suggested an exception to designing means of egress in accordance with the relatively demanding egress capacity requirements of NFPA 101:

"In outdoor grandstands and in very large indoor stadia, for which a professionally conducted hazards evaluation shows that fire and other life safety hazards are sufficiently controlled in all occupied areas and in means of egress, the width of means of egress from large seating areas shall be at least sufficient to permit a flow time not exceeding 10 minutes at any point in the egress system..."

While this performance language was not adopted for the 1986 edition of NFPA 102, the term "Smoke-Protected Assembly Seating" was introduced. Moreover, this term, along with the concept of "Life Safety Evaluation," was adopted – as an option – in the 1988 edition of NFPA 101 for places of assembly occupancy where 2,000 or more people were seated in a single space and egress width per person was reduced. The definition of "Life Safety Evaluation" was: "a written review dealing with the adequacy of life safety features relative to fire, storm, collapse, crowd behavior, and other related safety considerations."

Over several editions of NFPA 101, Life Safety Evaluation was applied to several difficult-to-enforce problems in assembly occupancies including, for example, "Festival Seating." Much additional detail on what constituted a Life Safety Evaluation was introduced to the Annex A of NFPA 101 beginning in the 2000. This detail, in the form of organized topics to consider in doing a Life Safety Evaluation, included the need to consider terrorism, for example, as one type of condition addressed in a facility operations manual.

Today, fire protection engineers (and others) must recognize that a Life Safety Evaluation is not merely an assessment of fire safety. For example, in large assembly facilities, the chance of injury, even death, due to a crowd crush is similar to that due to fire. The extent to which non-fire hazards are given short shrift in the treatment of design, construction and operation for large assembly occupancies raises even more questions that warrant careful examination by SFPE and other organizations concerned about life safety.

*Jake Pauls is an independent consultant in building use and safety. Ideas for this Viewpoint come from his presentation, "Life Safety Evaluation: What is it? How is it used? How is it misused?" in 1994 to the International Association of Assembly Managers (IAAM) Crowd Safety Conference and two years later to the NFPA Fall Meeting. The paper may be downloaded from [www.crowdsafe.com](http://www.crowdsafe.com).*

## Authors Awarded for Paper on Fire Plume and Sprinkler Interaction

On January 23, 2004, The Fire Protection Research Foundation of the National Fire Protection Association (NFPA) presented the third annual William M. Carey Award to the authors of a paper titled "Fire Plume and Fire Sprinkler Interaction." The award was presented at the Foundation's eighth annual Fire Suppression and Detection Research Application Symposium held in Orlando.

The authors are Dr. Richard Lueptow of Northwestern University, and John A. Schwille and Dr. Pravin Gandhi, both of Underwriters Laboratories Inc. The award recognizes the conference's best paper from the previous year, voted by attendees.

In the paper, the authors describe experiments in which the interaction of a fire plume with a sprinkler spray was directly measured. The shape and height of the fire plume was measured using infrared thermography. By measuring both the fire plume and the spray, the authors were able to quantify the degree of fire suppression based on the fire size and the spray characteristics.

The award honors the late William Carey, P.E., senior staff engineer at Underwriters Laboratories Inc. Carey made many major contributions to new fire suppression technologies and served on various technical advisory committees of the Foundation.

For more information, visit [www.nfpa.org](http://www.nfpa.org).

## Four Major Recommendations to Improve Future Building Failure Investigations

In its first annual report to Congress, The National Construction Safety Team (NCST) Advisory Committee made the following four major recommendations to improve future building failure investigations:

- Create an NCST Office within NIST's Building and Fire Research Laboratory with permanent staff and initial funding of \$2 million.
- Establish a safety team investigation research fund of \$2 million to be used at the discretion of the NIST Director to fund investigations when warranted.
- Establish a program to familiarize local and state investigating authorities about the NCST Act.

- Establish a research program investigating the factors affecting human decision-making and evacuation behavior during emergencies in buildings.

NCST is comprised of ten building and fire experts and was established to advise the Commerce Department's National Institute of Standards and Technology (NIST) in its conducting of technical building failure investigations as authorized under the NCST Act.

The 23-page report is available online at [www.nist.gov/ncst](http://www.nist.gov/ncst).

## NIST Reports Current Smoke Alarms Save Lives if Properly Used

A report issued on February 26, 2004, from the Commerce Department's National Institute of Standards and Technology (NIST) states that both types of commercially available home smoke alarms consistently provide people enough time to escape most residential fires. It stresses the need for immediate response to an activated alarm and shows that individuals caught in a flaming fire (as opposed to a smoldering fire) have an average of three minutes from an alarm's first warning to escape.

"The three-minute escape window for flaming fires differs from the 17 minutes NIST recorded in its seminal smoke alarm tests in the 1970s," says Richard Bukowski, the NIST researcher who conducted both studies. "It confirms what fire scientists have recognized for some time: Fires today seem to burn faster and kill quicker because the contents of modern homes (such as furnishings) can burn faster and more intensely. Our new research, however, proves that even with a three-minute warning, smoke alarms still offer enough time to save lives."

The report, "Performance of Home Smoke Alarms: Analysis of the Response of Several Available Technologies in Residential Fire Settings," may be downloaded at <http://smokealarm.nist.gov>.

**Correction:** On page 39 of the Winter, 2004 issue, article "Opportunities to Learn from 9/11," the units for the estimated total jet fuel burning rate over one floor were misstated. The correct units are kg/s. Additionally, the second equation should have read:

$$\frac{28,500\text{kg} - 9,400\text{kg}}{242 \frac{\text{kg}}{\text{s}}} = 79\text{s}$$



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

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# Assembly Property Fires

*By John R. Hall, Jr., Ph.D.*

**O**n February 20, 2003, a fast-moving fire in The Station nightclub fatally injured 100 employees and patrons, most of them otherwise healthy young adults out for a night of fun in West Warwick, Rhode Island. This tragedy was a reminder of the enormous potential for human loss in high-occupancy properties like those collectively described as public assembly. (High-occupancy properties would be any property with a large number of people, whether the density is high or not, and could include stores, offices, and residential properties other than dwellings.)

The assembly fire problem is neither as severe as it tends to seem in the immediate aftermath of one of these horrific tragedies nor as thoroughly tamed as it can seem in the often-lengthy intervals between such incidents. The purpose of this article is to paint a realistic and balanced picture of the assembly property fire problem, so that it can be provided with the urgency it deserves without overreacting or acting precipitously in the pursuit of fire safety.

The following is an overview of what qualifies as a public assembly property, using the categories and terminology of fire incident reporting. These categories have been in existence for a quarter-century and describe individual facilities rather than complexes. Some important types of more recent vintage – such as convention centers – are therefore not explicitly shown.

- Eating and drinking places
  - Restaurants, cafeterias, diners, lunchrooms, snack bars, or drive-ins
  - Nightclubs, bars, taverns, or dinner theaters
- Clubs
  - Country club facilities, primarily clubhouses
  - City club facilities, primarily athletic clubs, such as YMCA
- Religious or funeral properties
  - Places of worship – churches, temples,

- or mosques
- Religious education facilities
- Religious meeting or fellowship halls
- Funeral parlors
- Amusement places
  - Ballrooms or gymnasiums
  - Exhibition or exposition halls
  - Arenas or stadiums, including ball parks, racetracks, or any other place with grandstands
  - Bowling alleys
  - Pool halls
  - Amusement arcades
  - Ice rinks or roller rinks
  - Swimming pool facilities
  - Playgrounds
- Libraries, museums, and courthouses
  - Libraries
  - Museums or art galleries
  - Courthouses or legislative halls
- Theaters and studios
  - Legitimate or motion picture theaters
  - Auditoriums or concert halls
  - Radio, television, or motion picture studios
- Passenger terminals
  - Airport passenger terminals, including heliports
  - Rail terminals serving street-level, underground, or elevated rail systems
  - Bus passenger terminals
  - Marine passenger terminals

**Table 1. 20 Deadliest Single-Building or Complex Fires and Explosions in U.S. History**

	Number of Deaths
1. The World Trade Center New York City, New York September 11, 2001	<b>2,666</b>
2. Iroquois Theater Chicago, Illinois December 30, 1903	<b>602</b>
3. Cocoanut Grove night club Boston, Massachusetts November 28, 1942	<b>492</b>
4. Ohio State Penitentiary Columbus, Ohio April 21, 1930	<b>320</b>
5. Consolidated School (gas explosion) New London, Texas March 18, 1937	<b>294</b>
6. Conway's Theater Brooklyn, New York December 5, 1876	<b>285</b>
7. Rhythm Club Natchez, Mississippi April 23, 1940	<b>207</b>
8. Lakeview Grammar School Collinwood, Ohio March 4, 1908	<b>175</b>
9. Rhodes Opera House Boyetown, Pennsylvania January 12, 1908	<b>170</b>
10. Ringling Brothers Barnum and Bailey Circus Hartford, Connecticut July 6, 1944	<b>168</b>
11. Alfred P. Murrah Federal Building Oklahoma City, Oklahoma April 19, 1995	<b>168</b>
12. Beverly Hills Supper Club Southgate, Kentucky May 28, 1977	<b>165</b>
13. Richmond Theater Richmond, Virginia December 26, 1811	<b>160</b>
14. Triangle Shirtwaist Company New York, New York March 25, 1911	<b>146</b>
15. Eddystone Ammunition Company plant explosion Eddystone, Pennsylvania April 10, 1917	<b>133</b>
16. Cleveland Clinic Hospital Cleveland, Ohio May 15, 1929	<b>125</b>
17. Winecoff Hotel Atlanta, Georgia December 7, 1946	<b>119</b>
18. The Station Nightclub West Warwick, Rhode Island February 20, 2003	<b>100</b>
19. Our Lady of the Angels School Chicago, Illinois December 1, 1958	<b>95</b>
20. Happy Land Social Club New York, New York March 25, 1990	<b>87</b>

Source: NFPA archive files, 1984 Fire Almanac, and *The Great International Disaster Book*, by James Cornell, Pocket Books, New York, 1976.

Half of the 20 deadliest fires in U.S. history that were limited to a single building or complex (see Table 1) involved public assembly properties, beginning with the second deadliest (after the World Trade Center event of 9/11/2001), which was the 1903 Iroquois Theater fire where 602 people lost their lives. Others of historic size, listed in order of most deaths, were the 1942 Cocoanut Grove night club fire (third deadliest, 492 deaths), the 1876 Conway's Theater fire in Brooklyn (sixth, 285), the 1940 Rhythm Club fire in Mississippi (seventh, 207), the 1908 Rhodes Opera House fire in Pennsylvania (ninth, 170), the 1944 circus fire in Hartford, Connecticut (tenth, 168), the 1977 Beverly Hills Supper Club fire (twelfth, 165), the 1811 Richmond Theater fire (thirteenth, 160), The Station (eighteenth, 100), and the 1990 Happy Land Social Club fire (twentieth, 87). In the last 45 years, the only fires on this deadliest list have been assembly fires and terrorist attacks (World Trade Center in 2001 and Oklahoma City in 1995).

**Table 2. Fires in Eating and Drinking Establishments and Clubs Structure Fires Reported to U.S. Municipal Public Fire Departments**

Year	Eating places	Drinking places	Unclassified or unknown-type eating or drinking places	Loss in all eating and drinking places (Millions)	Clubs
1980	16,700	6,200	300	\$188.4	3,000
1981	16,100	5,700	600	\$176.1	2,500
1982	14,900	5,300	1,500	\$211.6	2,100
1983	12,400	4,600	1,200	\$203.4	1,800
1984	12,100	4,000	1,400	\$193.4	1,600
1985	13,400	4,200	1,400	\$210.0	1,900
1986	11,300	3,500	1,200	\$126.0	1,600
1987	11,400	3,100	1,100	\$129.3	1,500
1988	10,100	2,500	900	\$178.2	1,300
1989	9,000	2,300	1,000	\$145.5	1,200
1990	8,600	2,300	900	\$172.5	1,100
1991	8,700	2,200	800	\$174.2	1,100
1992	8,900	2,000	900	\$191.7	1,100
1993	8,400	1,900	900	\$162.8	1,100
1994	8,900	1,700	1,000	\$167.2	1,100
1995	8,300	1,500	800	\$129.3	900
1996	8,600	1,600	1,000	\$171.0	1,100
1997	8,600	1,600	1,100	\$172.5	900
1998	8,400	1,600	800	\$175.6	1,700
1999	8,400	1,500	900	\$199.7	1,200

Source: NFPA national estimates based on NFIRS and NFPA survey.

However, these historic-sized major fires are not typical of assembly property fires, which tend to have a very low risk of death in most years. And the assembly category contains as many differences as similarities. In this limited space, only the high points of trends and patterns can be addressed.

### EATING AND DRINKING PLACES AND CLUBS

In a typical year, most public assembly structure fires and associated losses involve eating or drinking places. Table 2 shows the trends in these fires since 1980. Fires in eating places (e.g., restaurants, cafeterias) declined by roughly half from 1980 to 1999, while fires in drinking places (e.g., nightclubs, bars) declined by roughly three-fourths in the same period. As the Station fire illustrated, the deadliest fires in these properties tend to be in drinking places, but in a typical year, eating places account for far more fires and slightly more fire deaths than drinking places. Table 2 also shows that assembly fire property loss is consistently in the nine-digit range but shows no consistent increase, whether or not one adjusts for inflation.

As part of references developed in connection with the Station night club fire, NFPA posted on its Web site a list of the 10 deadliest foreign nightclub fires since 1970 (see [www.nfpa.org/Research](http://www.nfpa.org/Research)). Five were in Asia, including a year 2000 disco fire in China where 309 died. Four were in Europe, of which the 1998 Swedish disco fire in Gothenburg was only the third deadliest. The tenth fire on the list was in South America, specifically Venezuela. (Identification and characterization of fire incidents is done using fire incident reports and reports from other responsible agencies, as contained in NFPA's in-house databases on major fires of technical interest. For some foreign incidents, the only details available are from news sources.)

As for the comparison of eating places to drinking places, the risk per facility of fire is slightly higher in drinking places, and the risk of death in a given fire is also higher in drinking places. In 1999, fires in eating places outnumbered fires in drinking places by roughly six to one. In 2000, eating

places outnumbered drinking places by about eight to one. This reflects 192,000 full-service restaurants, 211,000 limited-service eating places, 29,000 specialty food services, and 51,000 drinking places. (Source: U.S. Census Bureau, *Statistical Abstract of the United States: 2002*, Table 1244, establishments with payroll.)

Clubs other than nightclubs are coded separately in U.S. fire statistics, and Table 2 also shows the trends for structure fires in country clubs and city clubs. There is some ambiguity in coding between clubs and nightclubs. However, if the fires for drinking places comprise some or all of the fires associated with clubs, then drinking places have a higher risk than determined above for eating places.

### RELIGIOUS OR FUNERAL PROPERTIES

After eating and drinking places, the

largest share of public assembly structure fires occur in religious or funeral properties. Very few of these fires involve funeral properties, and most specifically involve churches, mosques, temples, or other places of worship. Although confirming documentation is thin, the deadliest single-building fire in world history is believed to be the 1863 fire at the Church of La Compañía, Santiago, Chile, where 2,500 people are reported to have died.

Table 3 indicates that structure fires in these properties declined by nearly half from 1980 to 1999. Special attention is given to intentional fires in Table 3. A national furor erupted in 1996 around allegations of sharp increases in church arson, and specifically in fires set for motives of religious or racial hatred. A National Church Arson Task Force was formed in June of that year, and federal agencies led by the Bureau of Alcohol, Tobacco, and Firearms (ATF) increased their support to local law enforcement,

**Table 3. Total and Intentional Fires in Religious or Funeral Properties Structure Fires Reported to U.S. Municipal Public Fire Departments**

Year	All fires	Intentional fires	Intentional as percent of all fires	Loss in all fires (Millions)	Loss in intentional fires (Millions)
1980	3,500	1,300	38%	\$62.1	\$39.9
1981	3,300	1,300	40%	\$79.2	\$34.5
1982	3,300	1,100	32%	\$43.3	\$18.3
1983	2,800	1,000	36%	\$114.0	\$21.0
1984	2,900	1,100	38%	\$50.4	\$29.0
1985	3,000	1,000	34%	\$60.5	\$28.4
1986	2,800	900	32%	\$51.5	\$29.0
1987	2,700	800	31%	\$51.7	\$29.5
1988	2,400	700	30%	\$69.0	\$25.0
1989	2,200	700	31%	\$59.0	\$30.0
1990	2,100	600	30%	\$62.1	\$21.4
1991	2,100	700	33%	\$56.9	\$30.1
1992	2,200	600	29%	\$70.7	\$33.2
1993	2,000	600	28%	\$57.7	\$26.6
1994	2,000	500	24%	\$60.7	\$18.5
1995	1,900	500	24%	\$52.1	\$24.7
1996	2,200	600	26%	\$62.1	\$19.5
1997	2,000	400	20%	\$43.6	\$12.3
1998	1,900	400	20%	\$68.4	\$25.5
1999	2,000	400	20%	\$110.8	\$32.1

Source: NFPA national estimates based on NFIRS and NFPA survey.

while also initiating a program of more intensive and routine investigations of fires at places of worship.

Table 3 shows that 1996 did involve a jump in intentional fires in religious or funeral properties but also a jump in unintentional fires in those properties. However, 1996 proved to be a singular anomaly. The 1996 jump was more than reversed in 1997, and the long-term trends have been down, not only for numbers of intentional and total fires in these properties but also for the intentional share of their fires, which has fallen by roughly half (from 38%-40% to 20%). The ATF investigations of fires in 1995-1999, meanwhile, found the same mix of motives, most of them not involving any type of hate motive, as are traditionally found in arson cases for all types of properties.

There are roughly 310,000 places of worship in the U.S., of which only about 2,000 are mosques and only about 3,000 are Jewish temples. (Source: U.S. Census Bureau, *Statistical Abstract of the United States: 2002*,

Table 63, plus miscellaneous Web site sources for estimates related to mosques.) While there is substantial information on numbers of facilities by denominations, including the scores of distinct Christian denominations, the fire incident databases do not distinguish by denomination, and so it is not possible to make fire risk comparisons between denominations.

Also, while worship are frequently perceived as older buildings, many communities of worship, and even a number of whole religious denominations, are of comparatively recent vintage. It is not clear from readily available statistics whether religious properties are older on average than other types of buildings.

Table 3 also shows trends in property damage in total fires and intentional fires for these properties. In a typical year, the average loss per fire is higher for religious or funeral properties than for other types of assembly properties or for most other property use categories generally.

## AMUSEMENT PLACES

Amusement places range from large arenas or stadiums, ballrooms or gymnasiums, and exhibition halls, down to playgrounds, bowling alleys, pool halls, ice rinks, and roller rinks. The diversity of design and function may be greater than for any other class of properties, and nearly half the amusement place structure fires in a typical year are reported as unclassified or unknown-type fixed or variable amusement place. Table 4 shows the trend for these fires, which declined by nearly two-thirds from 1980 to 1999.

The deadliest amusement place fire in U.S. history – the Connecticut circus tent fire cited above – shares some characteristics with the deadliest amusement place fires in recent world history. Most are not traditional buildings. In 1995, a tent fire in India, reported by news accounts as having only one exit for 1,500 occupants, was the site of a fire that killed 538 people. Better documented were the exiting problems of the open-air Bradford, UK, soccer stadium fire in 1985, where 56 people died. A second India tent fire, this one in 1981 with 58 dead, and another UK fire, this one intentionally set outside a London entertainment complex, resulting in 50 deaths, complete the list of deadliest world fires in amusement places since 1970.

The number of facilities varies widely by type of amusement place, and comprehensive figures have proven elusive. There are roughly 1,300 stadiums, 600 convention centers, 2,200 amusement arcades, 5,200 bowling centers, 23,000 fitness and recreational centers (e.g., gymnasiums), and 4,500 spectator sports companies, including 900 race-tracks. (Source: U.S. Census Bureau, *Statistical Abstract of the United States: 2002*, Table 1210, for establishments with payroll, except for the first two statistics, which were taken from miscellaneous Web site sources.)

This leads to perhaps the most surprising finding for this type of assembly property. Six of the seven costliest U.S. amusement place fires since 1970 – those involving \$10 million in direct damage before adjusting for inflation – were at racetracks, even though none of the fires reported any damage to expen-

**Table 4. Fires in Other Public Assembly Properties**  
**Structure Fires Reported to U.S. Municipal Public Fire Departments**

Year	Amusement places	Libraries, museums, and courthouses	Theaters and studios	Passenger terminals
1980	4,400	700	1,200	400
1981	4,100	600	1,100	400
1982	3,800	600	800	400
1983	3,300	400	800	300
1984	3,300	600	800	300
1985	3,200	600	700	300
1986	2,800	600	600	300
1987	2,700	500	600	300
1988	2,300	400	500	300
1989	2,000	500	500	200
1990	1,800	400	500	200
1991	1,900	500	400	300
1992	1,900	400	400	200
1993	1,700	400	400	200
1994	1,900	400	400	200
1995	1,800	400	300	200
1996	1,900	400	300	200
1997	1,700	400	300	200
1998	1,600	300	300	100
1999	1,600	400	300	200

Source: NFPA national estimates based on NFIRS and NFPA survey.

sive racehorses or other racing animals. (The seventh was a jai alai fronton.) There was also a Mexican racetrack fire in this loss range during this period.

As with the deadliest amusement place fires, racetracks are not traditional buildings. None of these facilities have the kind of compartmentation provisions associated with traditional buildings, and it may be that all of their design and usage choices – from the materials used in construction to the materials used in contents and furnishings to the absence of sprinklers – are such as to support rapid fire development and spread, particularly given unlimited access to fresh air to feed the fire. If this kind of fire potential is combined with the exiting problems repeatedly cited in

the deadliest incidents, such as the earlier-cited India tent fire, the potential for catastrophe seems clear.

These are not new concerns. The NFPA *Life Safety Code*®, for example, has detailed requirements for tents, grandstands, and other features that characterize these unusual properties. The problem, as usual, is in achieving compliance.

### LIBRARIES, MUSEUMS, AND COURTHOUSES

Table 4 shows that fires in libraries, museums, courthouses, and like properties declined by one-third to one-half from 1980 to 1999. This is a less dramatic decline than for the other assem-

bly properties, but the numbers were already fairly low. Prior to 1999, this category was also used for fires in historic buildings, but that status is now treated separately, as is more appropriate. In a typical year, libraries account for by far the largest share of these fires, with museums and courthouses having comparable numbers.

The properties in this category are especially likely to have highly vulnerable contents, although managers may well overestimate the potential damage from water (e.g., sprinklers) relative to the potential damage from fire. The properties in this category are also especially likely to have cultural heritage safety objectives, in addition to and possibly weighted more heavily than

**Table 5. Characteristics of Fires in Selected Public Assembly Properties – Annual Averages of 1994-1998 Structure Fires Reported to U.S. Municipal Public Fire Departments**

Characteristic	Eating places	Drinking places	Clubs	Religious or funeral properties	Amusement places	Libraries, museums, and courthouses	Theaters and studios	Passenger terminals
Percent with indicated major cause								
Cooking	47.7%	14.3%	10.9%	8.9%	7.0%	6.5%	15.5%	5.0%
Intentional	7.5%	28.3%	20.9%	22.1%	38.3%	25.1%	19.2%	18.7%
Electrical distribution	12.1%	18.4%	11.5%	17.5%	13.4%	21.0%	21.2%	11.6%
Smoking	3.9%	8.5%	14.4%	2.3%	5.2%	4.3%	6.1%	23.7%
Heating	6.3%	6.2%	8.7%	11.6%	7.2%	8.9%	5.4%	3.0%
Open flame (e.g., torch)	3.1%	4.6%	6.8%	7.4%	6.4%	8.8%	7.9%	11.5%
Natural causes	1.6%	1.1%	2.6%	5.4%	2.0%	3.9%	2.2%	1.0%
Percent with indicated active system present								
Sprinkler present	32.6%	12.0%	35.8%	4.6%	16.7%	28.0%	34.6%	34.7%
Detector present	44.5%	26.6%	57.4%	39.1%	31.6%	67.1%	50.5%	47.1%
Percent with indicated type of construction								
Fire-resistive	7.8%	4.2%	21.4%	6.9%	11.2%	18.9%	15.4%	42.7%
Noncombustible	13.8%	7.2%	12.8%	9.0%	17.6%	20.9%	27.0%	21.4%
Ordinary	46.1%	44.6%	33.1%	40.0%	33.7%	35.3%	38.6%	20.3%
Protected wood frame	15.9%	16.4%	11.9%	18.3%	7.6%	7.5%	6.7%	2.1%
Unprotected wood frame	13.8%	24.4%	17.2%	20.7%	20.2%	11.7%	7.4%	6.6%
Percent with indicated area of fire origin								
Means of egress	1%	5%	4%	7%	5%	8%	13%	14%
Concealed space, duct, shaft, chimney, or elevator	11%	16%	11%	17%	12%	17%	10%	17%
External surface	9%	19%	9%	13%	10%	8%	10%	8%

Notes: Electrical distribution includes wiring, cords and plugs, switches and outlets, lighting fixtures, signs, and overcurrent protection devices. Ordinary and noncombustible each include protected and non-protected construction.

Source: NFPA national estimates based on NFIRS and NFPA survey.

the traditional human and property loss objectives. These same heritage considerations may restrict fire protection options. Use of a standard tailored to these special properties is highly recommended, as is explicit engineering design, since each of these properties tends to have unique concerns.

There were roughly 4,000 museums and 32,900 libraries in the United States in 2000. (Source: U.S. Census Bureau, *Statistical Abstract of the United States: 2002*, Tables 1210 and 1130, the former counting establishments with payroll.)

## THEATERS AND STUDIOS

Table 4 shows the number of structure fires in theaters and studios has declined by about three-fourths, one of the largest declines among assembly properties. In this case, that decline may be partially driven by contraction in the industry. For example, using comparable data, the number of motion picture theaters declined from 7,800 in 1987 to 5,900 in 2000. (Source: U.S. Census Bureau, *Statistical Abstract of the United States: 2002*, Table 1098, and 1990, Table 1380, both establishments with payroll.) There were 9,300 performing arts companies in 2000, but it is not clear how many theater facilities they represented. (Source: U.S. Census Bureau, *Statistical Abstract of the United States: 2002*, Table 1210.)

Theaters have also become smaller in size over the years, with the advent of suburban multiplexes as a more flexible delivery system for matching capacity to variable demand. Looking back in time, however, it is clear that the list of the deadliest single-building fires is dominated by theater fires. Elsewhere in the world, high fire death tolls in theaters are not yet a thing of the past. Since 1970, seven theater fires have killed at least 50 people each. In Iran in 1978, according to newspaper accounts, terrorists locked all doors before igniting a gasoline fire outside, killing 422 people. In China in 1994, according to newspaper accounts, seven of eight exits were locked and barred, as 385 people were killed in that fire. In Italy in 1983, newspaper accounts say 10 exit doors were locked as 64 people died in a fire. In India in 1997, fire spread through air conditioning ducts and other routes, trapping most

victims in a balcony; in all, 57 people died. The other three fires are not necessarily different, only undocumented.

## PASSENGER TERMINALS

Table 4 shows terminal fires declined by one-half to three-fourths from 1980 to 1999. Roughly half these fires in a typical year involve airport terminals. The other half split roughly two to one for rail vs. bus terminals.

By contrast, there were 19,100 airports in 1999 compared to roughly 2,900 rail stations and perhaps 2,000 bus stations. (Source: U.S. Census Bureau, *Statistical Abstract of the United States: 2002*, Table 1045, for airports; American Public Transportation Association Web site for rail.) The largest bus carrier had 1,600 terminals and sales agencies, according to its Web site, and no data were available for other carriers. By any estimate, then, airport terminals account for far more than half of all passenger terminals.

Most airport terminals are small terminals, serving corporate jets or other small planes, but even these are comparable to a typical rail or bus terminal, and the largest municipal airport terminals have no counterparts among other ground or air transportation. Marine passenger terminals account for very few fires, and data were not available on the number of such facilities.

## CHARACTERISTICS OF ASSEMBLY FIRES

Cooking fires are, not surprisingly, the leading cause of eating-place fires, but it may be more surprising that the second leading major cause is electrical distribution equipment. (See Table 5.) Intentional fires are a distant third, accounting for one of every 14 eating-place fires.

Intentional fires are the leading cause in most other assembly property groups, except for theaters and studios, where they rank second to electrical distribution equipment fires, and passenger terminals, where they rank second to smoking-material fires. Intentional fires represent a large share, however, only in amusement places, where they accounted for roughly two of every five fires. Intentional fires accounted for about one-fourth of fires in

drinking places; libraries, museums, and courthouses; and religious or funeral properties.

Sprinklers (or other automatic suppression equipment) were reported present in one-fourth to one-third of reported public assembly structure fires, except for amusement places (one-sixth), drinking places (one-eighth), and religious or funeral properties (less than one in 20). In some communities, the Constitutional separation of church and state has been invoked as a barrier to the application of fire protection requirements on places of worship. This has not been an issue in the writing of code requirements, but in some regions and communities, it has reportedly been an issue in achieving enforcement.

Detectors are more in evidence in all types of assembly properties. Fire detectors were reported present in roughly one-half to two-thirds of reported public assembly structure fires, except for amusement places and religious or funeral properties (one-third) and drinking places (one-fourth).

Fire-resistive construction is commonplace in passenger terminals (nearly half of reported fires) and not unusual in clubs (one in five). Unprotected wood frame construction accounted for one-fifth to one-fourth of reported structure fires in drinking places, religious or funeral properties, and amusement places. Drinking places and religious or funeral properties often combined an absence of sprinklers with the use of more vulnerable construction materials.

Fires originating in means of egress can complicate safe escape. Such fires constituted a substantial share of fires in most assembly properties, particularly theaters and studios and terminals, where they accounted for one of every seven fires. Designers should provide for safety in assembly place fires for instances when a major escape route is cut off by fire.

Fires originating in concealed spaces or outside the building can be outside the effective range of sprinklers, detectors, and even compartmentation. A high percentage of assembly property fires originated in such locations, particularly drinking places and religious or funeral properties, where they accounted for one of every three fires. Designers should consider how safety would be

provided for instances when fire begins outside the usual occupied spaces.

### THE FUTURE

Assembly properties account for about 15,000 to 20,000 reported structure fires per year, but the numbers have dropped substantially over the past two decades. Deaths are few in a typical year, and most of the total deaths in assembly fires over the past two decades have occurred in a handful of extremely serious fires, specifically in nightclubs. Codes and standards have addressed the hazards that led to the worst incidents of the past, but compliance is still less than perfect, and the potential for a death toll in the hundreds still exists in thousands, if not tens of thousands, of facilities.

Each type of assembly property has its own special problems and vulnerabilities that justify continued close attention, because all assembly properties share the high potential for life loss

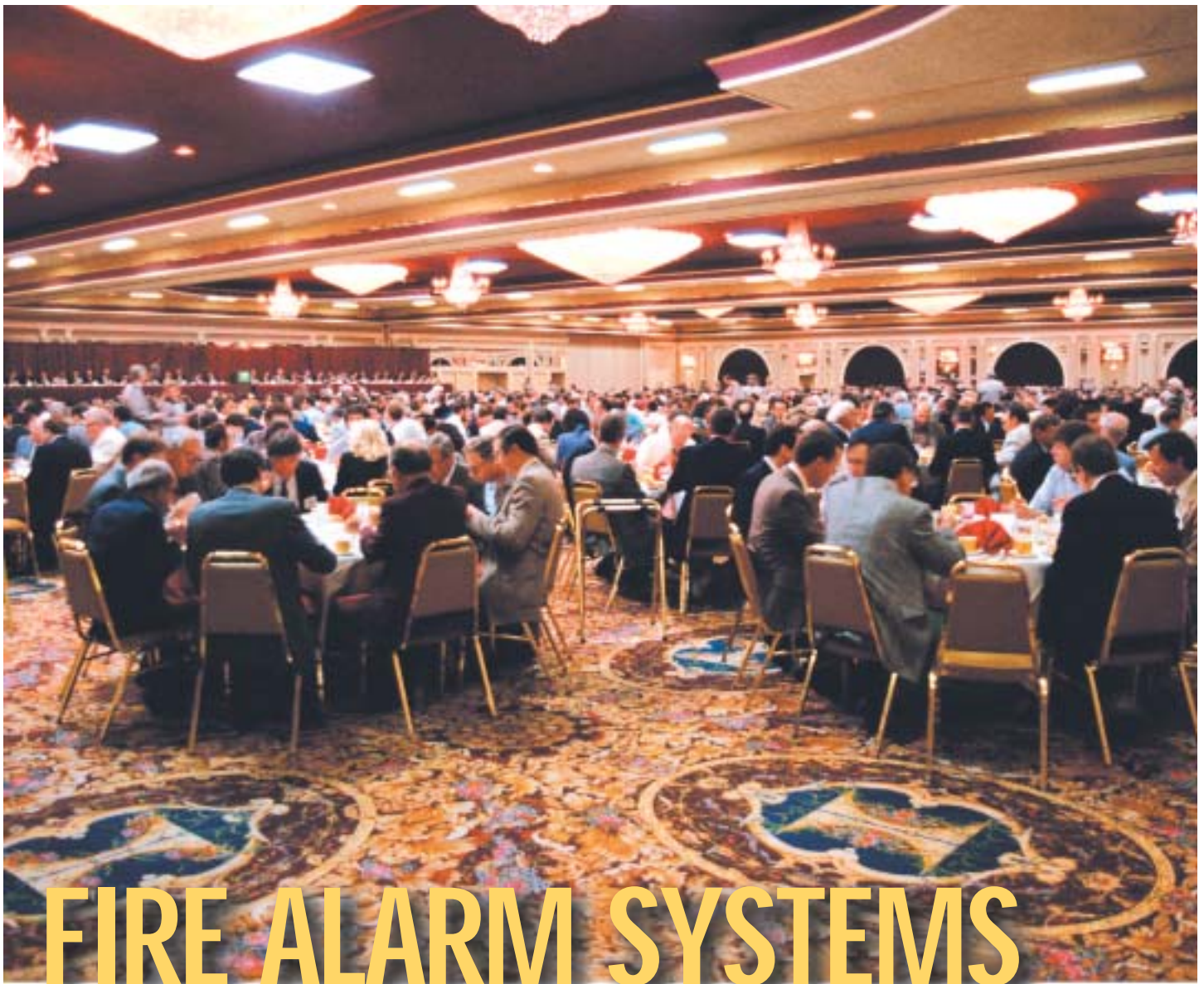
that comes automatically with high occupancy. Assembly property fires have involved even greater tragedies in many foreign countries, and these serve as a reminder of the importance of maintaining, reinforcing, and extending the controls that have been developed over the past century.

In the new world of performance-based design, applications to assembly properties need to be done with great care. Predictions of death tolls tend not to be robust, with huge variations possible from small changes in assumptions, because the predictions are extremely sensitive to the timing of occupant escape from threatened spaces and of the development of life-threatening conditions in those spaces. Safety factors can be used to reduce this sensitivity to specific conditions and assumptions, but the knowledge required to set those safety factors is thin for many key phenomena. Large shares of fires in these properties begin in places that are difficult to model

(e.g., concealed spaces) and difficult to control through conventional fire protection methods, whether active or passive. Exiting provisions are especially critical, and deficiencies in exiting provisions, whether inadvertently or through hostile action, are a recurring part of the deadliest assembly fires.

Many of the thousands of nonfatal assembly fires each year are near misses that very easily could have been major tragedies. Long periods of complacency alternating with punctuated moments of national panic are no way to make wise decisions about safety choices and their engineering consequences, but at the same time, it is not unreasonable to assume, as the public tends to do, that any major tragedy that could have been prevented should have been prevented. The historical record is there to help. ▲

*John Hall is with the National Fire Protection Association.*



# FIRE ALARM SYSTEMS

## Serving Assembly Occupancies: Looking Beyond Specifications

*By Jorge Velasco &  
Edward L. Fixen, P.E.*

**R**ecent nightclub tragedies have highlighted the need to revisit fire safety in nightclubs and other assembly occupancies in general. Among the many factors affecting fire safety in assembly occupancies, fire alarm systems play an important role in protecting people.

Assembly occupancies are characterized by a high concentration of people resulting in relatively high occupant loads in small and large buildings alike. This high-density, high-occupant load characteristic requires special fire safety consideration such as egress design, crowd management, human behavior, and adequate fire protection, among other factors. Additional factors such as security, special effects, and high ambient background noise levels are also among the factors that must be considered in the design of fire alarm systems serving various assembly uses.

**Table 1. Select Fire Alarm System Requirements for Assembly Occupancies**

Fire Alarm System Requirement	NFPA Life Safety Code <sup>8</sup> or NFPA 5000 Building Code <sup>7</sup>	International Building Code <sup>6</sup>
When Required	Occupant Load > 300	Occupant load > 300
Means of Initiation	Manual or sprinkler operation	Manual or sprinkler operation
Emergency Voice Alarm	Required when occupant load > 300	Required when occupant load > 1,000
Positive Alarm Sequence (See Note 1)	Permitted with approval of AHJ	Permitted with approval of AHJ
Access Control Egress Doors (See Note 2)	Permitted on any egress door, except when the building is occupied	Permitted on the main entrance/exit door only, except when the building is occupied
Delayed Egress Doors (See Note 3)	Permitted in light and ordinary hazard uses at exit doors other than main entrance/exit when building is fully sprinklered or provided with fire detection throughout	Not permitted in assembly occupancies

1 Positive alarm sequence is a manually initiated delay in the operation of an automatic alarm or voice alarm system for up to 180 seconds to permit investigation of the alarm signal. The alarm will automatically operate if the fire alarm system is not reset prior to the end of the delay period.

2 Access control egress door is an exit door that is locked by the access control system on the nonegress side but automatically unlocks upon operation of a sensor, loss of power, panic hardware, mechanical release device, or activation of the building fire alarm system.

3 Delayed egress door is a locked exit door that releases the locking mechanism within 15 seconds of operation of the door release device (typically panic hardware) or releases without delay upon loss of power or activation of the building fire alarm system.

A complete discussion of fire alarm systems serving assembly occupancies involves many complicated issues ranging from systems design to human behavior considerations to new detection and notification technologies. Many of these fire alarm system design issues and considerations are common to all occupancies and have been discussed in previous editions of *Fire Protection Engineering*.<sup>1,2,3,4,5</sup> This article specifically focuses on the characteristics of assembly occupancies that present significant fire protection engineering challenges to the design of fire alarm systems serving these occupancies. With these challenges in mind, this article is a high-level overview of key considerations and challenges involved in the design of fire alarm systems serving assembly occupancies.

### BASIC FIRE ALARM SYSTEM REQUIREMENTS FOR ASSEMBLY OCCUPANCIES

Generally, the *International Building Code*,<sup>6</sup> *NFPA 5000*,<sup>7</sup> and the *NFPA Life Safety Code*<sup>8</sup> require fire alarm systems in assembly occupancies with 300 or more occupants. The means of detection and notification differ slightly, but these codes have similar overall protection philosophies. While specific fire alarm system requirements must be individually evaluated based on the specifics of the project, Table 1 summarizes select assembly occupancy fire alarm system requirements based on each code.

In all cases, the standard for the design and installation of fire alarm systems is the *National Fire Alarm Code* (*NFPA 72*).<sup>9</sup>

### DESIGN CHALLENGES

Within the assembly occupancy classification, there are numerous uses that each has special considerations unique to that use. Assembly uses include airports, arenas, casinos, churches, cinemas, entertainment parks, exhibit halls, nightclubs, restaurants, theaters, and stadiums, to name a few. Similar to the many assembly uses, the characteristics and challenges related to design of fire alarm systems serving these various assembly occupancies are numerous. Some of the more common issues ad-

ressed in this article include:

- Balancing Security with Fire Safety
- Special Effects
- Notification Effectiveness
- Systems Integration

Many other issues, such as preventing nuisance/false alarms, for example, are important in the overall design process and require special consideration, but are beyond the scope of this article.

### BALANCING SECURITY WITH FIRE SAFETY

The locking of exit doors is always of primary concern and is particularly critical in assembly occupancies. While fire alarm systems cannot directly prevent the inappropriate locking of exit doors, well-designed integration of the security and fire alarm systems can help reduce

the occurrence of locked exit doors by removing the need for owners/operators to illegally lock exit doors.

The use of delayed egress doors at exit doors that are not part of the day-to-day circulation can help to reduce the undesirable behavior of owners/operators locking secondary exit doors in an attempt to prevent unauthorized en-

try. The concept is similar to the benefit of providing automatic hold-open devices at fire doors in common circulation paths to prevent the doors from being blocked open. While the use of delayed egress doors in assembly occupancies must be considered carefully to avoid potential crushing incidents or undesirable crowd behavior, it can be a

useful design approach to reduce the occurrence of illegally secured exit doors in many circumstances. Secondary exits located in back-of-house and/or unsupervised locations are candidates for delayed egress doors to avoid unwanted locking of exit doors. The use of delayed egress doors will require that the entire facility be provided with an early warning fire detection system throughout the building, in addition to other required fire protection systems. The installation of an early warning system throughout the building should result in improved detection time within the assembly occupancy and more than offset the 15-second delay associated with delayed egress doors.

While design of security systems may not be the responsibility of the fire alarm system designer, coordination with the security system and consideration of fire alarm design approaches that facilitate anticipated security measures must be performed.

## SPECIAL EFFECTS

The use of pyrotechnics, theatrical smoke, and other special effects are common in many assembly occupancies, particularly theaters, nightclubs, and concert venues. Besides the inherent fire safety problems, special effects create one of the greatest challenges to the operation of fire alarm systems in assembly occupancies that use special effects. A fire alarm system is designed to detect the same signatures created by pyrotechnics and many special effects. The use of special effects often leads to fire alarm detection systems being temporarily disabled to prevent nuisance alarms. Should the fire detection system be temporarily bypassed for the purpose of special effects, the impairment itself should be electrically supervised to assure that the system is restored as soon as possible and not inadvertently left in the bypass mode. However, the use of special effects not only inhibits the detection system but may negatively affect or impair visual notification systems as well.

The conflict between pyrotechnics/special effects and early warning detection systems highlights the need to be able to rely on fire sprinklers monitored

by the fire alarm system in assembly occupancies using pyrotechnics and other special effects. Fire sprinklers are not prone to the nuisance alarms caused by special effects. The installation and monitoring of automatic sprinkler systems provide a more robust and reliable means of detection in a special effects environment. However, the lack of or disabling of fire detection systems when special effects are used potentially creates a conflict when delayed egress doors or other systems require early warning systems to initiate an auxiliary function such as releasing delayed egress door locks. This issue needs to be carefully reviewed prior to reaching a final design concept.

Clearly, there is no simple answer to the best fire safety solution when pyrotechnics or special effects are involved. It is suggested that there is a need for a detailed fire safety evaluation that addresses the design of the fire alarm system and other critical fire safety considerations when pyrotechnics are used in

an assembly occupancy. Similar to considerations of potential security measures, the potential impact of special effects and related operational behavior should be anticipated and addressed by the fire alarm system designer in assembly occupancies.

## NOTIFICATION EFFECTIVENESS

Perhaps the most prevalent fire alarm system design challenge common to most, if not all, assembly occupancies involves the design of an effective occupant notification system. Even the most effective fire detection system has little value if the notification system fails to evacuate occupants. In order for fire alarm notification systems serving assembly occupancies to be effective, two things must happen. First, the evacuation information must be clearly understood. Second, the evacuation message must provide meaningful information that will motivate the occupants to follow evacuation directions. To achieve

this, an emphasis must be placed on both the intelligibility of voice alarm systems and the content of emergency evacuation information given to assembly occupants.

Places of assembly are often associated with intermittent or constant high ambient background noise, particularly in places such as nightclubs, concerts, and sporting events. The effectiveness of audible alarm systems for these uses requires special consideration in order to be intelligible. Fire alarm systems can shutdown building systems, but not a loud or cheering crowd. Therefore, the signal-to-noise ratio in these circumstances must be adequate to overcome the high level of ambient noise.

However, just being louder than the crowd is not enough. In fact, many times it is because a system has been designed to overcome high ambient noise levels without regard to distortion or reverberation that the signal becomes unintelligible. Accordingly, the design of a notification system must address dis-

tortion and reverberation in addition to audibility to be intelligible. If any one of these three factors is not addressed adequately, the intelligibility of the notification system will be unclear and insufficient to effectively evacuate occupants. These factors require consideration of signal strength for sound pressure levels, speaker distribution at appropriate power settings for clarity, and evaluating the acoustical nature of the protected space for potential reverberation. For further guidance and detailed discussion on intelligibility as it relates to fire alarm system design, refer to the Annex of the *National Fire Alarm Code (NFPA 72)*.<sup>9</sup>

The issue of intelligible audibility is heightened in large assembly buildings where high ambient background noise and large spaces with high ceilings can require alarm audible levels often near the upper decibel limits of safe audibility. Often, this situation is handled by installing speakers at the upper end of their power settings resulting in highly distorted and unintelligible signals. Further complicating this situation, spaces with hard surfaces/finishes can cause significant reverberation further reducing intelligibility. In some cases, maximum sound levels established for safety reasons may not be adequate to overcome ambient noise levels. In these instances, supplemental visual graphics interfaced with the voice evacuation message may be advisable.

In addition to the intelligibility of the voice alarm system needing to be addressed, the designer must develop a strategy

for implementing an effective voice alarm message. Voice alarm systems have been demonstrated to be significantly more effective than general alarm signals.<sup>10</sup> Bryan has noted that, to be effective, a fire alarm system must direct an adaptive behavioral response by the occupants by providing essential definitive and directive information.<sup>5</sup> Definitive and directive information consists of:<sup>10</sup>

- What has happened.
- What the occupants are to do.
- Why they should do it.

While voice alarm systems have the capability to provide this information, there are several challenges to successfully implementing an effective voice alarm message. To be credible, the message must be nonambiguous about the occurrence and location of the event. As important, the message must clearly communicate what actions are to be taken and why it is important that occupants follow those actions. Unfortunately, the importance of emergency voice communication and training of the operator are all-too-often-neglected aspects of the fire alarm system.

**A detailed fire safety evaluation should be performed to determine the numerous potential fire scenarios and the most effective voice message corresponding to the appropriate fire response.**

The general challenge in most assembly occupancies is that the potential number and combination of fire locations and recommended exit paths are numerous. Prerecorded voice alarm messages may be effective in high-rise buildings with typical floor plans. However, a voice alarm message serving an assembly occupancy where building areas are not typical and occupants are likely to be unfamiliar with the building requires a different approach to implementing voice alarm messages. A detailed fire safety evaluation should be performed to determine the numerous potential fire scenarios and the most effective voice message corresponding to the appropriate fire response.

As a final note on notification effectiveness, the use of positive alarm sequence, where the operation of the voice alarm system may be delayed for up to 180 seconds while personnel investigate the alarm, is common in large assembly occupancies to prevent unwanted nuisance alarms. Obviously, the evacuation of thousands or even tens of thousands of occupants during a major entertainment or sporting event as a result of a nuisance alarm is highly undesirable. However, the use of positive alarm sequence only increases the importance that should be placed on designing an effective occupant notification system in assembly occupancies. Unfortunately, the model codes leave acceptance of positive alarm sequence up to the AHJ and do not provide guidance as to when its use is or is not recommended.

## SYSTEMS INTEGRATION

Another aspect of fire alarm design that must be addressed in assembly occupancies is the need for integration with other building systems. Security system integration discussed previously is not the only building system that should be carefully integrated with the fire alarm system.

In most large assembly occupancies, the operation of the fire alarm notification system must be integrated with the public address (PA) system. In some cases, the PA system is shut down by operation of the notification system, while in other cases notification utilizes the PA system. Provided the PA system meets the emergency power and quality control standards of a voice alarm system, there are many arguments in favor of using the facility PA system.

A primary advantage of using the facility PA includes improved testing and maintenance. The normal use of the PA system as part of the facility operations will provide an economic incentive for the owner/operator to use and maintain the PA system more effectively than normal code-mandated testing/maintenance requirements. Also, the audio capabilities of state-of-the-art public address systems are generally superior to fire alarm audio systems and are designed to operate without distortion or reverberation in high ambient noise environments. Use of the PA system can eliminate many of the problems of intelligibility often associated with fire alarm notification systems in large, acoustically challenging environments. Building management will also realize cost savings by eliminating the need to install and maintain a secondary system.

In addition to security and audio integration, in assembly occupancies such as theaters where the lighting levels are allowed to be reduced during performances, the facility lighting system should ideally be integrated with the fire alarm system to automatically raise exit illumination levels to a minimum of 1 footcandle (10 lux) upon activation of the fire alarm system.

Related industries that have exemplary records of fire safety and crowd management can be looked to as models for assembly occupancies. The entertainment and professional sports industries are two such industries that provide some

insight into building and operating relatively safe assembly occupancies. Interestingly, the fire alarm systems serving these occupancies are not technically different from other assembly occupancies. Instead, these industries set themselves apart through employee training, crowd management, and fire prevention efforts. This highlights the fact that a properly engineered fire alarm system must take into account many factors beyond technical specifications that contemplate anticipated operational features, human behavior, and proper emergency management/planning. ▲

*Jorge Velasco and Ed Fixen are with Schirmer Engineering Corporation.*

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# Fires in Clean Rooms

## The Effects of Downward Air Flow on Ceiling Jet Flow

By Massimo Manganaro

**T**he purpose of this article is to provide a basic analysis of the effects of downward air flows in a clean room environment on fire protection system operation.

Other important aspects that are typical of a clean room environment, such as plastic process equipment and systems (wet benches, ductworks, etc.), furnaces, flammable liquids, pyrophoric gases, and other process hazards, are beyond the scope of this analysis.



Clean rooms are specific types of occupancies which, especially over the last few decades, have become more and more widespread in a large variety of industrial fields, primarily semiconductors, electronics, and pharmaceuticals, but also food processing, biotechnology, healthcare, aerospace, and automotive. The main characteristic which differentiates a clean room environment from other industrial occupancies is the high level of cleanliness maintained inside and the extremely low contamination from outside by any kind of particles.

Table 1. Classification of Clean Room According to Federal Standard 209D

Classification	1	10	100	1,000	10,000	100,000
N. of Particles/m <sup>3</sup> $\geq 0.5\mu\text{m}$	35	350	3,500	35,000	350,000	3,500,000

**Table 2. General Guidelines on Air Flow Velocity and Clean Room Classification**

Class	Average Downward Air Flow Velocity (m/s)
100,000	0.005 – 0.050
10,000	0.050 – 0.120
1,000	0.120 – 0.200
100	0.200 – 0.400
10	0.300 – 0.450
1	0.400 – 0.500

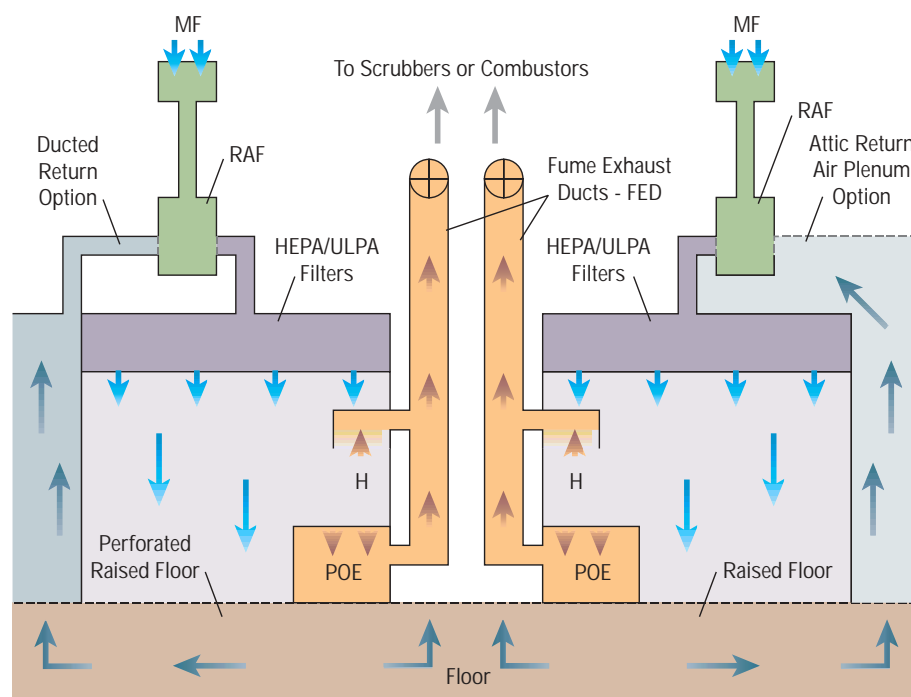
The main function of air handling systems is to reduce the amount and the size of particles in the environment.

Clean rooms are classified by their air cleanliness level. The method most largely known and applied is the one suggested in Federal Standard 209, version "D", where clean room is classified according to the number of particles equal to and greater than  $0.5 \mu\text{m}$ , present in one cubic foot ( $0.028 \text{ m}^3$ ) of air. Table 1 is a simplified version of Federal Standard 209D.

This type of classification is especially applied to clean rooms in the semiconductor fabrication industry. Clean rooms in pharmaceutical operations are commonly classified according to their European Union designation, which consists of a grading from A to D, where A and B approximately correspond to class 100, grade C corresponds to class 10,000, and grade D corresponds to class 100,000.

According to classification in Table 2, each class is also characterized by a typical average downward air flow (veloc-

**Figure 1. A Clean Room Air Handling System**



**Legend:**

HEPA Filters = High-Efficiency Particulate Air Filters

ULPA Filters = Ultrahigh Particulate Air Filters

MF = Makeup Air Fan (Fresh Air Inlet)

RAF = Recirculating Air Fan

FED = Fume Exhaust Ducts with diameters of main ducts up to 800mm

H = Hood for exhausting fumes and gases towards scrubbers and/or combustors

POE = Process Operation Equipment

↓ Clean Air – Downward air flow from the ceiling to the floor

↑ Dirty Air – Upward air flow from side return air duct to outside and/or recirculating air fan

↑ Exhausted process gases and fumes

ity) from the ceiling or, to be more precise, from the suspended ceiling to the floor, and this downward air flow is what typically differentiates a clean room occupancy from other industrial occupancies. Table 2 provides general correspondence between air flow veloc-

ity and cleanliness levels.

The described differentiation among several classes of cleanliness is extremely important for fire protection engineering, because different downward air flow velocities may affect smoke detector and sprinkler activation.

## AIR HANDLING SYSTEMS IN CLEAN ROOMS AND CLEAN ROOM APPLICATIONS

Downward air flow in a clean room environment is provided by a dedicated air handling system, which can be con-

**Table 3. Measured Temperatures from Experiment at Several Radial Locations from the Center of the Fire Plume and at a Distance of 0.051 m Below the Test Room Ceiling**

Downward Air Flow	Heat Release Rate	Average Measured Temperatures in the Experiment at 0.051 m below Ceiling ( $Z = 0.929$ m)	Radial Distance from the Center of the Fire Plume as in the Experiment
0.26 m/s	17.30 KW	151 °C	R = 0.12 m
		96 °C	R = 0.22 m
		57 °C	R = 0.40 m
		31 °C	R = 0.70 m

sidered the core system of a clean room. The main function of air handling systems is to reduce the amount and the size of particles in the environment. Air handling systems provide the required degree of cleanliness mainly through a combination of piping, makeup air units, fans, and filtering media as needed to guarantee the qual-

ity and effectiveness of process operations and to prevent products from contamination.

As far as typical industrial applications are concerned, class 1 and class 10 clean rooms are generally quite difficult to achieve and are characterized by a unidirectional, laminar air flow (typically a unidirectional downward air

flow). Class 1 and class 10 are found almost exclusively in semiconductor fabrication plants, where manufacturing of circuits with dimensions in the order of microns and/or submicrons requires a very high level of air cleanliness.

In these applications, the air flow velocity needed to guarantee such a level of cleanliness inside can reach 0.45 – 0.50 m/s, often requiring a percentage up to around 100% of ceiling coverage with filtering systems (HEPA or ULPA filters) which also require a very complex air handling system layout. From a fire protection standpoint, a very high downward air flow velocity might hinder the quick operation of fire protection systems located on the ceiling.

Semiconductor plants can also employ clean rooms with lower level of cleanliness, from a class 100 downward (where, generally, airflow is no longer unidirectional and is turbulent). In this situation, the structure of the enclosure and of the air handling system arrangement may be less complex than for class 1 and class 10 clean rooms.

Another industrial occupancy where clean rooms or sterile zones are largely used is pharmaceutical manufacturing. Most of the process operations carried out in pharmaceutical plants require an extremely sterile work environment, even if generally limited to clean areas with a level of cleanliness from class 100 downward (however, pharmaceutical clean rooms are generally classified according to European Union designation).

For a major analysis of structure and characteristics, Figure 1<sup>1</sup> provides a typical clean room arrangement, with air handling units, including fans, filters (commonly known as HEPA/ULPA filters) located at ceiling level (suspended ceiling), and also a prefiltering system, where return and makeup air pass after mixing and before entering the HEPA/ULPA filters.

## FIRE RISKS IN CLEAN ROOMS AND POSSIBLE LOSSES

Major fire risks in clean rooms may include flammable and combustible liquids, which are largely used in manufacturing processes, pyrophoric and flammable gases, combustible process equipment, and combustible sandwich

panels. Flammable and combustible liquids can be alcohols, or alcohol-based mixtures, stored in glass or plastic containers. Process liquids, both flammable and nonflammable, are often heated using hot plates, electric immersion heaters, or bonded heating systems. Flammable and pyrophoric gases, such as silane, arsine, diborane, and phosphine, are used in automated process equipment such as diffusion furnaces.

Another large source of fire risk is combustible furnishing materials, which may include work stations, wet benches, suspended ceiling and raised floor tiles, fume exhaust duct systems, and sandwich panels, often made with plastic based materials.

A class 100 clean room may approach a value on the order of \$10,000/m<sup>2</sup> of surface area, including buildings, equipment, and stock inside, not including monetary losses due to business interruption.

### FIRE TESTS IN CLEAN ROOMS

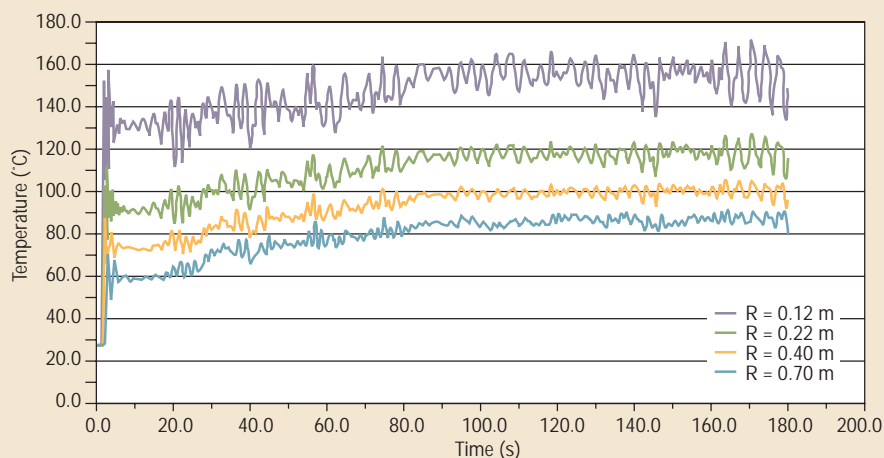
In order to understand the response of fire protection systems and their performance in clean rooms, attention has been focused on small-scale experiments concerning flame spread and heat detection, and experiments regarding fire behavior and smoke release from furnishing materials used in clean rooms.

Based upon some of this data, it is possible to consider the effectiveness of fire protection systems in clean room environments. To this end, the applicability of NIST's Fire Dynamics Simulator (FDS) in clean room environments was judged by comparing experimental data to model predictions of ceiling jet flow temperatures in a fire in a room with unidirectional downward air flow.

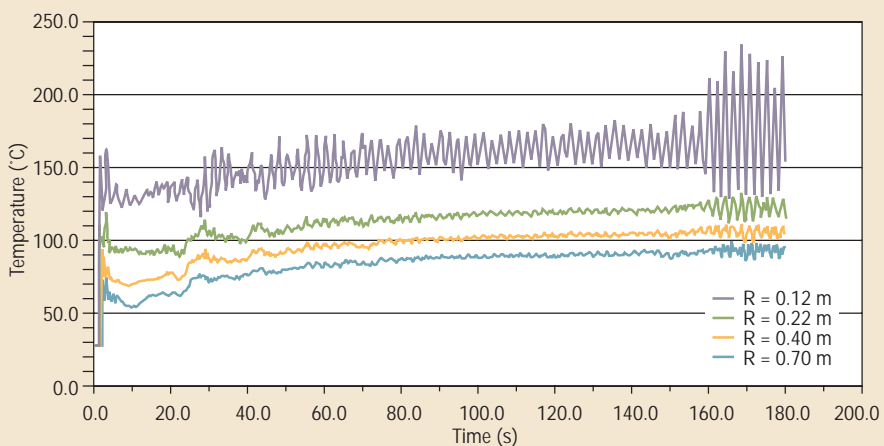
Experiments were conducted in a 4.8 m x 6.0 m x 2.44 m (high) test room.<sup>2</sup> The clearance between the ceiling and the floor was 0.98 m. The fire source a circular methane gas burner that was 0.23 m in diameter, centered in the room and located a height of 0.17 m above floor. A suction blower was located inside the subfloor to produce a uniform flow of 0.26 m/s from the ceiling to the floor.

Temperatures at different elevations

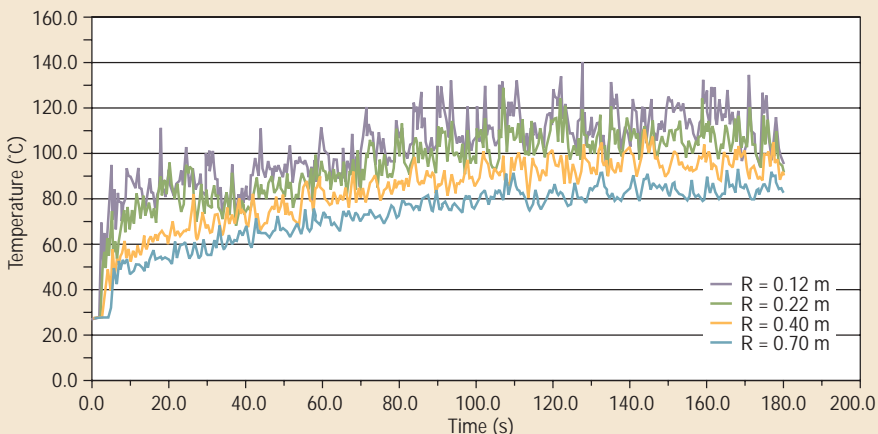
**Figure 2. Ceiling jet temperatures for a 0.12 m grid size and downward air flow source located 0.98 m above floor (at ceiling level)**



**Figure 3. Ceiling jet temperatures for a 0.08 m grid size and downward air flow source located 0.98 m above floor (at ceiling level)**



**Figure 4. Ceiling jet temperatures for a 0.08 m grid size and downward air flow source located 0.50 m above floor**



above the fire source and near the ceiling were measured with thermocouples. Table 3 shows experimental data from one of these fire scenarios.

### INFLUENCE OF DOWNWARD AIR FLOW ON CEILING JET FLOW TEMPERATURES: POSSIBLE IMPLICATIONS ON QUICK OPERATION OF CEILING FIRE PROTECTION SYSTEMS

Before running FDS simulations, to understand how a clean room unidirectional downward air flow could affect fire plumes and ceiling jet temperatures, the data in Table 3 were compared to calculations performed assuming no downward air flow.

Considering the ceiling jet flow produced by a steady fire, it is possible to predict the fire plume and ceiling jet temperatures using correlations developed by Alpert.<sup>3</sup> Predictions are made at ceiling level, where temperatures (because of the boundary layer created by the ceiling) might be lower than at a distance of 0.051 m below the ceiling, which is location where temperatures were measured in the experiment.

Alpert's correlations state:

$$T_{\max} - T_{\infty} = \frac{16.9 \dot{Q}^{2/3}}{H^{5/3}} \quad \text{for } R/H < 0.18$$

$$T_{\max} - T_{\infty} = \frac{5.38 (\dot{Q} / R)^{2/3}}{H} \quad \text{for } R/H > 0.18$$

Where:

$\dot{Q}$  = heat release rate [kW]

$H$  = distance from the base of the fire to the ceiling [m]

$R$  = radius [m]

$T_{\max}$  = maximum ceiling jet temperature [°C]

$T_{\infty}$  = ambient temperature [°C]

Applying Alpert correlations, for

$\dot{Q} = 17.3$  kW,  $R = 0.12$  m and  $0.40$  m,

$H = 0.98$  m -  $0.17$  m =  $0.81$  m, it follows:

For  $R = 0.12$  m,  $T_{\max} = 161 + 27 = 188$  °C

For  $R = 0.40$  m,  $T_{\max} = 82 + 27 = 109$  °C

Another industrial occupancy where clean rooms or sterile zones are largely used is pharmaceutical manufacturing.

**Table 4. Comparison of Average Experimental Temperatures and FDS-Computed Outputs of Temperature**

Radial Distance from the Center of the Fire Plume as in the Experiment)	Average Measured Temperatures in the Experiment at 0.051 m below Ceiling (Z = 0.929 m)	Average Predicted Temperatures by Alpert Correlation, with No Downward Air Flow, at Ceiling Level	Average Temperatures at 0.051 m below Ceiling (Z = 0.929 m) Simulation 0.12 m Grid Size	Average Temperatures at 0.051 m below Ceiling (Z = 0.929 m) Simulation 0.08 m Grid Size	Average Temperatures at 0.051 m below Ceiling (Z = 0.929 m) Simulation 0.08 Grid Size Downward Air Source Locate 0.50 m Above Floor
R = 0.12 m	151 °C	188 °C	155 °C	165 °C	112 °C
R = 0.22 m	96 °C	-	117 °C	120 °C	104 °C
R = 0.40 m	57 °C	109 °C	99 °C	104 °C	93 °C
R = 0.70 m	1 °C	-	86 °C	90 °C	82 °C

Comparing this to the data in Table 3, the measured ceiling jet temperatures at radial distances of 0.12 m and 0.40 m from the center of the fire plume were respectively around 151 °C and 57 °C. These measured temperatures are considerably lower than temperatures predicted in the absence of a downward air flow. This result may have implications on the performance and quick operation of fire protection systems located on the ceiling in a clean room.

#### APPLICATION OF FDS TO FIRES IN CLEAN ROOMS WITH DOWNWARD AIR

Predictions made using FDS were compared to the experimental data from the 4.8 m x 6.0 m x 2.44 m (high) clean room, with 0.26 m/s downward air flow described earlier. Specifically, measured temperatures at radial distances of 0.12 m, 0.22 m, 0.40 m, and 0.70 m, from the center of the fire plume at distances 51 mm below the ceiling were compared to predicted values. Simulations were run for 180 seconds and average temperatures were taken over the range of 80 - 180 seconds.

One of the challenges in setting up the FDS computation regarded how to model the unidirectional downward air flow. Several trials were conducted to choose the best location of the unidirectional downward air flow source. Outputs differed with the choice of the grid size adopted and location of the unidirectional downward air flow source. The modeling results showed slight differences in ceiling jet temperatures among the different simulated cases. The results of these simulations can be seen in Figures 2 through 4.

## CONCLUSIONS

This simple application of CFD simulation techniques to a small-scale fire scenario in a clean room suggests that predicting fire behavior in clean rooms can be complex, especially as the distance from the center of the fire plume increases. FDS can be sensitive to some input parameters for simulation of clean room fires. When simulating ceiling jet flow, these include sizing of grid cells and simulation of downward air flow conditions. Improper selection of these parameters can result in inaccurate predictions of ceiling jet flow temperatures which could affect predictions of fire protection system operation. For this reason, FDS should be verified by experimental data in order to get the most realistic outputs.

Moreover, this analysis of the influence of downward air flow on ceiling jet temperatures suggests that the operation of detectors and sprinklers could be delayed in clean rooms, especially as the distance from the center of the fire plume increases. Even slight differences in temperatures might have a harmful impact on possible losses in a clean room, since even marginally longer exposures to smoke in clean rooms can have a major impact on losses due to the high susceptibility of equipment. ▲

## ACKNOWLEDGEMENTS

Sincere thanks for precious advice and comments about this article are extended to Professor Jennifer Wen of Kingston University, and to Mr. Giorgio Franzini.

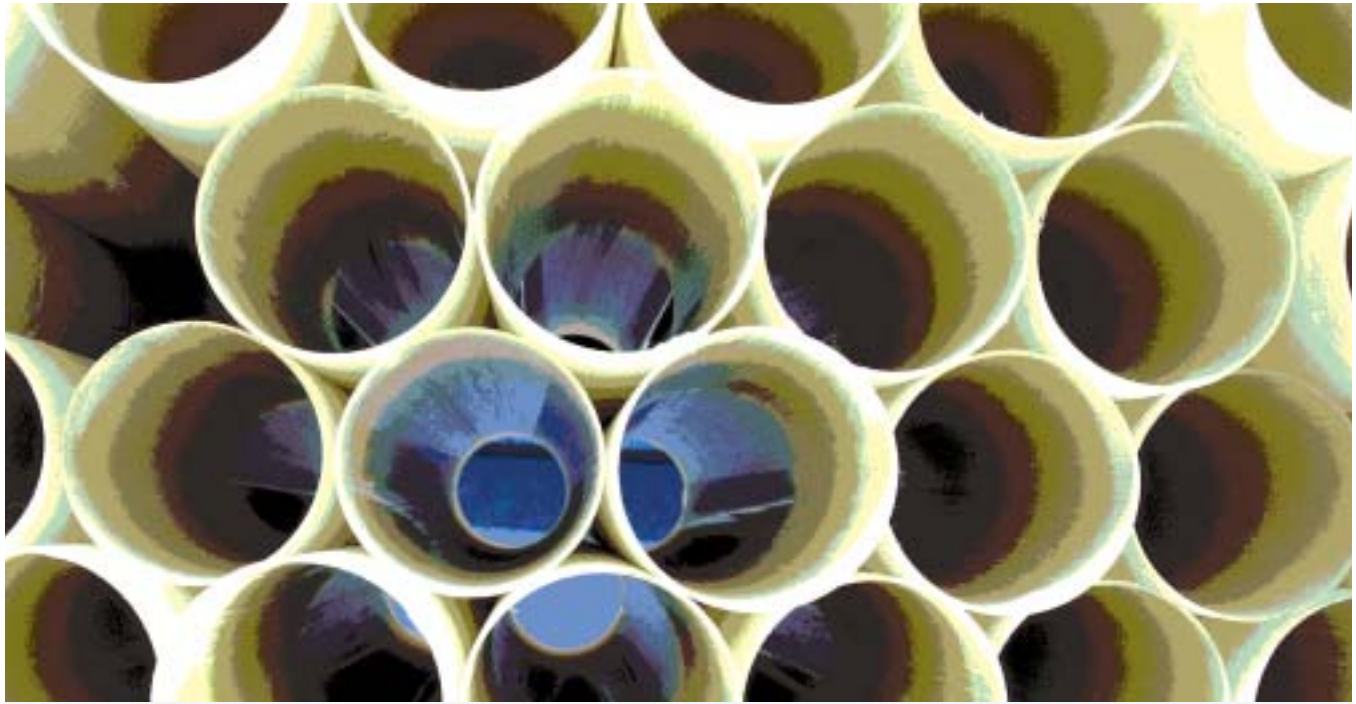
*Massimo Manganaro is with Zurich Risk Engineering, Italy, as a loss prevention engineer.*

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# Plastic Pipe and Fire Safety



*By Joseph B. Zicherman, Ph.D.*

As the use of plastic piping (such as ABS, CPVC, PE, and PVC) in construction gained popularity, considerable testing and research took place to address issues related to fire performance. Likewise, installation technologies and building codes governing the use of plastic have evolved considerably as performance warranting its use was demonstrated for applications in more demanding building types and occupancies. Consistent with the preceding, that evolution can be traced by comparing descriptions of early technology and regulations related to plastic pipe use<sup>1, 2</sup> with the current state of the art as reviewed here.

## PLASTIC PIPE IN FIRE-RESISTIVE CONSTRUCTION

How does the inclusion of plastic pipe in a room when a fire starts impact the life safety of its occupants? Plastic pipe is routinely installed behind materials that form room “linings” which typically resist a growing fire for 15 minutes or more.<sup>3</sup> This feature prevents direct flame impingement on the majority of piping installations.

Although a very small fraction of plastic pipe used is exposed rather than installed behind room linings, does the

presence of small amounts of such exposed plastic pipe increase the level of fire hazard? Five decades of U.S. fire incident data show no unique hazard or relationship linking plastic piping to unusual fire ignition or fire spread.<sup>4</sup> Consistent with this, testing (both fire endurance testing and hose stream tests) and post-fire evaluations of buildings constructed with nonmetallic plumbing systems demonstrate that plastic piping materials generally either burn away and char at wall lines, or melt and drop in a wall cavity (see Figures 1 & 2).

The observed behavior is consistent with the low thermal conductivity of plastic piping materials, which suggests that ignition or the threat of fire spread due to temperature rise (i.e., high temperatures developing) across fire separation walls penetrated by plastic pipe is unlikely. Also, while temperatures in wall cavities may exceed plastic-melting temperatures during the early stages of a structural fire, (as simulated in the first half hour of ASTM E-119 testing), they are still well below ignition temperatures of the pipe. This behavior is similar to the properties of approved plastic glazing and ceiling inserts which are designed to fall to floors of affected rooms before their ignition point is reached. Figure 3 illustrates the condition of an unburned segment of plastic DWV pipe within a test wall cavity after a 30-minute ASTM E 119 fire exposure.

## DESIGN SPECIFICATIONS

Design features requiring fail-safe fire-resistant detailing are typically needed at locations where building services cross floor-to-floor or unit-to-unit boundaries. Building subsystems routinely found at such locations include plumbing, electrical, and HVAC components.

Openings in fire-resistive walls – penetrations – for plastic pipe must be addressed in design specifications. The term “through penetration” refers to openings that transverse a fire-resistive assembly while “membrane penetrations” contain openings on one side only. The latter class of penetrations includes single-sided plumbing penetrations. Openings for all such penetrations in both walls and floor/ceilings must be protected to prevent unwanted fire spread and spread of smoke and hot gases.

Flame spread performance is another property typically addressed by the codes. Regulations governing the use of plastic pipe or any other combustible building product installed in air handling spaces are found in both mechanical codes and *NFPA 90A*.

The impact that combustion products from burning plastic pipe installed in fire-resistive construction may create on life safety deserves comment. A first consideration is the amount of plastic piping used. Analysis demonstrates that this quantity is relatively small – especially when compared with other combustible construction materials and furnishings. In addition, combustion products created when plastic piping burns do not evolve early in a fire due to how and where they are installed. In addition, testing and field data indicate that resulting gases are no more toxic than other common building and furnishing materials.<sup>5-8</sup>



Figure 1. DWV stack with calcined wallboard removed, private residence, San Jose California.



Figure 2. Vent and DWV stacks post- fire. ABS remains in concealed spaces. Note charring of adjacent wood.

## FIRESTOPPING

In the 1970s, initial testing of plastic piping installations in fire-resistive assemblies was conducted with walls containing both metal and wood stud structural elements.<sup>9-16</sup> In both cases, the use of the plastic plumbing pipes did not reduce fire endurance provided penetrations were not oversized and they were sealed properly. More recent test results conducted under positive-pressure testing conditions assure that such installations will resist transmission of hot gases to unexposed specimen surfaces.

Overall, fire endurance tests of cavity wall constructions that include plastic pipe demonstrate that successful installations can be made using generic firestopping for smaller diameters of pipe and approved penetration firestop systems for larger diameters of pipe. In such test exposures, horizontal through penetrations made with small-diameter plastic pipe [1.5" (37.5 mm) or less] melted quickly and at the back, unexposed wall surfaces, sealed off, and no flame passage occurred. In the same tests, vertical drain and vent sections melted and dropped within walls without flaming occurring on unaffected back-face wall surfaces. By firestopping penetrations with appropriate, approved materials and techniques, the fire-resistance properties of the penetration can be made equal that of the original, unpenetrated assembly.

## HISTORY OF PLASTIC PIPE REGULATIONS

In the 1960s and 1970s, building code regulations that defined fire endurance requirements prescribed the ASTM E-119 method, which did not specifically address:

- 1) measurement of [allowable] temperatures on piping assemblies,
- 2) furnace pressure at which testing was to be conducted, or
- 3) allowable penetrating element configurations.

These issues were relevant because, during a fire, pipe installations that were vented could be expected to behave differently from unvented ones. In addition, metallic pipe and plastic pipe systems could be expected to conduct heat through affected assemblies differently. This performance attribute was demonstrated during development of the ASTM E-814 standard, in which the thermal response of metallic penetrating elements – such as pipes or sleeves – varied significantly depending on the length of the sample – a direct consequence of thermal conductivity and exposed pipe surface area.<sup>17</sup>

As the volume of plastic pipe use has grown, marketplace competition has been vigorous. The interested parties included manufacturers of competing plumbing product materials (usually metallic pipe manufacturers) as well as unions and cost-plus contractors who have seen their markets and margins shrink. Regulators have been drawn into this controversy as occasionally specious technical arguments have been advanced to limit the expanded use of plastic pipe systems.<sup>18-20</sup>

In the late 1970s, partially in response to the growing con-

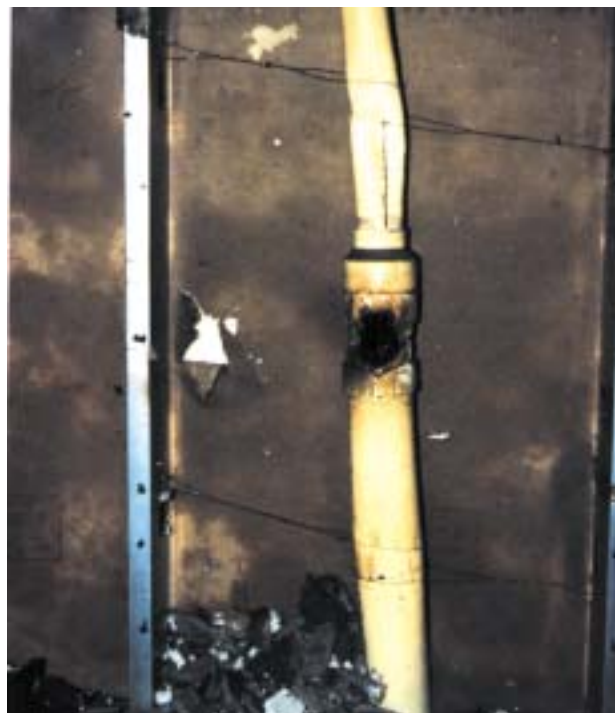


Figure 3. Appearance of PVC DWV specimen following 30-minute E-119 fire exposure.

troversty as to how best to test plastic pipe installations in fire-resistive construction, the ASTM E 05 committee developed the ASTM E 814 Standard (Standard Test Method for Fire Tests of Through-Penetrations Fire Stops, also known as UL 1479 and UBC Std 7-5), first approved in 1983. This method addressed shortcomings of the more general ASTM E 119 method and clarified testing criteria for through penetrations of fire-rated assemblies.

In the 1980s, code changes to address use of plastic pipe, tube, and conduit in fire-resistive construction were advanced in the model codes. Similar activities by the Council of Building Officials – Board for the Coordination of the Model Codes (CABO-BCMC) resulted in the “Final Report on Protection Requirements for Vertical Penetrations” in 1986.<sup>21</sup> Almost a decade later, in 1995, the BCMC guidelines were updated further with publication of the report “Protection of Penetrations and Joints in Building Wall, Floor, and Roof Assemblies.”<sup>22</sup>

One result of these activities has been a requirement for testing under positive furnace pressures today. Such testing is conducted in the range of 0.01" of water column (2.5 Pascal) to simulate worst-case conditions found in post-flashover fires. BCMC was the first group to adopt such a positive pressure caveat in its guidelines.

Unfortunately, positive pressure testing has also called into question the results of early testing of pipe penetrations in furnaces where a variety of pressures was used. While no field data suggesting shortcomings in the results or implications of those early tests have been presented, the concept is important from a theoretical perspective in that structural fires do not show uniform pressures from floor to ceiling. Rather, maximum positive pressures are found in the top 1/3-1/2 of affected rooms while pressures below are typically negative and may actually encourage an inflow of cooling air at through penetrations low on walls where drains for sinks are located.<sup>23</sup> Likewise, pressures above at-



Chase wall including firestopping devices and PVC plumbing installation.

mospheric are not uncommon in tall buildings due to stack effects.

Installation information for plastic pipe in fire-rated construction was first provided in an organized format in 1985.<sup>24</sup> That document “Plastic Pipe in Fire-Resistive Construction” was the subject of a CABO National Evaluation Report in 1992, and two later editions of this document have been published.<sup>25</sup>

Historically, the model code organizations also produce plumbing codes which address performance of piping materials and systems. These generally do not address fire safety issues. An exception to this has been the *Uniform Plumbing Code*<sup>26</sup> which before 1999 severely restricted use of plastic pipe in fire-resistive buildings. That code was modified in 2000 to allow unlimited use of plastic pipe in constructions of all types.

The *International Building Code*<sup>27</sup> (IBC) includes comprehensive provisions for plastic piping system applications in fire-resistive construction. IBC Sections 603 (Combustible Material in Type I and II Construction) and 711

(Penetrations) address conditions and requirements for use of plastic piping materials in all building types, including those with noncombustible structural frames.

In the 1991, the *NFPA 101 Life Safety Code* recognized and addressed the importance of protecting through penetrations in fire-resistive construction for piping as well as for non-metallic electrical raceway systems. That code utilizes the ASTM E 814 test method and includes a table of performance requirements for penetrations with both metallic and nonmetallic piping types. These provisions are based upon the BCMC report<sup>22</sup> and are contained in an appendix note found there.

Initial ASTM E 119 and later E 814 fire testing of penetrations incorporating plastic pipe has provided model code developers an improved understanding of the characteristics and properties of plastic pipe used in structures as compared to what was available 25 years ago. Testing archives include literally thousands of fire endurance test reports based on assem-

bly testing by accredited third-party testing labs and research institutes.

## FIRE PERFORMANCE GUIDELINES

It is extremely rare for a fire-resistive assembly to be built exactly as found in the generic form described in the tables of model building codes or the *Gypsum Association Handbook*.<sup>28</sup> However, thermoplastic piping materials tend to behave similarly on exposure to fire, and certain “rules of thumb” can be applied to evaluate and analyze performance in various installations. In 1965, Harmathy<sup>29</sup> presented a seminal analysis on the performance of fire-rated assemblies which are of use to reasonably predict the impact of design variables in the field. Several of those rules, paraphrased from the HUD Guidelines for the fire performance of archaic building materials<sup>30</sup> are reviewed below in the context of plastic piping applications.

**Rule 1:** Thicker assemblies (such as walls and floor ceilings) will – with all other factors being held constant – last longer than thinner walls of the same composition exposed to the same fire conditions.

**Rule 2:** Fire-resistive assemblies containing hollow spaces tend to outperform similar analogs composed of the same materials without hollow spaces.

**Rule 3:** Insulated assemblies can be expected to perform better than uninsulated ones.

**Rule 4:** Smaller openings in walls will lead to lesser diminution of fire endurance than larger openings.

As such, if a fire-resistance-rated assembly is deeper or thicker than a tested assembly, it will last longer whether or not it includes piping. If insulation is present in a rated design which was originally tested without insulation, whether or not it includes piping, the insulated wall will last longer than the uninsulated version. If a wall is tested with a given size of penetration, the presence of a smaller penetration than the one originally tested will not reduce its fire endurance.

## ACCEPTANCE OF PLASTIC PIPE SYSTEMS IN FIRE-RESISTIVE CONSTRUCTION

A 1978 survey of high-rise buildings identified 108 high-rise or noncombustible buildings in 28 states that had been constructed using plastic piping for DWV systems.<sup>31</sup> This survey was completed eight years before the first regulatory efforts to specifically address use of plastic piping products in such applications took place. To the author’s knowledge, all of these systems are still in use and none have suffered fire-related problems. No other systematic data exist quantifying the use of plastic pipe in such complex structures in relation to fire performance, although these materials are routinely used in fire-rated buildings in many parts of the world today.

In 1983, a draft Environmental Impact Report<sup>32</sup> was published in California to address the expanded use of plastic pipe and the lack of regulations in that state. Based in part on the first draft of that study, Stanford Research Institute (SRI) issued a report in 1989<sup>33</sup> and the State of California, Department of Housing and Community Development, published a final report in 1998<sup>34</sup> endorsing use of plastic pipe in fire-resistive construction.

## PLASTIC PIPE AND SPRINKLER SYSTEMS

Plastic piping materials used in sprinkler systems have had a significant impact on fire safety and their use has grown significantly over the past 15 years. Initially, fire protection and cost/benefits provided through use of such systems substantially impacted both fire safety levels in single-family dwellings and in light hazard occupancies. Performance consistent with provisions of *NFPA 13*, as well as demonstrations that CPVC-based systems can be used in air-handling spaces – as regulated by the model mechanical codes and *NFPA 90A* – has assisted in this growth.

At this point, plastic-pipe-based sprinkler systems can be used with both exposed piping (when fast response sprinklers are used) and with standard-response sprinklers for con-

cealed piping. They cannot be used in dry pipe systems and must not be installed with other types of plastic piping materials, such as those used for supply or DWV piping. A comprehensive review of initial development efforts related to plastic-pipe-based sprinkler systems was prepared by Wilging in 1988.<sup>35</sup> ▲

*Joseph B. Zicherman, is with Fire Cause Analysis*

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# Combining Emergency Voice and Nonemergency Paging Systems

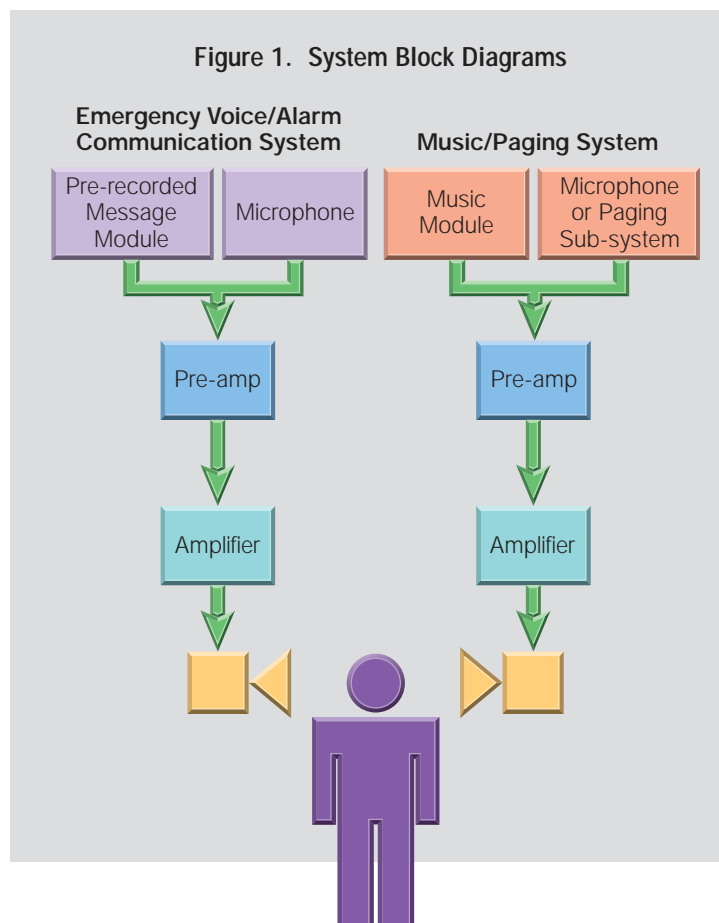


Setting Standards for Excellence

The use of voice messages to initiate evacuation or relocation during fire and other emergencies is increasing. Building, fire, and life safety codes typically require voice systems in large assembly occupancies, high-rise buildings, and other spaces where egress is complex. In the wake of recent tragic nightclub incidents and a devastating fire in the Düsseldorf airport, experts are reevaluating the need for, and the application of, voice signaling.

Many occupancies that either require emergency voice alarm communication (EVAC) systems or that could benefit from them regularly have and use systems for general, nonemergency voice paging, public address, or background music. Is it necessary to have two overlapping systems with similar equipment? Can the systems be combined to

Figure 1. System Block Diagrams



save costs and reduce equipment installation?

Previous articles in this series sponsored by the National Electrical Manufacturer's Association (NEMA) have discussed voice system intelligibility, message content, and overall system reliability. This article looks at the functional similarities and differences of emergency and nonemergency systems, and discusses how and why the systems might be combined.

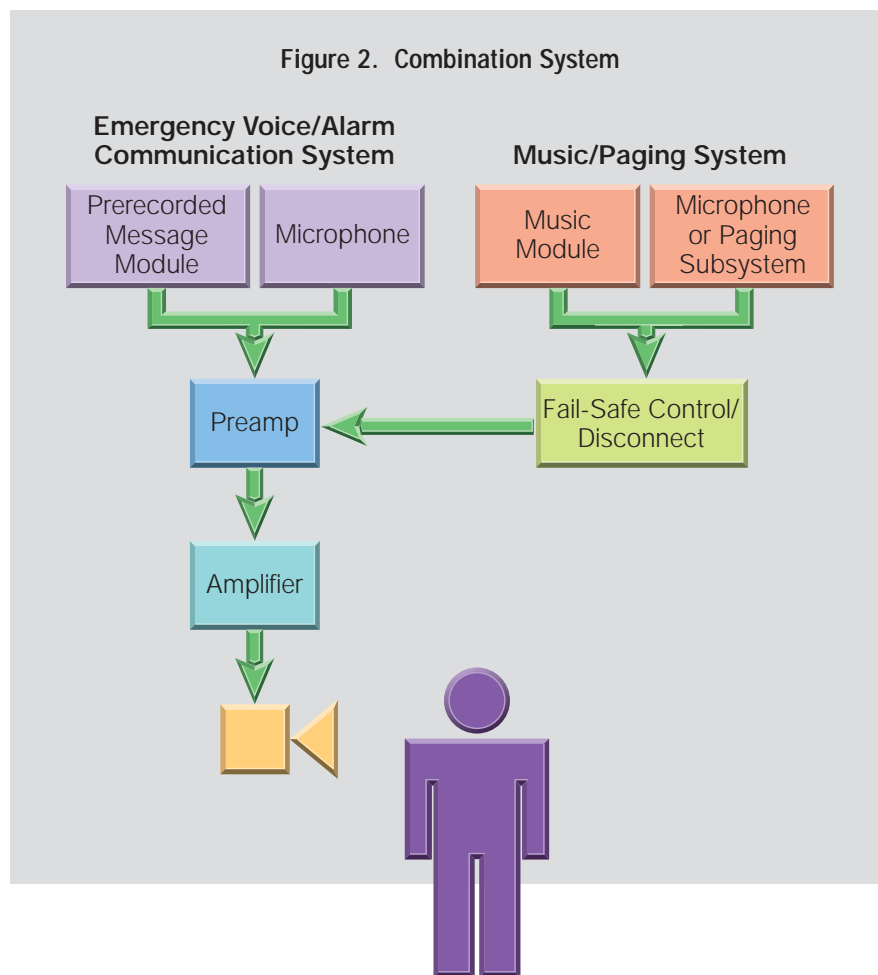
Figure 1 shows simplified block diagrams for an EVAC system and for a general paging/music system. To reduce confusion, in this article one will be referred to as the "EVAC" or "emergency" system and the other simply as the "paging" or nonemergency system. The basic architecture of each system is similar, though their purposes are quite different. Nevertheless, it appears that there is an oppor-

tunity to combine some or all of the system components to eliminate duplicate equipment and reduce the overall costs to the owner.

**Purpose:** An emergency system is intended to initiate certain occupant responses – most often either evacuation or relocation. It does so by providing information: what has happened, what people should do, and why they should do it. A paging system is used to convey nonemergency information, while a music system provides background noise for comfort, entertainment, or to mask ambient noise.

**Use:** An EVAC system is seldom used – only during an emergency or once per year when tested. Background music systems are generally used whenever a building is occupied. Paging systems may be used almost constantly, such as in an airport or hospital; frequently, such as in grocery stores; or less frequently, such as in a commercial office spaces. Emergency systems are activated either automatically by a fire detection and alarm system or manually by staff or emergency forces, such as fire department personnel. Because it is seldom used, the emergency system must be relatively easy to use by persons with only a general familiarity with such systems. In addition, it is intended to be used during an emergency, so its default mode is automatic and its manual mode has defaults arranged to ensure that spoken messages go to the affected areas without requiring much operator action – if any. Certainly, nonemergency paging systems must also be easy to use. However, users have time to practice and become familiar with the systems. With the exception of hospital systems, if a user fails to immediately succeed in the use of a paging system, there is little or no downside risk compared to the timely use of an emergency system.

**Characteristics:** The differences in purpose and use of emergency and non-emergency paging systems lead to differences in function and in characteristics of the systems. Both systems must be intelligible, but a paging system must not be too intrusive or it will disrupt the general use and performance of the occupancy. An emergency system can, and should, be intrusive. Also, nonemergency systems



generally require a higher level of intelligibility (not necessarily audibility) since a lower level of intelligibility that may be acceptable for an emergency system would result in listener fatigue for a system that is frequently used. The sound quality of a music system or a paging system that is frequently used needs to be comfortable to the listener – not a critical characteristic for an emergency system. For some applications, a music system needs to reproduce the sound with fidelity, or truthness. For an emergency system, the output does not need to faithfully reproduce the voice of the talker – it can come out sounding like a computer synthesized voice, as long as it is intelligible. One major difference in function is that certain components of emergency systems are required to be monitored for integrity. Failure of these critical components results in a trouble signal to warn of the need for repair or maintenance of the system. No such re-

quirement exists for nonemergency paging systems.

Despite the many differences in purpose, use, and characteristics, both emergency and nonemergency systems are intended to take input, process it, and distribute it to listeners. Therefore, as shown in the simplified block diagrams of Figure 1, they have an overlap or redundancy of certain equipment. Is it possible, and if so, is it permitted for the two systems to share components? The answers are yes and yes.

## COMBINATION SYSTEMS

*NFPA 72, the National Fire Alarm Code, would refer to such a hybrid system as a combination system.<sup>1</sup>*

### 6.8.4 Combination Systems.

*6.8.4.1\* Fire alarm systems shall be permitted to share components, equipment, circuitry, and installation wiring with nonfire alarm systems.*

**6.8.4.2** *If common wiring is used for combination systems, the equipment for nonfire alarm systems shall be permitted to be connected to the common wiring of the system.*

In a simplified way, such a combination system might be arranged as shown in Figure 2.

The combination system may have a single user interface (microphone, switches, etc.) or it may have separate interfaces for the general-use systems versus the emergency system. In some configurations, the point of interface may occur after preamp processing or even after amplification. Regardless of how or where the interface occurs, a key requirement of the code is that any failure or fault in the nonemergency part of the system *“shall not interfere with the monitoring for integrity of the fire alarm system or prevent alarm, supervisory, or fire safety control signal transmissions.”* When paging is the only non-emergency use, the simplest way to meet that requirement is for the entire system to be a listed and properly designed EVAC system. True combination systems come into being when it is desired to add music or to add other user interfaces such as the ability for users to page using their telephones. A combination system may also be needed when it is desired to have nonemergency paging occur at lower sound levels than the emergency messages. The system would then have to be arranged to fail-safe to the louder fire alarm system mode.

Even though 6.8.4.1 of the 2002 *National Fire Alarm Code* explicitly permits combination systems, 6.8.4.5 imposes limitations on combination paging systems:

**6.8.4.5\*** *Speakers used as alarm notification appliances on fire alarm systems shall not be used for nonemergency purposes.*

*Exception No. 1: If the fire command center is constantly attended by a trained operator, selective paging shall be permitted as approved by the Authority Having Jurisdiction.*

*Exception No. 2: Use for nonemergency purposes shall be permitted where all of the following conditions are met:*

**1** *The speakers and associated au-*

*dio equipment are installed or located with safeguards to prevent tampering or misadjustment of those components essential to intended operation for fire.*

**2** *The monitoring integrity requirements of 4.4.7 and 6.9.4.4 shall continue to be met while the system is used for nonemergency purposes.*

**3** *It is permitted by the Authority Having Jurisdiction.*

There may be several ways to interpret and apply these requirements. First, it appears that 6.8.4.5 permits an EVAC system (speakers used as alarm notification appliances on fire alarm systems) to be used for nonemergency paging when the conditions of the first exception are met. The associated annex text reads as follows:

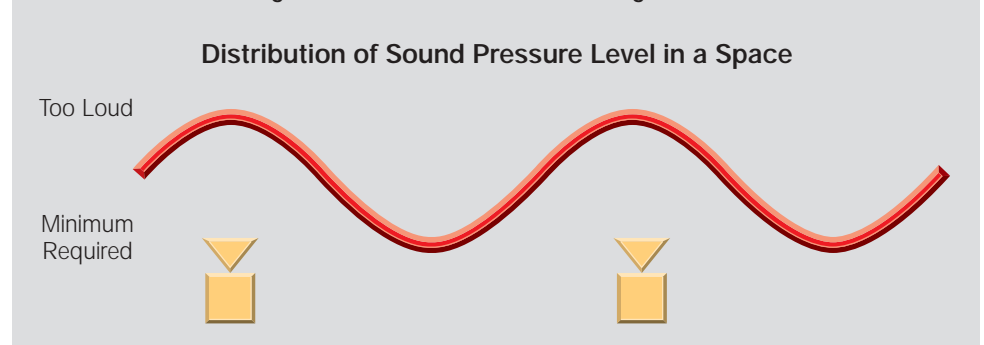
**A.6.8.4.5** *In Exception No. 1, if the building paging system can be controlled by personnel at the fire command center, and if permitted by the Authority Having Jurisdiction, the building paging system can be used as a supplementary notification sys-*

*tem to provide selective and all-call fire alarm evacuation voice messages and messages for occupants to relocate to safe areas in a building.*

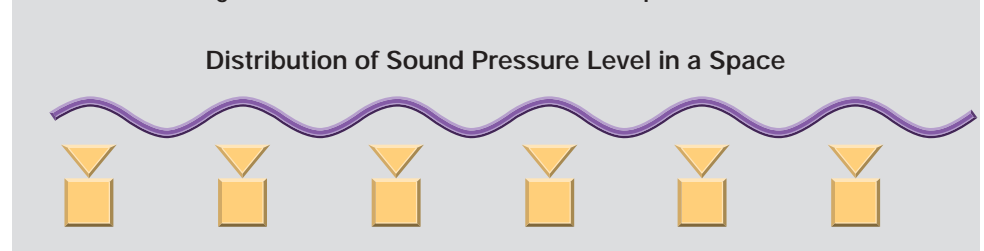
The annex text says that the opposite configuration is permitted. That is, a nonemergency system can be used for emergency messaging, but only as supplemental signaling. In *NFPA 72*, a supplemental system is one that is not required by *NFPA 72* and designated as such by the Authority Having Jurisdiction (AHJ). In a way, the annex text does not make any sense. If the non-emergency system is used as supplemental notification, there must still be a required EVAC system with its own speakers. The annex text was added by the committee into the 1999 edition of *NFPA 72* and included the following Committee Substantiation:

*In many buildings, such as airports, the building-wide all-call and selective paging system provide more-efficient and more-reliable speaker systems than those provided with an emergency voice/alarm communications system.*

**Figure 3. Common Fire Alarm Design Practice**



**Figure 4. Even Distribution of Sound at Optimum Level**



Another proposal submitted to the committee attempted to explicitly spell out in the body of the code (rather than just the annex) that nonemergency systems could be used for emergency purposes. The submitter used the exact same substantiation (above) that the committee wrote for its own proposal. That proposal was rejected by the committee with the following Committee Statement:

*The committee feels that the existing requirements are necessary to insure reliability of voice communications. This proposal could seriously degrade this reliability.*

Exception 2 provides a clearer path to the use of the emergency system for nonemergency purposes. Also, Exception 2 permits the use for music as well as general paging, unlike Exception 1 that addresses only paging. The annex text for Exception 2 discusses design and considers implementation strategies.

## OTHER CONSIDERATIONS

Whether the base system is an EVAC system or a nonemergency sound reinforcement system, the possibility exists that the system could be vandalized if occupants are annoyed by a system's constant use as a music or paging system. System vandalism is site-specific and not the general case. The most common form of tampering is the blocking of a speaker, which would not be found by monitoring the integrity of the circuits. One solution to reduce possible tampering is the use of loudspeakers listed as vandal-resistant (an existing listing category).

Proper design, installation, and use of the combination system may also reduce the likelihood of tampering. Standard fire alarm system design practice is to use fewer speakers than a non-emergency system design for the same space. For a combination system, that practice invites tampering because it results in places close to the speaker where the level is very loud in order to get the minimum level required for intelligibility at a point farthest from the speaker. See Figure 3.

If a sound system annoys the staff, it is reducing productivity and it is most likely also annoying customers, to the

detriment of business and the investment made in the system. To reduce the chances of tampering at the speakers, a system needs to be properly balanced and more evenly distributed than past fire alarm design practice. The use of more speakers at a lower level is best. The Notification Appliances Committee of NFPA 72 changed the code to remove a requirement for audible appliances to produce a minimum of 75 dBA at 10 feet. This permits designs that have a more distributed sound level as shown in Figure 4.

Still, the goals for the emergency and the non-emergency use may require two differing sound levels – one for general use and a higher sound level for emergency purposes. Automatic level control at the front end amplifier is one possible solution. It is also possible to have level control at some or all speakers. One method uses speakers with two voice coils. One coil is connected to a monitored EVAC circuit while the other is connected to a non-emergency paging circuit. Similarly, variable power taps controlled by the fire alarm system and arranged to fail-safe to the higher level are another possible solution.

Combination systems can result in significant cost savings for building owners and can also improve the performance and reliability of the emergency communications system. The cost savings for a combination system compared to a separate paging system with a separate emergency voice system may be significant. However, the savings depend on the chosen configuration of the combined system, which depends on the non-emergency purpose and use.

- Combining the building paging system and the emergency voice communications system into one not only eliminates the cost of duplication but also provides other important benefits:
  - Combination voice systems that are used daily are more likely to be intelligible in order to meet the day-to-day communications needs within a facility.
  - Combination voice system that affect daily business needs are likely to be well maintained (for example, defective speakers will likely be replaced well before required test intervals).
  - Combination voice systems that are

used daily will be familiar to operate in an emergency.

- Combination voice systems that are required to be tamper resistant are less likely to be degraded by vandalism or miss-adjustment.

In many occupancies, emergency voice notification is not required. The fire alarm may only be required to use tone signaling. By using a combination system, the occupants and fire service benefit by having a notification system that uses voice, which has been shown to be more effective than tone-only signaling.<sup>2,3</sup> Voice systems are more easily expanded than tone-only systems. That is, a circuit is not limited in the number of appliances in the same way as tone-only systems. The limit is not based on available power supply current, only by wire size and amplifier capacity. Thus, systems can more easily be designed and installed to permit future expansion. Also, most speakers have multiple power taps permitting greater flexibility in making field adjustments to the loudness of the system. The owner and installer benefit by the greater flexibility and expandability of voice signaling versus tone signaling systems. ▲

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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.



# Resources

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Info: [www.cibworld.nl](http://www.cibworld.nl)

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Slovak Republic  
The High Tatras  
Info: [uvt.tuzvo.sk/wfs/english/info/g\\_info.htm](http://uvt.tuzvo.sk/wfs/english/info/g_info.htm)

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Third Edition of the International Workshop –  
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Salt Lake City, Utah  
Info: [www.nfpa.org](http://www.nfpa.org)

## July 5-7, 2004

Interflam, 2004  
Edinburgh, UK  
Info: [www.intercomm.dial.pipex.com](http://www.intercomm.dial.pipex.com)

## September 1-3, 2004

Public Fire Safety – Professionals in Partnership  
3rd International Symposium  
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Info: [grupos.unican.es/gidai](http://grupos.unican.es/gidai)

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## False Fire Alarm Stopper

The Stopper® II is a pull station cover that mounts directly to the wall over an existing pull station. When the cover is lifted, a self-contained alarm sound draws immediate attention to the area. Someone pulling a false alarm will run or be caught, helping to prevent a false fire alarm. The cover does not restrict legitimate fire alarms from being activated.



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—Fire Fighting Enterprises Ltd.

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www.detrionics.com  
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# Products/Literature

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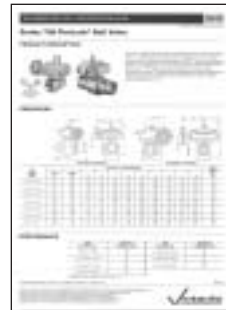
This new, super-tough, see-through polycarbonate enclosure offers excellent protection and immediate access for fire alarm control panels installed externally. The STI Clear & Accessible Control Panel Protector guards against vandalism, dirt, dust, and grime. Two models are available: the STI-7521 is secured with a thumb lock, and the STI-7520 is secured with a key lock.



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—Victaulic Company of America

## Retrofit Ball Valve Supervisory Switch

This retrofit ball valve supervisory switch (RBVS), designed specifically for the fire sprinkler industry, detects the fully open position of quarter-turn ball valves. It provides the opportunity to have the ball valves supplied as component parts of back-flow devices brought into full compliance with the requirements stipulated by NFPA 72. Additionally, the ball valves installed in alarm lines on wet, dry, and pre-action systems may now be brought into full NFPA compliance.

[www.pottersignal.com](http://www.pottersignal.com)

—Potter Electric Signal Co.



## Free Courses Online

Wheelock, Inc., provides a self-paced online training program offering a comprehensive course curriculum that serves designers, installers, specifiers, contractors, end-users, and other professionals involved in the fire alarm, security, and facility communications industries. Courses include a wide range of topics covering technical, applications, and sales approaches. The programs carry CEU credits. The free courses may be accessed at [www.wheelocku.com](http://www.wheelocku.com).



[www.wheelockinc.com](http://www.wheelockinc.com)

—Wheelock, Inc.



## Smoke Detectors

The F220 Series of smoke detectors is self-testing. Other features include compatibility with 12 VDC or 24 VDC systems; drift compensation of the detector chamber; sensitivity readout through an onboard LED; patent-

pending, time-saving way to clean the chamber; "needs to be cleaned" signal; and wide range of available bases.

[www.boschsecurity.us](http://www.boschsecurity.us)

—Bosch



## Product Catalog

Tyco's 68-page, full-color Fire Protection Products catalog contains detailed information about the company's automatic sprinklers, system valves and devices, and piping and electrical products. Sprinkler specification charts are also provided. The catalog includes photos, specification information, examples of applications, and more.

[www.Tyco-Fire.com](http://www.Tyco-Fire.com)

—Tyco Fire & Building Products

## Factory-Built Grease Duct

Metal-Fab G Series™ Grease Duct Systems are factory-built in a controlled environment to ensure quality fabrication. They are assembled with a liquid-tight connection system. No welding is required to connect components, ensuring that no leaks contaminate insulation, compromise fire integrity, or cause health hazards. The systems have a 12-year warranty.

[www.metal-fabinc.com](http://www.metal-fabinc.com)

—Metal-Fab, Inc.



## COIN™ Quick Response Space Sprinkler

This new COIN™ quick response combustible interstitial space sprinkler from Viking Corporation has been tested and listed for use in specific light hazard combustible and non-combustible concealed horizontal spaces requiring sprinkler protection per installation standards. In some cases, it can allow the use of any listed CPVC piping system within concealed spaces requiring sprinkler protection.

[www.vikingcorp.com](http://www.vikingcorp.com)

—Viking Corporation





## B R A I N T E A S E R

An examination is being taken by a student who is not prepared. The exam consists of 80 multiple choice problems, each problem having four possible choices. Assuming that each problem has only one correct answer and the student needs at least 20 correct answers to obtain a passing score, what is the probability that, if the student guesses at each problem, the student would receive a passing score?

### Solution to last issue's brainteaser

Four people of different ages told each other how old they were. One of them said, "If I multiply my age by any of your ages, the product is a permutation of the digits of the two ages." How old is everyone?

First, assume one person's age is one digit and another's is two digits. Call the ages  $s$  and  $[tu]$ , where  $s$ ,  $t$ , and  $u$  are single digits. (Here, the brackets mean that the digits are not multiplied.) Then,  $s$  times  $[tu]$  is a permutation of  $s$ ,  $t$ , and  $u$ . In the case of  $[uts]$ ,  $u$  times  $s = [ns]$ , and  $t$  times  $s = [u(t-n)]$ , where  $n$  is an integer.

For  $n = 0$ ,  $u$  times  $s = s$ , and  $t$  times  $s = [ut]$ . Either  $u = 1$  or  $u = 5$ , and  $s$  is odd. If  $u = 1$ , two solutions are  $(s, t) = \{(3, 5), (6, 2)\}$ . The solutions are 6 & 21 and 3 & 51. If  $u = 5$ , there are no solutions.

For  $n > 0$ , there are no solutions. No other permutations have solutions.

Now, assume the ages being multiplied are both two digits. Call the ages  $[rs]$  and  $[tu]$ .  $[rs]$  times  $[tu]$  = some permutation of  $r$ ,  $s$ ,  $t$ , and  $u$ . From above, one of the two numbers must end in 1 or 5. The permutation  $[utrs]$  gives solutions 21 & 60 and 51 & 30. The permutation  $[stru]$  gives the solution 21 & 87, and the permutation  $[ruts]$  gives the solutions 15 & 93 and 27 & 81.

The ages are therefore 6, 21, 60, and 87.

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1300 East 9th Street  
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216.696.7000, ext. 9721  
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# What it Means to be a Professional Engineer



A handwritten signature in black ink that reads "MORGAN" followed by a stylized flourish.

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

In the United States, engineers who are licensed to offer engineering services directly to the public earn the title "Professional Engineer," or "P.E." for short. Licensure as a professional engineer requires a combination of education and experience. The typical requirement includes graduation from an engineering school, successful completion of the fundamentals of engineering, or "EIT" exam, a minimum of four years experience and successful completion of the principles and practices of engineering, or "P.E." exam. Given that licensure is administered on a state basis, the specific requirements may vary slightly from state to state, and some states allow the substitution of additional experience above the minimum requirement in lieu of some of the other requirements.

Professional engineering examinations are available in a number of engineering disciplines, such as mechanical, electrical, civil and fire protection. The Society of Fire Protection Engineers is responsible for developing the fire protection engineering exam. Approximately 55% of all SFPE members are licensed as professional engineers.<sup>1</sup>

Anecdotally, there seems to be a wide range of views about the meaning of licensure as a professional engineer. These views range from opinions that licensure does not mean anything to opinions that licensed engineers are capable of anything within the field (or at least think that they are). Of course, the correct meaning lies somewhere in between these extremes.

In the United States, the National Council of Examiners for Engineering and Surveying sets the bar for licensure in any engineering discipline as "minimally competent" within the licensee's field of engineering. "Minimally competent" is defined as possessing at least the minimum amount of engineering expertise to protect public health, safety and welfare in the practice of engineering.

Each time that the fire protection engineering exam is graded, SFPE assembles a diverse group of licensed engineers to define "minimally competent" and how it corresponds to the questions on the P.E. exam. Examples of the standards of minimal competence include "a thorough understanding of fundamental systems and practices as they pertain to life safety and to fire prevention, detection, control and extinguishment. This includes the ability to apply this understanding in conjunction with commonly used fire protection standards."<sup>2</sup>

No exam could determine whether an engineer has all of the knowledge that they would need for to solve any problem that might arise. Indeed, in some engineering subjects, the standards of minimal competence uses words like "awareness" or "basic understanding." Licensure as a professional engineer means more than having a certain amount of experience and having passed a few examinations – it also means that an engineer can be held responsible if they fail to protect public health, safety and welfare through their practice of engineering.

Licensure as a professional engineer is an achievement for which any engineer should be proud. However, licensure in itself should never be interpreted as meaning that the engineer is all knowing and above reproach. Similarly, lack of a professional engineer's license in itself does not mean that an engineer is not at least "minimally competent;" it simply means that the engineer has not met the criteria associated with obtaining a professional engineering license.

## REFERENCES

- 1 Society of Fire Protection Engineers, "2003 Profile of the Fire Protection Engineer," Bethesda, MD, 2003.
- 2 Lataille, J. "The Discipline of Fire Protection Engineering," *Fire Protection Engineering*, 3, Summer 1999, pp. 40-42.