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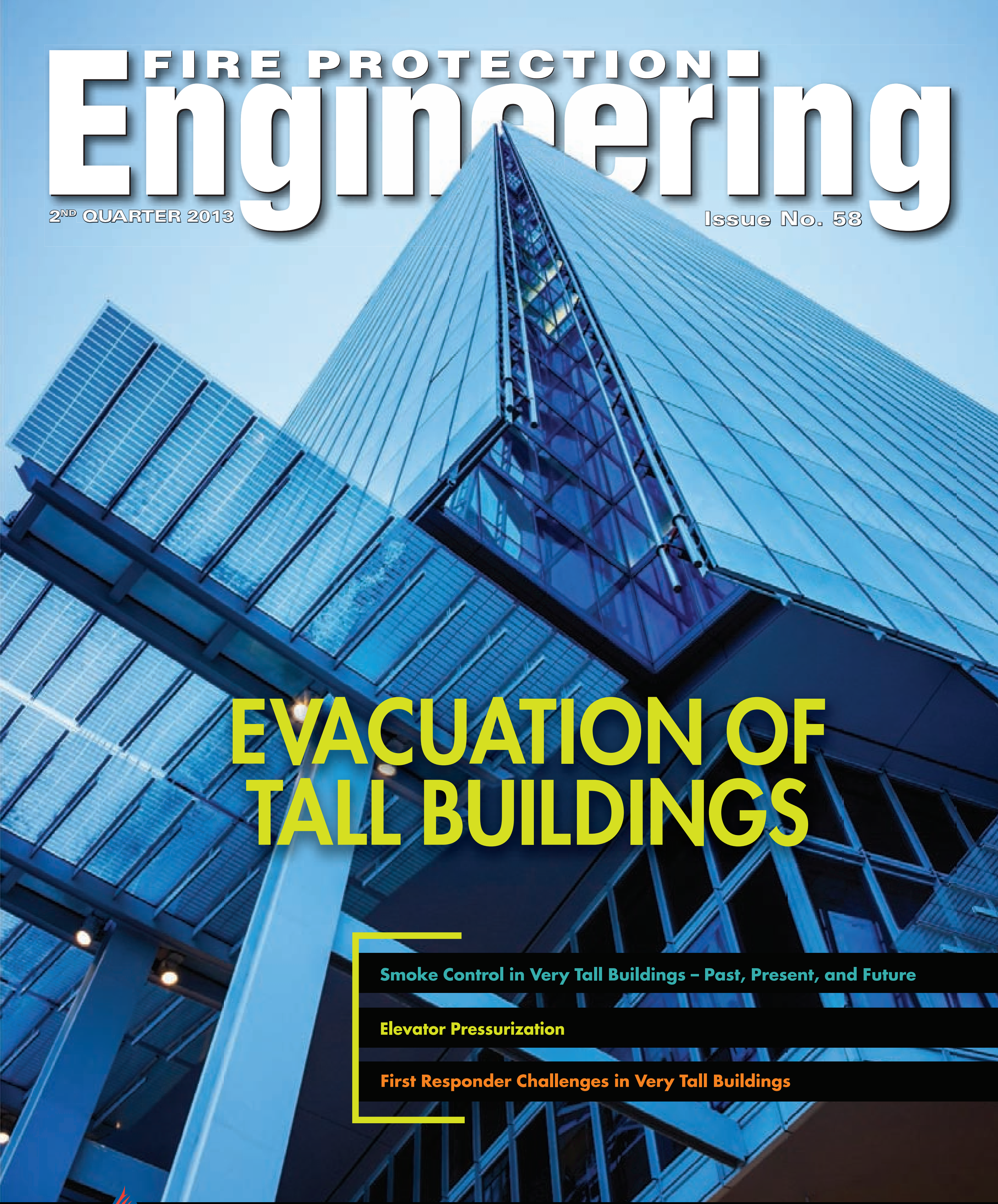

EVACUATION OF TALL BUILDINGS

Smoke Control in Very Tall Buildings – Past, Present, and Future

Elevator Pressurization

First Responder Challenges in Very Tall Buildings

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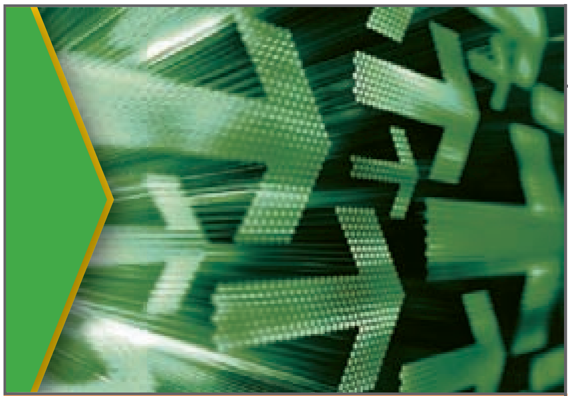

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From the TECHNICAL DIRECTOR

Achieving the Right Balance – Safety and the Cost of Safety

Fires exact a toll on society. These costs come from two sources. One source, which is the most easily recognized, is the losses that occur during and following a fire. The second source is not as apparent: the cost of providing fire protection in buildings. When designing fire safety in buildings, it is necessary to balance the cost of providing fire safety with the potential costs associated with fire losses.

Losses that are suffered in fires can be grouped into two categories: direct losses and indirect losses. Direct losses encompass the replacement costs of things that are damaged by fire. This includes damages to the building itself (whether repair or replacement is necessary) and the value of things that are located within a building that are damaged or destroyed by fire. Direct losses also include deaths and injuries to people from fire; the "value" of these losses is inherently difficult to quantify, but necessary to consider nonetheless.

Indirect costs include the monetary value of losses that occur as a result of a fire but are not associated with the repair or replacement of a building or its contents. An example of indirect costs is the cost of obtaining alternate building space and lost revenue due to business interruption.

In the United States, direct fire losses were $14.2 billion in 2009. Indirect costs added another $1.9 billion.[1]

Fire safety itself has attendant costs. These include the costs associated with providing fire safety measures in buildings, such as fire suppression systems, fire detection and alarm systems, smoke control systems, and fire-resistant construction. In 2009, the cost of fire safety in buildings was estimated to be $41.6 billion.[1] Other fire-related costs include the costs of providing firefighting services and the costs of providing insurance.

All human endeavors bring with them some risk, and it is not possible to achieve an environment entirely free of risk. Buildings are no exception. A building could be constructed entirely using noncombustible materials, but once furnishings, electrical and mechanical systems and people are brought into a building, they bring with them some fire risk. It is possible to minimize this risk by providing fire safety systems, but it is not possible to completely eliminate it.

The costs of fire (direct and indirect) are balanced by the costs of providing fire safety. As additional fire safety is provided in a building, the costs of fire would decrease. However, there is a point of diminishing returns, where additional expenditures on fire safety are not worthwhile.

The challenge is to find this balance point between fire safety and the cost of fire safety. While fire protection engineers can assist greatly with finding this balance, the choice is not left to fire protection engineers (or individual regulatory officials for that matter). Instead, society determines where this balance occurs. And, society values different risks differently. Society generally will not tolerate large fires that result in the total loss of a building that serves an important function in the community. Similarly, society will not tolerate a fire that results in a large loss of life.

What further challenges finding the balance between safety and the cost of safety is that society does not explicitly state the amount of loss that it can tolerate. Society's loss tolerance is reflected, to a certain degree, in the building and fire codes that it adopts. However, case law also plays a role, as society may find some losses that occur in fully code-compliant buildings to be unacceptable.

So, what does this mean for designers of fire safety in buildings? For most buildings, code compliance is sufficient, since code-compliant buildings provide a level of safety that has been accepted by society. However, fire protection engineers should consider risks that might not be typical for a given building type, and design appropriate mitigation approaches accordingly. Similarly, whenever the equivalency provision in a code or standard is used, the engineer should be certain that the alternate approach provides a solution that is at least as safe as that required by the prescriptive provision for which equivalency is sought.

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

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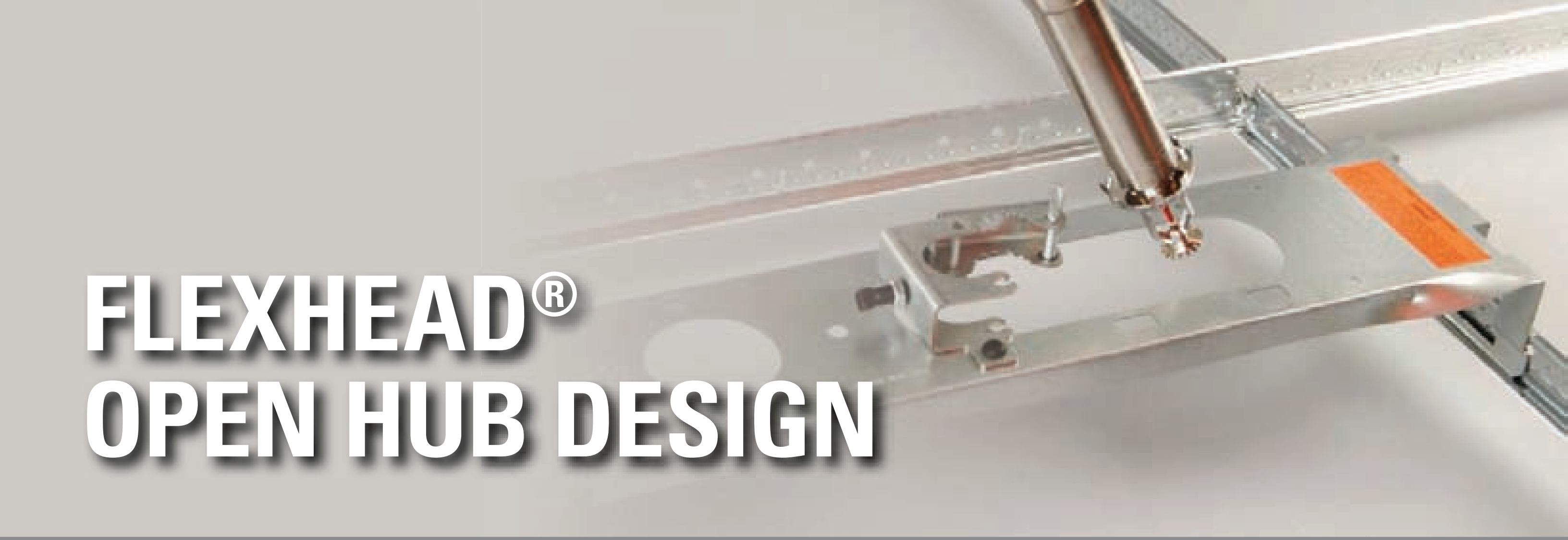

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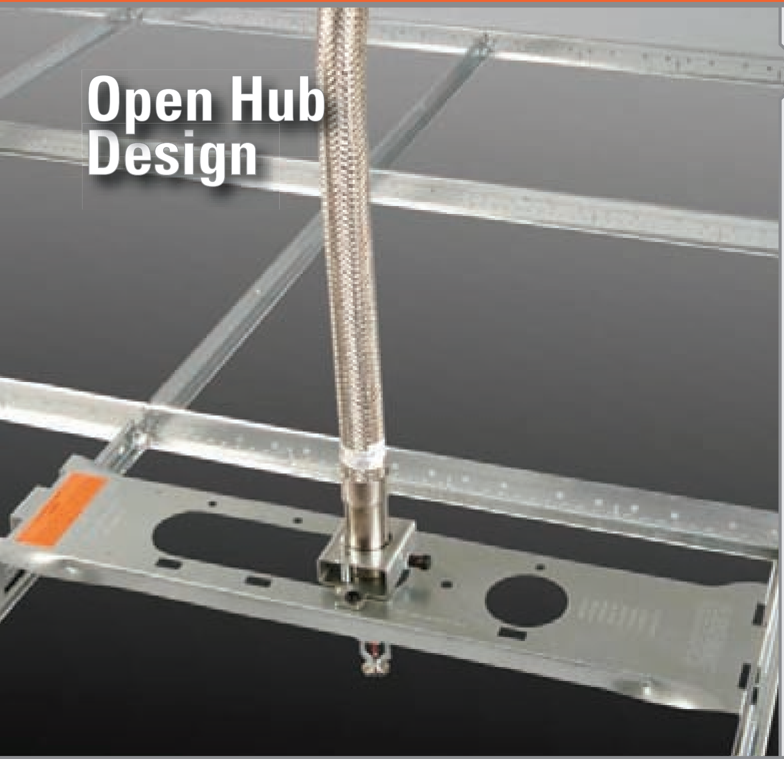

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Fire and Life Safety in This New Era of Supertall Buildings

By Peter A. Weismantle

Donald Trump's representatives arrived at the offices of Skidmore, Owings & Merrill in Chicago early on a beautiful late summer morning. They had flown in from New York to kick-off the design of a new supertall, mixed-use project located on the Chicago River, just off of Michigan Avenue. The project, Trump International Hotel & Tower, was discussed in terms of superlatives. Not only would it be the most luxurious, ambitious, and mixed-use project yet to be undertaken by the Donald, but it would also be the tallest. As a matter of fact, it was possible that Trump International could be the tallest building not only in the city of the Sears (now Willis) Tower, but the tallest building in the world.

As it happened, the Trump team arrived on Sept. 11, 2001. As events of that morning unfolded, it became obvious that the world had changed. Immediately following the events, there was a lot of soul-searching and wondering what "went wrong." Since that time, many investigations have taken place and many lessons have been learned about what happened, caused by what was fundamentally a terrorist attack. We have also learned that, all things being equal, those structures performed remarkably well. And we have recognized that the prevention of a similar tragedy involves more than "hardening" the building. Proactive common-sense approaches to security, stand-off distances, and surveillance were the first steps. And now, more than a decade down the road, we are seeing implementation of provisions in the model building codes that are meant to enhance the robustness and resilience of both the physical structure and the fire and life safety systems in tall buildings.

No one who was watching on TV that day will ever again look at a tall building without having the images of the events of 9/11 in the back of their minds. It was not hard to imagine that the era of very tall buildings may have ended forever. Having said that, here we are, now in the midst of a period of unprecedented tall building construction worldwide. The reasons behind building tall are still as valid as they were before 9/11. The increasing urbanization of the world, limited land area and high land cost, the desire for views, the prestige, the economic incentive, the value creation of a tall building and the ego behind creating a tall landmark are especially compelling in the rapidly developing areas of the world. Tall buildings and a dramatic modern skyline are still the most important self-image that cities around the world want to project.

When I began my career, there were only five buildings in the world, all in the United States, that could be considered as "supertall," that is to say, exceeding 300 meters (about 1,000 feet) as defined by the Council on Tall Buildings and Urban Habitat. Although two of those five came down on 9/11, there are now 68 supertall buildings in the world plus more than 100 under construction! Furthermore, the vast majority of these buildings are in areas of the world that only recently have seen the social, economic, and technological development that allows the construction and management of projects of this magnitude.

There are a number of challenges, beyond the obvious technical ones, that face the designers of the new crop of supertalls. The vast majority of these buildings are being designed to internationally recognized codes and standards, which assume a high level of technical competence, not only on the part of the contractor, but also on the building owner/operator. These codes and standards make certain assumptions on the part of third parties such as the local municipal infrastructure including the fire authority and emergency services. Furthermore, they are being built and operated in parts of the world that may not have the tradition, background, education, or experience in these areas.

It is incumbent, therefore, for the architect and the full consultant team to keep in mind "first principles" when designing the fire safety systems for these unique structures. Passive along with active, simple along with sophisticated, local along with international, redundant, resilient and enhancements, are all concepts that must be more than just words in a project description. The team must take into account that these buildings will be around a long time and that the initial design must be easily maintained and operated using the resources locally available.

Furthermore, a comprehensive approach to collaboration is an important concept that must be honored. By this I mean to say that beyond the usual internal design team collaboration and coordination, the design team must reach out to the other project stakeholders. In terms of fire life safety, this goes beyond just the efforts made to secure approval to build the project from the local authorities or how to obtain high-tech equipment for a relatively low-tech location. It must mean a genuine effort to understand the concerns and abilities of the folks that will construct, operate and maintain the projects we design because, in an emergency, they will all depend on the building's systems behaving as we assumed when designed. With this approach, it is hoped that these projects will be a positive, long-lasting legacy of this new era of supertall buildings.

Peter A. Weismantle is with Adrian Smith + Gordon Gill Architecture.


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WPI Honored for Developing Technology that Increases Firefighter Safety

Worcester Polytechnic Institute (WPI) was honored at the 23rd Annual "Firefighter of the Year" award ceremony with the 2012 State Fire Marshal's Award, which recognizes significant contributions to the fire service made by those outside of the service.

"For more than a decade, a group of WPI faculty has been diligently working to develop technologies to protect our first responders," said Dennis Berkey, president and CEO of WPI. "They have worked closely with the Worcester Fire Department, with federal researchers and with industry to move this important work forward. This award recognizes their hard work and it echoes the pride that the entire WPI community feels for this exceptional team."

NIST Strategic Roadmap Aims to Reduce the Nation's Fire Burden

Fires claim more than 3,000 lives a year, injure more than 90,000 firefighters and civilians, and impose costs and losses totaling more than $300 billion — equivalent to about 2% of the nation's gross domestic product.

Researchers at the National Institute of Standards and Technology (NIST) have developed a plan to significantly reduce that burden over the next two decades. *Reducing the Risk of Fire in Buildings and Communities: A Strategic Roadmap to Guide and Prioritize Research*, sets short-, medium-, and long-term goals — from fewer than three years to more than eight — for reducing the nation's fire burden by a third.

The publication is available at *http://www.nist.gov/el/fire_research/fire-090512.cfm.*

ICC Recognizes NFPA's National Electrical Code®

The International Code Council has designated NFPA 70®, the *National Electrical Code®* (*NEC®*), as the electrical code for use with the ICC's International Family of Codes or "I-Codes." The set of 15 I-Codes are model building codes used in every state and most jurisdictions. Similarly the NEC, which is developed by the National Fire Protection Association (NFPA), is the model code used as the basis for electrical regulations throughout the country, and it has been referenced for more than 10 years in the I-Codes as an integral part of the building safety framework.

"Sprinkler Saves" Blog Records 500 Saves

Viking Group's "Sprinkler Saves" blog recently recorded its 500th "sprinkler save."

The "Sprinkler Saves" blog recently celebrated its one-year anniversary. Fire sprinkler success stories from throughout North America are posted daily to the blog. One of the goals is to influence how the media reports on successful sprinkler activations to help the public gain perspective on the value of automatic fire sprinklers in saving lives and property. The 500th blog entry analyzed the 500 "sprinkler saves" and provided statistics such as:

- 197 (39%) of the 500 saves occurred in residential occupancies
- 37 occurred in nursing homes or senior living facilities
- 22 were in hotels/motels
- The activities of 40 arsonists were foiled due to a successful sprinkler activation.

For more information, go to *http://sprinklersaves.blogspot.com.*

EVAC→ UATION OF TALL BUILD→ INGS

By Bryan Hoskins, Ph.D.

Tall buildings began to dramatically change the skylines in major cities more than a century ago. Technological advances made it possible for people to effectively use spaces at heights far above grade level. Tall buildings provide challenges for the designers of fire protection systems not found in other buildings.

Like previous editions, the 2012 edition of NFPA 101, the *Life Safety Code*[1] allows building designers to use performance-based options in designing the egress system in the building. The performance criterion is given in Section 5.2.2. Based on this section of the code, the designer must consider the different fires that could occur in the building, how these fires will impact tenability, and how long the occupants will require to safely evacuate the building.

When using this approach, all of the assumptions and design methods must be included in the simulation of the evacuation. This means that the egress system designer must develop assumptions about how the population is expected to behave during the evacuation of a tall building. These assumptions then have to be applied to the calculation using data that is available.

What is not directly stated by NFPA 101 is that the egress system designer needs to understand the source of

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the data and how it applies to tall buildings. Some behaviors might be insignificant for someone going down a single flight of stairs, but become more significant as the travel distances become much larger.

One potential solution is to apply safety factors to the design. With only a limited understanding of the data, a large safety factor may be required so as to not subject the building occupants to undo risk.

This article will look at components of the evacuation time of occupants in tall buildings and the assumptions that are made by egress system designers. The focus will be on the movement to and within the stairs as well as the data used to develop an estimate of the descent rate. How the data was collected relative to its application for use in tall buildings will be analyzed. Finally, other egress options will be discussed.

FIRST ASSUMPTION: TIME REQUIRED TO START EVACUATING

The egress system designer needs to consider two sets of conditions in parallel. On one side, there is the fire growth and tenability in the different building areas. On the other side, there are the building occupants that need to get to a place of safety. For people remote from the fire, they need to receive some cue (e.g., smell smoke, see flames, or hear an emergency announcement) before they will start to evacuate. Occupants remote from the ignition location may require some time before they start to evacuate. In a tall building, direct observation of fire cues might not be possible for occupants located many floors away and/or on the opposite side of the building. In tall buildings, it is likely that many of the building occupants will not become aware of the need to evacuate until the fire alarm system activates.

In tall buildings, it is likely that many of the building occupants will not become aware of the need to evacuate until the fire alarm system activates.

The egress system designer could add the time for

the alarm to activate to the time calculated for egress. In this case, the assumption is that all of the occupants hear the alarm and immediately start toward the exit. It is based on all people perceiving the alarm, paying attention to it, comprehending what it means, realizing that it applies to them, and then deciding to evacuate. Research has shown that many people do not recognize the temporal-three signal as applying to fires.[2] Even when people in tall buildings do realize that there is an emergency, they have reported doing other tasks.[3] When using the pre-evacuation times from tables, using the average value creates two potential limitations. First, the data has only been collected from a relatively small number of incidents. Training and other unknown variables could cause these times to be too short or too long. More data is needed to be able to fully understand what the most appropriate values are. Second, NFPA 101 requires that all occupants remote from ignition be protected from untenable conditions. If some vulnerable populations require more pre-evacuation time, using the average value will leave them at risk for not being able to evacuate before conditions become untenable.

SECOND ASSUMPTION: MOVEMENT WITHIN THE STAIRS

For the evacuation of a tall building, stairs are intended to allow people to descend and leave the building. While there is some travel distance on the floor of origin, NFPA 101 limits that travel distance. After descending fewer than 11 floors, the building occupants have travelled further within the stair than before they reached it.[4]

The descent times in tall buildings can be substantial. While the stairs can usually be considered safe, a poor estimate of how people descend could lead to crowded conditions that prevent people from the floors from entering the stairs.

One equation that has been used for calculation of movement on stairs is found in the *SFPE Handbook of Fire Protection Engineering*.[5] The *Handbook* does not provide any limitations on the applicability of the results. For densities

greater than 0.54 persons/m^2 and less than 3.8 persons/m^2, the SFPE Handbook equation is:

$S = k - akD$ (Equation 1)

where:

S = Speed along the line of travel (m/s or ft/min)
D = Density (persons/m^2 or persons/ft^2)
k = constant for four different riser and tread combinations
a = empirical constant (0.266 when calculating m/s, 2.86 when calculating ft/min)

For densities less than 0.54 persons/m^2, the people are able to travel at their free speed (the speed at 0.54 persons/m^2). For densities greater than 3.8 persons/m^2, the flow comes to a stop.

Based on this formula and no limitations, it is then possible to predict the evacuation time. In order to do so, there are several more assumptions that are made.

THIRD ASSUMPTION: THE ORIGINS OF THE SFPE HANDBOOK EQUATION APPLY TO TALL BUILDINGS

For travel down stairs, the *Handbook* equation is based primarily on the work of two researchers from the 1960s and 1970s. The equation comes mainly from the work of Pauls and Fruin.[5]

The work of Fruin[6] primarily involved pedestrian planning for horizontal egress and ingress components. For level surfaces, he developed six "levels of service" (*A* to *F*) to qualitatively explain the ability of people to choose their walking speed at different densities. He extended his observations by observing two different stairs. One of the stairs was indoors and the other was an outdoor stadium.

Again the "levels of service" ranged from Level *A* (below 0.54 persons/m^2), where people are free to choose their own speed to Level *F* (above 2.70 persons/m^2), where the descent is reduced to a shuffling pace. In neither case was it reported that the building occupants were in tall buildings.

In the 1960s and 1970s, Pauls[7] observed evacuations of 58 tall buildings in Canada with a range of riser and tread dimensions. These buildings were up to 20 stories in height, but most were shorter. In his study, he looked at building averages and a limited number of spot measurements. From this data, he proposed that the descent speed could be calculated based on:

$S = 1.08 - 0.29D$ (Equation 2)

where:

S = Speed along the line of travel (m/s)
D = Density (persons/m^2)

If, in Equation 1, the constants for the metric units and 17.8 cm riser height and 27.9 cm tread depth are used, the two equations are equivalent.

Using the same data, Pauls[8] later reported that most of the stairs in his study had 17.8 cm riser heights and 27.9 cm tread depths. He theorized that people might descend stairs at different rates depending on the riser height and tread depth. With his theoretical equation, he calculated what the different speeds might be for four different combinations. He also explicitly stated that the values were not based on actual data and should not be used in practice.

Based on these three pieces of research, Nelson and MacClennan[9] developed Equation 1. When the density was less than 0.54 persons/m^2, they used the findings of Fruin[6] to determine the free movement speed. The subsequent speed values for the 17.8 cm

riser height and 27.9 cm tread depth case was based on the work of Pauls.[7] The 3.8 persons/m^2 end point was based on where the graph crossed the x-axis. It is at a much greater density than Fruin[6] gave for level of service *F* and well beyond the maximum density observed by Pauls.[7] For the other three *k* values, Nelson and MacClennan[9] used the theoretical values that Pauls[8] had said should not be used in practice. These other *k* values came from the assumptions made by Pauls and not from data that had actually been collected.

It should be noted that Pauls[7] and Fruin[6] did not measure density in the same manner. Pauls[7] identified a boundary layer that people leave between themselves and walls. His density measurements are based on the effective width. The previous approach used the entire area. Thus, value from Fruin[6] should have been adjusted to be comparable to the measurements of Pauls.[7]

FOURTH ASSUMPTION: THE SFPE HANDBOOK EQUATION APPLIES IN ALL CASES

There are seven issues that challenge the assumption that Equation 1 is valid for use in tall buildings:

- The reliance on averages could lead to underestimating times for vulnerable populations.
- The basis on density rather than human interactions might not match reality.
- The untested *k* values might not be valid.
- For buildings over 20 floors (and possibly less due to sample size issues), the buildings are taller than those used to collect the original data.
- The population considered might not be representative of the earlier population.

- The measurement methods used might not be consistent.
- The equation can be applied to densities that were not observed.

Equation 1 is primarily a regression equation that was developed using averaged values. While this can give an approximation of the mean value, it does not give any indication of the scatter of the data. In order to develop an appropriate safety factor, the expected minimum movement speeds need to be known. This is especially true if those minimum values apply to a particular subpopulation. If that subpopulation will always move slower than average, it is not conservative to apply the average value to them.

With the intent to protect all occupants not intimate with ignition, relying on just average values could lead to vulnerable populations not having sufficient time to evacuate. For example, Boyce, Shields, and Silcock[10] found that people with varying levels of physical impairments required greater time to descend stairs.

Another underlying assumption of Equation 1 is that people behave like a fluid. The flow rate out is a constant and the people do not interact in any way other than the density; no one person will slow down the other people around them. Pauls[8] specifically addressed this point by noting that people passed slower individuals to keep the ultimate flow in line with the expected results. However, Shields, et al.[11] found that occupants were unwilling to pass a wheelchair user being assisted down the stairs (approximately 40 cm available to pass) and Proulx, et al.[12] found that occupants using the handrail or with disabled occupants ahead of them did not pass slower moving occupants. Finally, Shields, et al.[13] found that people moving behind a slower moving occupant chose not to pass. Even beyond the considerations of the vulnerable populations, people will interact as they descend. For example, Jones and Hewitt[14] discussed groups forming during evacuations and how those people interacted both before and during their descent.

A better understanding of these interactions could result in an improved understanding on the amount of time that people will require to descend. However, assuming that the slower moving people will just be passed is not conservative.

Another potential limitation with Equation 1 is the *k* value that is used. While the work of Templer[15] indicates that there could be differences in speed based on riser heights and tread depths, it is unknown if the *k*-values in Equation 1 are accurate. Applying the equation to any situation other than a 17.8 cm riser height and 27.9 cm tread depth is outside the scope of the data that was collected. How much of an error this will make in the final predicted value is unknown.

The scope of the data could also limit effects that would manifest themselves as people descended greater distances. The Joint Committee[16] believed that fatigue would start to play a role when there were no merging flows, and Galea and Blake[17] reported instances where fatigue was caused by footwear. Equation 1 does not have any difference in speed caused by fatigue. Based on the equation, a person descending from the top of a hundred story building would never slow down. If fatigue is an effect, then Equation 1 presents an optimistic estimation of speed on stairs in tall buildings.

Questions have also been raised about the applicability of data collected nearly half a century ago on the population of today. Pauls, Fruin, and Zupan[18] were unsure about whether the changing demographics of the population would cause descent speeds to be slower.

It is important to note that the researchers whose work enabled the creation of Equation 1 questioned whether it was still applicable or not.

Hoskins and Milke[4] explain the different methods to measure occupant density that have been used by previous researchers and include a method for calculating landing distances not done for Equation 1. Also, related to the previous issue about the *k* values, Hoskins[19] has proposed a method for equating densities on different tread dimensions, and when landings are included, to make equations applicable to more stair configurations. However, this method needs to be validated using more data.

The final potential problem that can arise when using equation 1 for tall buildings is to have theoretical conditions that do not match reality. The maximum density does not match the observations of Fruin[6] or any observation made by Pauls[7]. Any calculations that involve the highest density conditions may not be accurate.

All seven of the limitations come back to one central point when considering people movement in tall buildings: Equation 1 could be accurate. How accurate is unknown and thus requires safety factors. After all, in smaller buildings, an estimated time that is off by a few seconds per floor results in errors that fall within the level of the noise of the data. As the buildings get taller, those seconds can become minutes if not tens of minutes. The errors can then rise above the level of the noise.

USE OF COMPUTER MODELS

Many of the issues involving Equation 1 apply to the use of the computer models. When a model is used, the system designer needs to be aware of the limitations of the model, the basis of the calculations, and how the default settings alter the results. Simply using the default settings might not provide accurate results for evacuations from tall buildings for all of the reasons that applied to Equation 1.

VULNERABLE POPULATIONS

The travel time down stairs required for vulnerable populations could be substantial, or they might not be able to descend the stairs at all. The 2012 edition of NFPA 101[1] allows the use of elevators for occupant-controlled egress prior to phase 1 emergency recall. This should help to meet the goal of protecting all building occupants not intimate with ignition in tall buildings.

Bryan Hoskins is with Oklahoma State University.

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SMOKE CONT IN VERY TALL BUILDINGS

PAST, PRESENT, AND FUTURE

ROL

By Erik Anderson, P.E.

INTRODUCTION

In comparison to low-rise buildings, very tall buildings have several inherent attributes that increase the variety, probability, and severity of potential fire events, including: higher occupant loads; longer evacuation times; access issues for responding fire departments; potential water pressure/availability issues; pronounced stack effect; the potential for multiple concurrent occupancies to be present; and their iconic, high-visibility nature. Specifying adequate smoke control provisions during the design of very tall buildings plays a key role in addressing several of these issues.

"Smoke control" in the broadest sense simply means controlling the movement of smoke throughout a building via passive and active means. The installation of fire and smoke barriers with protected openings is a form of passive smoke control. Arguably, automatic sprinkler systems provide a form of smoke control by limiting the size and growth rate of fires and by cooling the smoke and thereby reducing buoyancy and pressure differences.

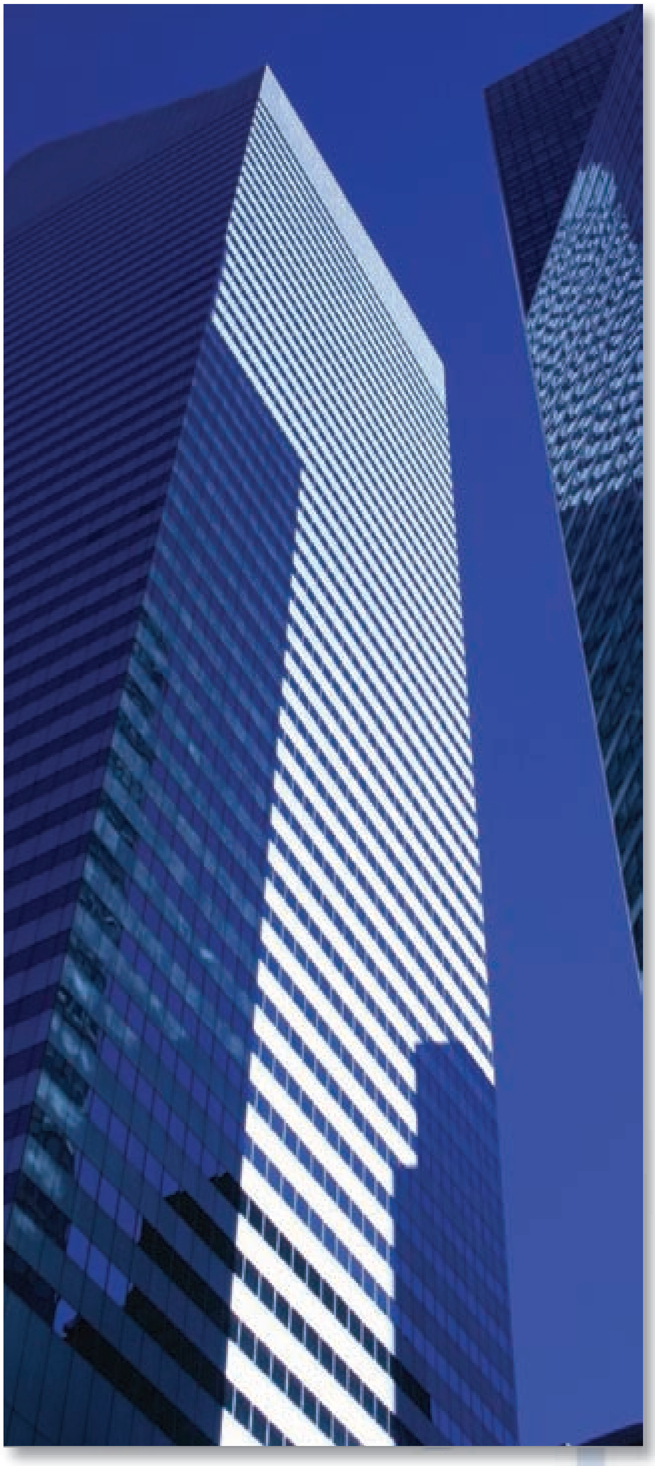
This article will focus on engineered smoke control systems in very tall buildings, which use mechanical

means to produce pressure differentials across barriers to inhibit smoke spread. It will discuss the code trends of the past and some of the relevant design considerations for smoke control in very tall buildings of the future.

SYSTEM TYPES

Common types of engineered smoke control systems in high rises and very tall buildings include:

1. **Atrium smoke control systems** – It is common for very tall buildings to contain one or more atria or even to contain a covered mall or other large-volume space.[1] Most consensus codes in the United States require a smoke management system for multiple-story atria. This would typically consist of a mechanical smoke exhaust system to extract smoke from the top of the atrium with low-level, low velocity make-up air at the bottom of the atrium in order to maintain the smoke layer above the occupied areas and their associated means of egress for a specified time period.
2. **Stair pressurization** – Most building codes require high-rise buildings to be provided with smokeproof exit stairs or stair pressurization.[2] The *International Building Code* (IBC) allows three methods for compliance: exterior stair balconies, mechanically ventilated stair vestibules, or stair pressurization. Mechanical stair pressurization is the most commonly used approach to meet this requirement for high-rise buildings in the United States.
3. **Pressurized elevator hoistways** – The IBC permits the omission of elevator lobbies if a hoistway pressurization system is provided. In order to meet the aesthetic and functional needs of the building, this design option is often chosen.
4. **Post-fire smoke removal** – Post-fire smoke removal systems are intended to facilitate smoke removal during post-fire salvage and overhaul operations. To meet this requirement, the IBC and various previous codes have allowed operable windows/panels, or mechanical equipment capable of providing a prescribed number of air changes per hour.
5. **Zoned smoke control system** – Defined as a smoke control system that divides the building into separate smoke control zones and creates pressure



Early building and fire codes usually required at least one exit stair in buildings over a certain height to meet requirements for "smokeproof towers."

differentials to inhibit smoke spread. Mechanical exhaust is provided for the areas containing smoke and pressurization is provided for the other contiguous zones. In a high-rise building, zones may consist of entire floors, but sometimes floors are subdivided into multiple zones. An example is the pressure "sandwich" effect in which the fire floor is exhausted and the floors above and below are pressurized. These systems have the drawback of being very complex due to the necessary coordination with other HVAC equipment, controls, operational matrices, and so on.

PAST CODES

Early building and fire codes usually required at least one exit stair in buildings over a certain height to meet requirements for "smokeproof towers." For example, the 1927 Edition of the *Uniform Building Code* (UBC) required buildings five or more stories in height to be provided with at least one exit meeting the requirements for smokeproof towers.[3] Early editions of the *BOCA Basic Building Code* (BOCA) dating prior to the 1960 Edition required at least one smokeproof stair tower in buildings over 75 ft (23 meters) in height. The requirements for these smokeproof towers were met by constructing exterior stair balconies or stair vestibules with openings to the outside.

In 1975, the *BOCA Basic Building Code* included a dedicated section on high-rise buildings, which included smoke control requirements. Allowable smoke control methods in that edition included: HVAC equipment

designed to exhaust air to the outside, operable panels or windows for natural ventilation, tempered glass windows, or, a continuous shaft used to mechanically exhaust one air change per minute from within the building. In 1990, BOCA provided prescriptive requirements for zoned smoke control systems in high rises based on a required number of air changes per hour. However, operable windows/panels were still permitted as an alternative. In 1993, zoned smoke control requirements were removed entirely from the BOCA high rise requirements. The 1993 BOCA Commentary indicated that: *"high-rise buildings have life safety systems including: sprinklers, pressurized stairs, control of the HVAC system, and smokeproof enclosures. In the absence of floor openings, these systems, along with the story-to-story compartmentation provided by continuous floor construction, provide an acceptable level of safety. As such, smoke control is not a consideration unless the building also contains an atrium."*[4]

While BOCA eliminated all high rise zoned smoke control requirements in 1993, the UBC requirements went in the opposite direction. The 1994 UBC required an engineering-based zoned smoke control system in all high rises with the stated purpose of providing a tenable environment during an evacuation. Stack effect, temperature, effect of fire, wind, and HVAC systems all needed to be evaluated. These requirements remained in the UBC through its final edition in 2000.

PRESENT CODES

A consensus definition for "very tall building" has not yet been determined. Like its predecessor codes, the IBC defines "high rise" as a building with an occupied floor(s) 75 ft (23 m) or more above the lowest level of fire department vehicle access. The IBC provides several additional requirements for high-rise buildings, including extra requirements for stair enclosures. If stair pressurization is used as an alternative to a smokeproof stair enclosure, the stair must be positively pressurized to a minimum of 0.10 inches of water (25 Pa) and maximum of 0.35 inches of water (87 Pa), relative to the building

The 1994 UBC required an engineering-based zoned smoke control system in all high rises with the stated purpose of providing a tenable environment during an evacuation. Stack effect, temperature, effect of fire, wind, and HVAC systems all needed to be evaluated.

internal pressure, with all stairwell doors closed. The stair vestibule (if provided) is required to be ventilated such that it is supplied with at least one air change per minute with an exhaust capacity of at least 150 percent of supply.

Recent editions of the IBC have included additional requirements for buildings exceeding 420 ft (128 meters) in height, such as increases in the minimum construction type permitted, increases in required fire resistance ratings, and requirements for more robust stair and elevator shaft construction. However, no additional smoke control system requirements were added. Thus, regardless of the height of the building, the IBC has never required a zoned smoke control system due to building height alone. However, since 2009, the IBC has incorporated language that requires the provision of a natural or mechanical system or method to assist with smoke removal during post-fire incident clean-up operations in high-rise buildings.

Recent editions of the IBC have included additional requirements for buildings exceeding 420 ft (128 meters) in height, such as increases in the minimum construction type permitted, increases in required fire resistance ratings, and requirements for more robust stair and elevator shaft construction.

INTERNATIONAL PERSPECTIVE

The Middle East is home to many of the world's tallest buildings. The United Arab Emirates (UAE) Ministry of the Interior published the *UAE Fire and Life Safety Code of Practice* in 2011, which is now a mandatory compliance document for new projects submitted for approval to Civil Defense.[5] The code contains a chapter on smoke control. For all high-rise buildings, the UAE code requires pressurized stairs and a zone-type smoke control system for egress corridors.

China is also home to many of the world's tallest buildings. Requirements for tall buildings in China, Hong Kong, and other countries in that region are similar to the U.S. codes. One exception is that the Chinese codes require refuge floors to be located every 20 stories.[6] These stories must remain dedicated for refuge use and must be open to the exterior. Buildings over 780 ft (238 m) in height must have additional protection, but such protection is undefined. Smoke control or pressurization is also required in stairs and in corridors in buildings over 105 ft (32 m) in height.[7]

The Society of Fire Protection Engineers created the first edition of a new guidance document entitled: *Engineering Guide – Fire Safety for Very Tall Buildings*.[8]

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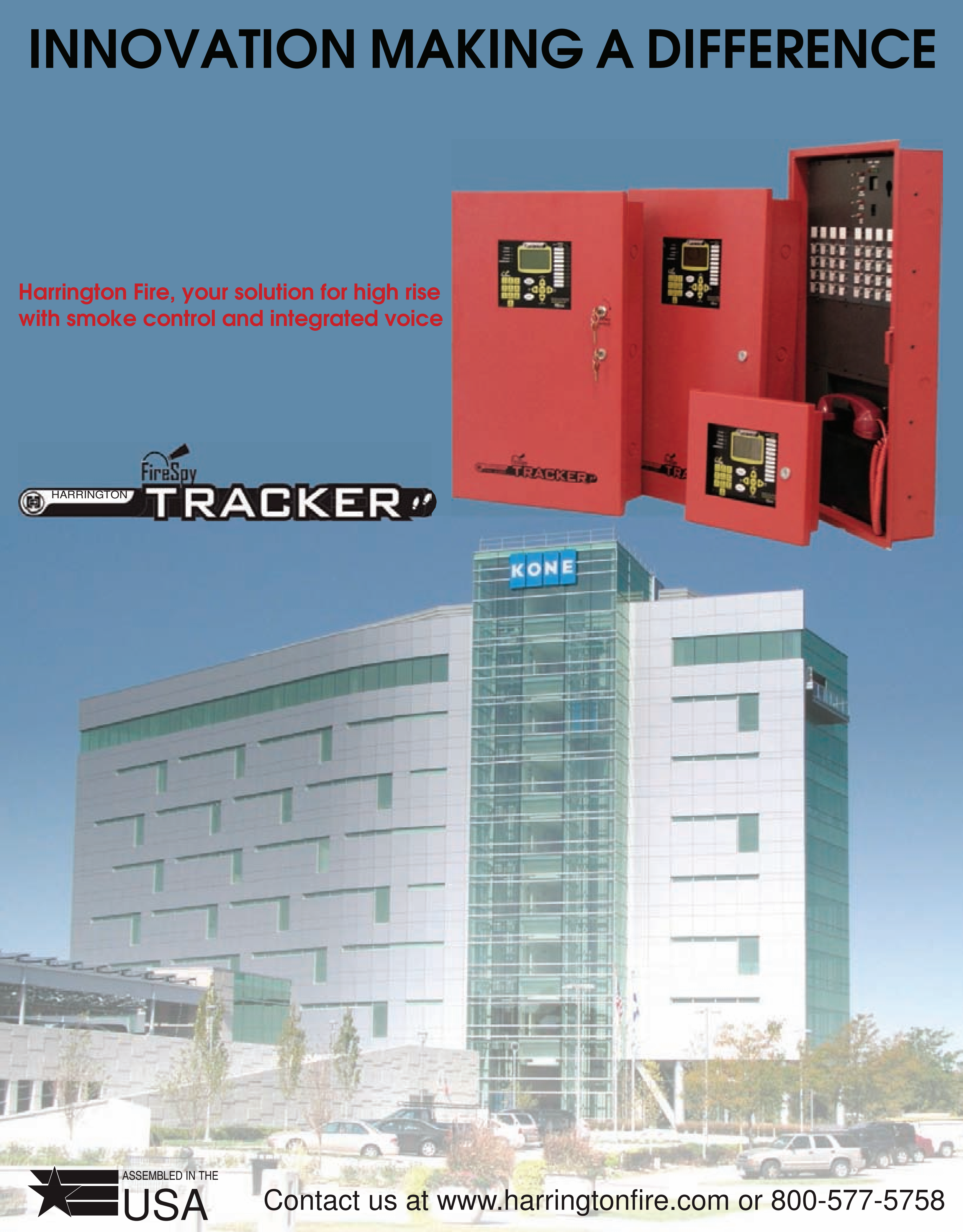
CONSIDERATIONS DURING DESIGNS

Very tall buildings are subjected to the same forces that drive smoke movement within any other building (buoyancy, expansion, ventilation systems, elevator piston effect, stack effect, and wind). However, by nature of their height, very tall buildings warrant additional attention to the following features:

Stack effect – Stack effect and reverse stack effect are terms that describe the vertical air movement within a building resulting from air density differences between the building interior and exterior or between two interior spaces.[9] These flows can cause smoke from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Building Height	Outside Temp [°F] (°C)	Inside Temp [°F] (°C)	ΔP [in. w.c.] (Pa)
75 ft (23 m)	0 (-18)	70 (21)	0.08 (20)
300 ft (91 m)	0 (-18)	70 (21)	0.33 (82)
984 ft (300 m)	0 (-18)	70 (21)	0.54 (130)
2133 ft (650 m)	0 (-18)	70 (21)	0.72 (180)

Table 1. Stack Effect Induced Pressure Differentials by Building Height

fires to spread between floors of tall buildings through vents, stairs, and other shafts. The pressure difference due to stack effect can be expressed by:[10]

$$\Delta p = 3840\ (1/T_o - 1/T_s)\, h$$

where:

Δp = pressure difference [Pa]
T_o = absolute temperature of outside air [degrees K]
T_s = absolute temperature of air inside shaft [degrees K]
h = distance above neutral plane [m]

Table 1 shows the impact that shaft height can have on stack effect induced pressure differentials, given a constant temperature differential.

Compared to the pressure differences generally created by smoke control systems, the stack effect in very tall buildings can be significant. It should be noted that the pressure differentials shown in Table 1 are calculated between a shaft and the outside of a building, whereas smoke control systems are intended to create pressure differentials between areas within a building. In any case, stack

effect can create large pressure differentials that can lead to dangerous smoke movement in a building, make it difficult to open doors, or have an adverse effect on smoke control systems.

In order to limit the stack effect, shafts in very tall buildings should be interrupted at regular intervals. For example, mechanical shafts can be capped every so often. Stair shafts can be interrupted with transfer passageways or refuge areas.

Wind – Like stack effect, wind on the outside of a building can also create pressure differentials, which can lead to smoke movement within a building. This pressure differential is a complex phenomenon and depends not only on wind velocity but also on the building geometry and can vary locally over a wall surface.[8] Average wind velocity increases with height above the ground, so wind becomes more of a concern in very tall buildings. In buildings that are tightly constructed with all windows closed (typical of modern high rises), the effect of wind on air movement inside the building is small.[9] However, wind can become a much more critical factor if a window is broken during a fire event.

Heating, ventilation, and air conditioning (HVAC) systems can play a role in interior smoke spread by extracting and recirculating smoke from the fire area or by pressurizing the fire area and forcing smoke into adjacent building areas.

Wind tunnel testing or computer modeling of very tall buildings may be necessary to evaluate the effects of wind induced pressure differentials on smoke movement within the building and the impact on any smoke-control systems.[11] Window breakage scenarios should be considered.

Piston Effect – The term "piston effect" refers to the transient pressure differentials created by the movement of an elevator car. Very tall buildings experience piston effect due to the large number of elevators employed and the high speeds at which the elevators travel. Providing elevator hoistway ventilation can reduce the piston effect, but this phenomenon needs to be evaluated during the design of smoke control systems for very tall buildings.

Building Mechanical – Heating, ventilation, and air conditioning (HVAC) systems can play a role in interior smoke spread by extracting and recirculating smoke from the fire area or by pressurizing the fire area and forcing smoke into adjacent building areas. The building codes address this issue by requiring HVAC fan shutdown upon smoke detection in the ductwork and the installation of fire/smoke dampers at fire-resistance rated shaft enclosures, fire barriers, and smoke barriers as a way to reduce smoke spread in a building. Full integration of HVAC systems with any engineered smoke control system is critical.

Long Egress Times – Prescriptively designed stairs are usually required to be sized based on the highest occupant load of any single floor the stairs serve (or multiple floors, if merging occurs). In very tall buildings, the issue is that the stairs are not sized for a simultaneous total building evacuation. Significant delays and queuing can occur in the stairs during simultaneous total evacuations.[12] Therefore, tenability inside the stair needs to be maintained for long periods of time. Pressurizing the stair is a well-recognized method of maintaining tenability. Long egress times and queuing will result in stair doors remaining open, which will have an impact on the required fan size needed to maintain the necessary pressure differential.

Refuge Areas – Even during a staged evacuation, many occupants are not capable of walking continuously down dozens of flights of stairs. In very tall buildings, occupant refuge areas located at certain intervals vertically along the path of egress to grade may be necessary. These refuge areas should be considered an extension of the pressurized stairs and protected accordingly. The stairs serving these refuge areas can

be offset from one another to help obstruct vertical smoke spread through the stair. Connecting these refuge areas to multiple stairs would provide alternative routes in case one stair becomes unusable during an emergency. Interrupting the stairs also limits the stack effect by limiting the shaft height.

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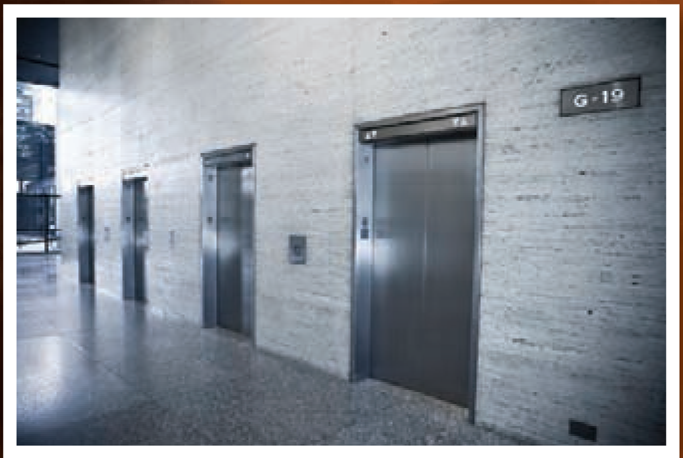

ATION

The elevator pressurization systems discussed in this article are intended to prevent smoke from flowing through an elevator shaft and threatening life on floors remote from a fire. Elevator pressurization is an alternative to enclosed elevator lobbies. The material in this article is based on the treatment of pressurized elevators in SFPE's smoke control seminars[1,2] and a new smoke control handbook.[3] This article does not address smoke control for elevator evacuation, which is discussed in the new handbook.

Many pressurized elevators are in buildings that have pressurized stairwells, and the focus of this article is on both of these pressurization systems operating together. In the rare situation where pressurized elevators are the only pressurization smoke control system in a building, the information in this article should be useful.

The pressures produced by elevator car motion has the potential to adversely impact the performance of a pressurized elevator system, and this elevator piston effect should be taken into account in the design of a pressurized elevator system. For more information about elevator piston effect, see the smoke control handbook.[3]

DESIGN ANALYSIS

Network analysis models are often used for design analysis of pressurization smoke control systems, and CONTAM[4] is so extensively used for such analysis that it has become the de facto standard. CONTAM was used for the simulations discussed in this article. Generally a CONTAM analysis is needed to determine if pressurized elevators and pressurized stairwells of a particular building are capable of being balanced to perform as intended.

Design of pressurized elevators is much more complicated than design of pressurized stairwells, but there are a number of systems that can deal with this complexity. The reasons for this complexity are: (1) often the building envelope is not capable of effectively handling the large airflow resulting from both elevator and stairwell pressurization, (2) open elevator doors on the ground floor tend to increase the flow from the elevator shaft at the ground floor, and (3) open exterior doors on the ground floor can cause excessive pressure differences across the elevator shaft at the ground floor.

In most large cities, the fire service props open exterior doors when they get to a fire to speed up mobilization, and the *International Building Code*[5] considers that elevator pressurization functions with open exterior doors. Occupants also open some exterior doors during evacuation. In this article, it is considered that elevator pressurization needs to operate with a number of exterior doors open. If the system cannot also operate as intended with all exterior doors closed, some of these doors may need to open automatically before the elevators are pressurized. At locations where the fire service does not prop open exterior doors, a different approach to open exterior doors may be appropriate.

The elevator pressurization systems discussed here are: (1) the basic system, (2) the exterior vent (EV) system, (3) the floor exhaust (FE) system, and (4) the ground floor lobby (GFL) system. The following discussion of these systems is for buildings that also have pressurized stairwells.

CONTAM SIMULATIONS

Thirty-six CONTAM simulations were used to study the performance of the systems in the example building of Figure 1.[1] The example building was chosen to illustrate the elevator pressurization systems mentioned above,

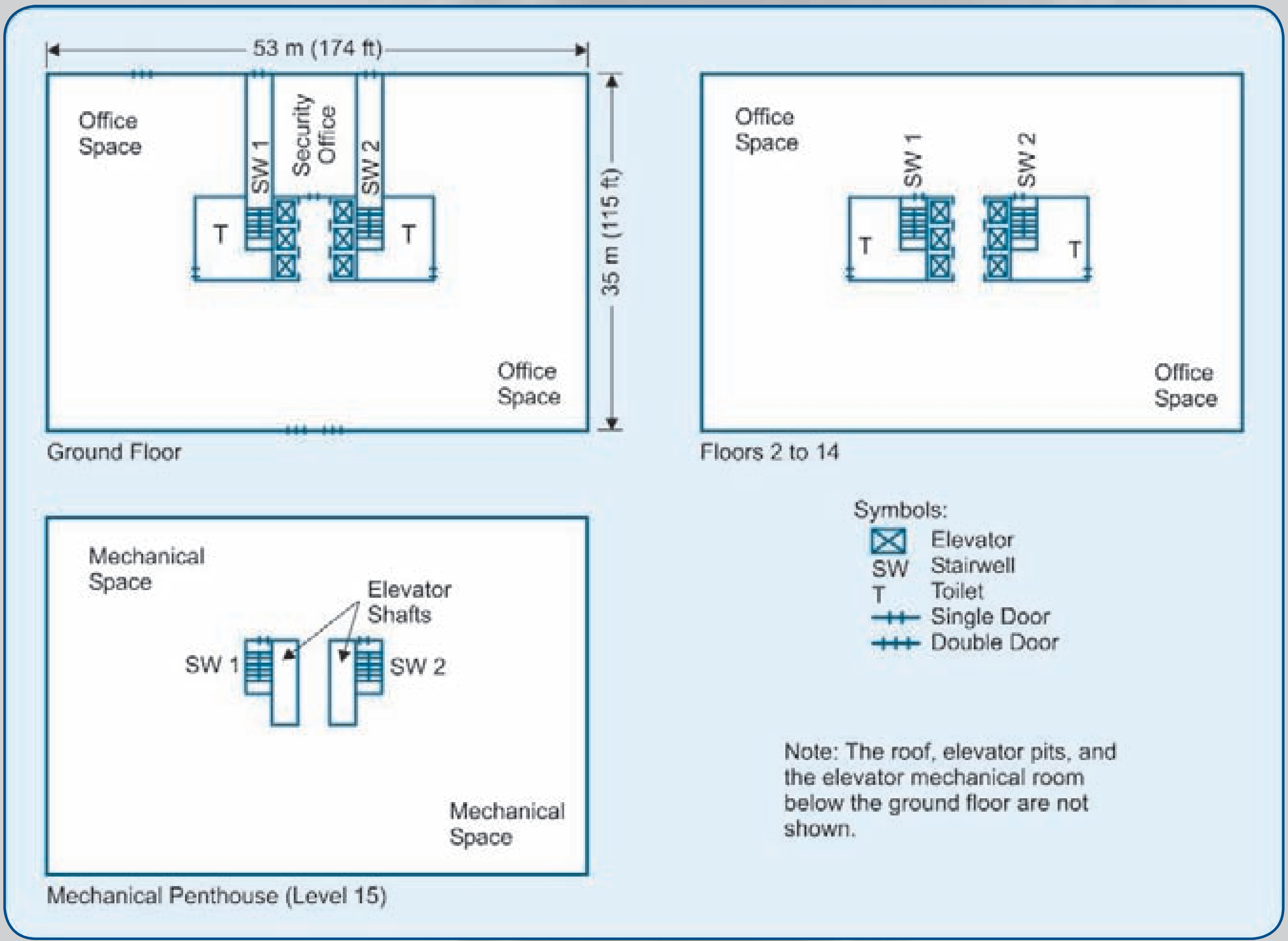

Figure 1. Floor plans of the example building for the CONTAM simulations.

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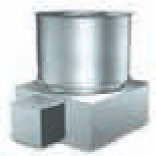

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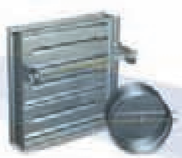

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New questions abound about CPVC and steel pipe hybrid systems.

On January 1, 2013, some CPVC manufacturers announced they are no longer listing steel pipe in their compatibility certification programs.

Here are a few considerations professionals must weigh when they specify materials for fire sprinkler systems.

What are the real cost differences between CPVC and steel?
In most markets, the product costs are comparable. CPVC can be fabricated in the field. Most steel pipe needs to be prepared in-shop and shipped to the job site. While smaller steel sizes can be machined on-site, some contractors prefer not to do so. But steel has a much longer service life than CPVC, making all-steel systems most practical.

What are some of the lifetime risks to CPVC and steel?
It would be quicker to list what *isn't* a risk to CPVC performance. Compatibility risks exist before, during and long after installation of CPVC. Careless material handling—now and in later post-construction alterations—can compromise CPVC pipe. There are also concerns about mixed CPVC use in commercial and residential construction.

What do the histories of CPVC and steel in fire sprinkler systems say about their futures?
CPVC has been used in fire sprinkler systems for less than 40 years. More than 50 materials and/or products have been identified as incompatible and cannot come into contact with CPVC.

Steel has been the material of choice since sprinkler systems were first designed and installed more than 100 years ago. Many of those systems are still in service today. With no incompatible substances and a long service life, steel continues to be the material of choice.

How specific should specifications be?
Miscommunication between engineers and contractors can compromise a safety system. Misinterpreted specs can cause more problems later. You can't afford a contractor or subcontractor who makes an uninformed decision. When municipal codes suggest that options are "equivalent," you should ask, "Are they really?" Steel is always the safe choice. There is no real equivalent.

Why has this liability transferred to contractors, AHJs and engineers, when it previously fell on the manufacturer?
The contractor chooses the materials for the fire sprinkler system and submits them to the engineer for approval prior to installation. The AHJ then gives final approval. Thus, if the system fails due to improper CPVC use, the contractor and all involved in the process are held liable for selecting improper materials.

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and it was based on an actual building to assure that it had appropriate elevator capacity. For this reason, the example could be thought of as an update to an existing building rather than a building designed to a specific code.

For the simulations, the pressure difference criteria listed in Table 1 were used, and these criteria are consistent with pressure differences requirements in the *International Building Code*.[5] The minimum pressure difference criteria are intended to prevent smoke flow into the elevator shafts and stairwells. The maximum pressure difference criteria for stairwells are intended to prevent excessive door opening forces. The maximum pressure difference criterion for elevators is intended to prevent the elevator doors from jamming.

For the CONTAM simulations of the example building, supply air was injected at the top of the elevator shafts, but about half the supply air was injected at the top of the stairs and the rest at the second floor.

Building leakage has an impact on the performance of pressurized stairwell systems, and various leakage values were used in the CONTAM simulations. The leakage of exterior walls has a major impact on system performance, and the leakage classifications of exterior walls were tight, average, loose, and very loose.

System	Minimum in. H_2O (Pa)	Maximum in. H_2O (Pa)
Pressurized Elevators	0.10 (25)	0.25 (62)
Pressurized Stairwells	0.10 (25)	0.35 (87)
The above criteria are for the elevator simulations discussed in this article, and some projects may have different criteria depending on code requirements and requirements of specific applications.		

Table 1. Pressure Differences Criteria for Elevator Pressurization Simulations[5]

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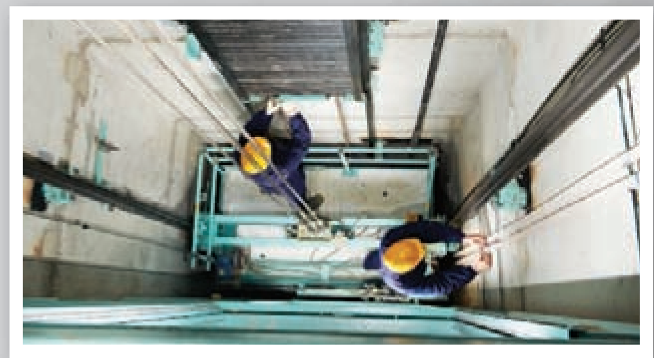
In 1999, Persily studied building leakage, and found that many buildings were relatively leaky in spite of the energy conservation concerns of the time.[6] The leakages of toilet exhausts and the HVAC system were not explicitly included in CONTAM simulations discussed here, but it was recognized that they are part of the leakage of the building envelope.

For all the systems, the amount of pressurization air needed depends on the leakage of the elevator shaft walls and the elevator doors. For the simulations, the leakage of interior walls was loose, and that of elevator doors was about average. Relatively large floor-to-floor leakage (paths in floor slabs and gaps between the floor slab and curtain wall) tends to even out extremes of pressure differences across stairwells and elevator shafts, and the simulations showed that this leakage was important for the GFL system.



BASIC SYSTEM

In the basic system, each stairwell and elevator shaft has one or more dedicated fans that supply pressurization air. As mentioned above, the building envelope is not capable of effectively handling the large airflow from both the elevators and stairwells, and this is why the basic system does not result in successful pressurization for most buildings. By successful pressurization it is meant that the pressure differences across the elevator shaft (or stairwell) are within the design minimum and maximum values of Table 1.

For the basic system in the example building with average and leaky exterior walls, it can be seen from Figure 2 that the pressure differences across the elevator shaft at the ground floor greatly exceed the maximum

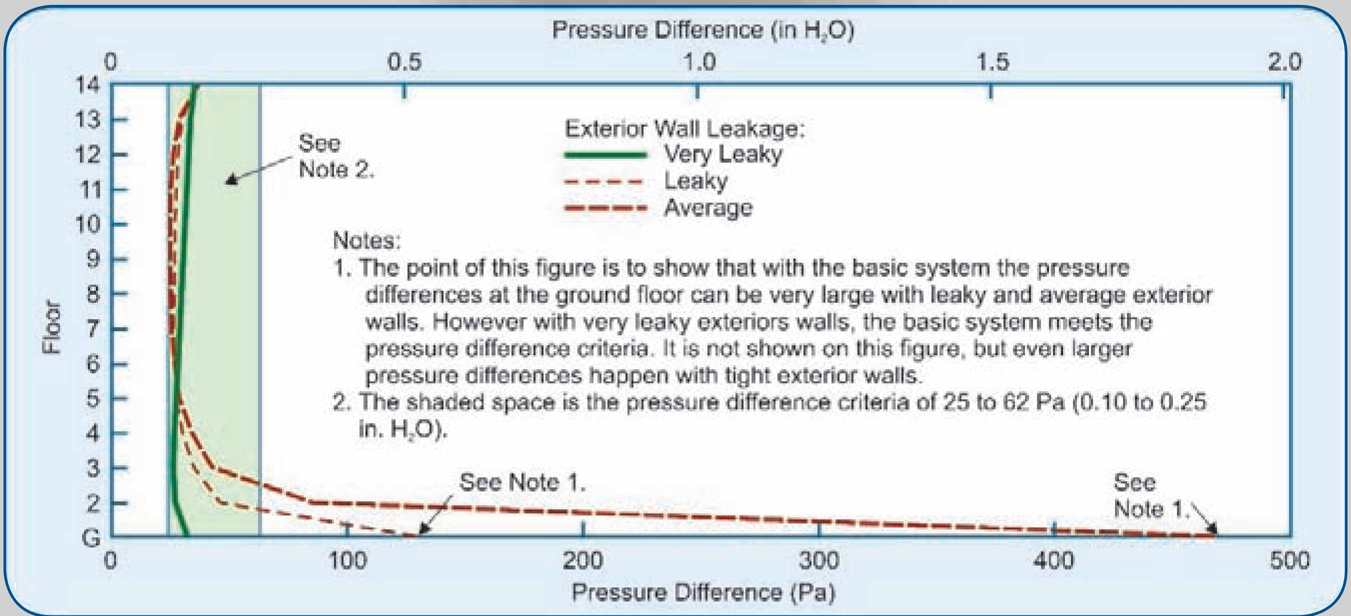


Figure 2. Elevator pressure differences for basic system in the example building.

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criterion. However it also can be seen that with very leaky exteriors walls, the basic system is successfully pressurized. The air needed for successful pressurization is 27,700 cfm (13 m^3/s) for each elevator shaft and 6,560 cfm (3.1 m^3/s) for each stairwell.

It is expected that for relatively leaky buildings, there may be enough wall leakage to accommodate the large amount of pressurization air needed for elevators, and successful pressurization may be possible with the basic system. For a specific building, analysis with CONTAM can evaluate if the basic system is feasible. If not, the systems discussed below should be considered.

EXTERIOR VENT (EV) SYSTEM

The idea of this system is to increase the leakage of the building such that successful pressurization can be achieved. Because the example building is an open plan office building, this can be done by the use of vents in the exterior walls. For the example building (Figure 3a), the CONTAM simulations showed that the vents can be sized to meet the design criteria. In the example building, the EV system needed the same amount of pressurization air as was needed with the basic system.

For a building that is not open plan, the flow resistance of corridor walls and other walls can have a negative impact on system performance. This negative impact can be overcome by the use of ducts as shown in Figure 3b. The ducts are a path for airflow

> The idea of this system is to increase the leakage of the building such that successful pressurization can be achieved.

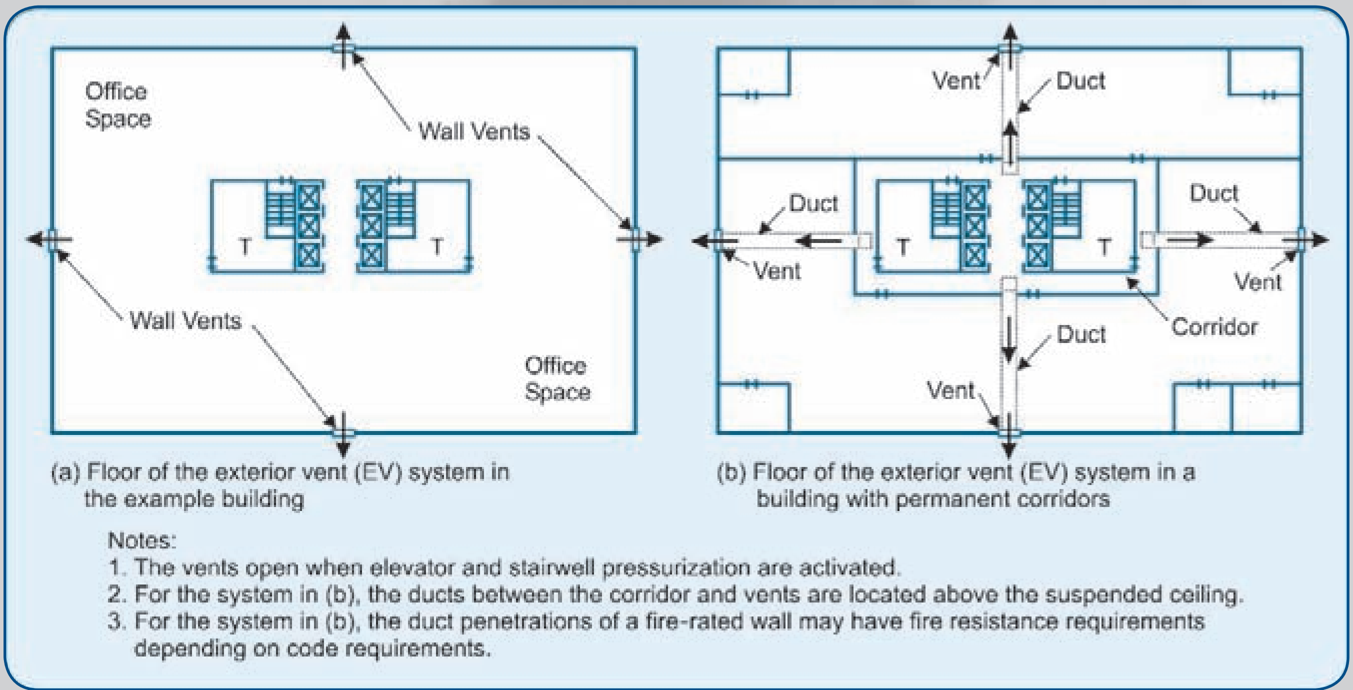


Figure 3. Typical floor plans of buildings with the exterior vent (EV) system.

from the elevator to the outdoors thus eliminating the impact of the corridor walls and other walls.

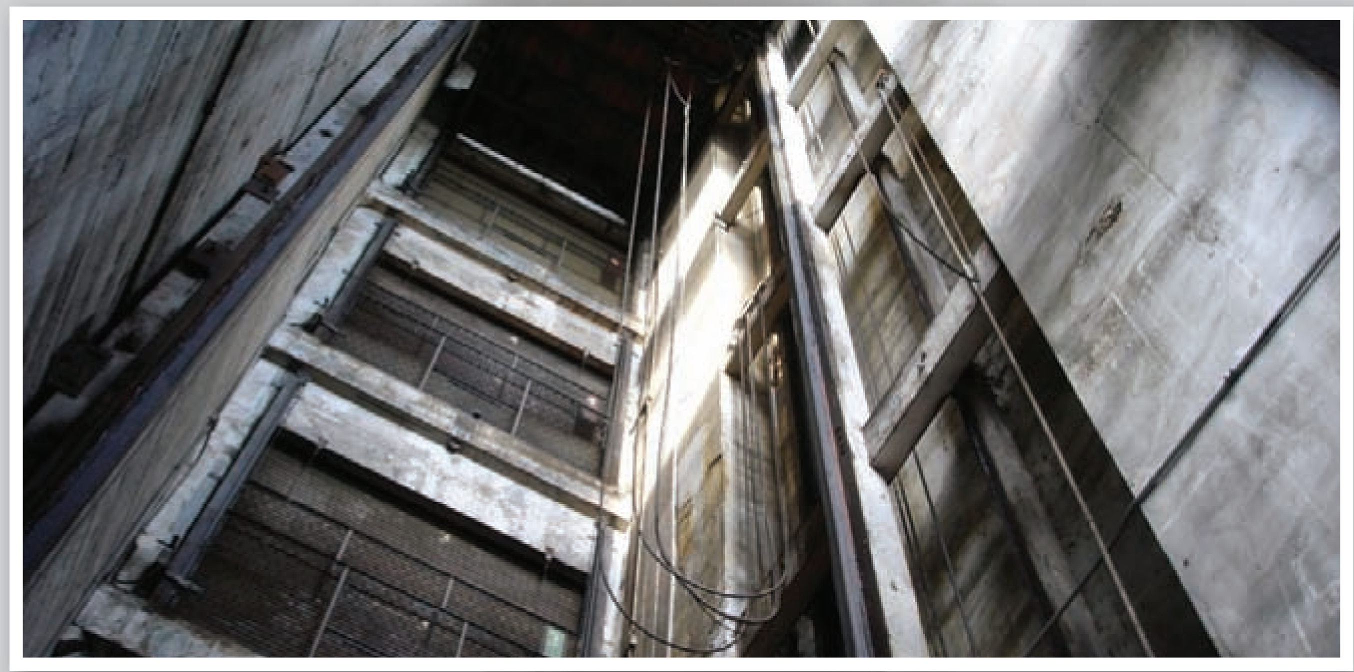
The vents should be located in a manner to minimize adverse wind effects, and the supply intakes need to be located away from the vents to minimize the potential for smoke feedback into the supply air. These vents may need fire dampers depending on code requirements. The ducted EV system can be used for other occupancies, such as hotels and condominiums. Duct penetrations of a fire-rated wall may have fire resistance requirements depending on code requirements.

With open, exterior doors, it is not necessary to have exterior vents on the ground floor. Because the EV system may not be able to achieve acceptable pressurization with some or all the exterior doors closed, it may be necessary to have some of the exterior doors open automatically upon system activation. The number of exterior doors that need to be opened automatically can be evaluated by the CONTAM analysis.

> The floor exhaust system deals with the building envelope issue by reducing the amount of supply air used.

FLOOR EXHAUST (FE) SYSTEM

The FE system deals with the building envelope issue by reducing the amount of supply air used. In the FE system, a relatively small amount of air is supplied to the elevator shafts and the stairwells, and the fire floor is exhausted such that acceptable pressurization is maintained on the fire floor where it is needed. It is common to also exhaust one or two floors above and



below the fire floor. Because the FE system only maintains pressurization at some floors, it must be approved by the AHJ.

For the example building, the FE system is shown in Figure 4a. The simulations of this building showed that each elevator shaft needed 15,100 cfm (7.1 m^3/s), and each stairwell needed 3,800 cfm (1.8 m^3/s). The floor exhaust ranged from 4,800 (2.3 m^3/s) to 5,400 cfm (2.5 m^3/s), depending on the particular floor being exhausted. For a building with many interior partitions, the exhaust can be from the corridor that the elevators and stairwells open onto as shown in Figure 4b.

As with the EV system, some of the exterior doors on the ground floor may need to open automatically upon activation of the FE system, and the number of such doors can be evaluated by the CONTAM analysis.

GROUND FLOOR LOBBY (GFL) SYSTEM

This system has an enclosed elevator lobby on the ground floor, but the other floors do not have any enclosed elevator lobbies. This system is the complete opposite of the normal practice of having enclosed elevator lobbies on all floors except the ground floor, but it has the potential for successful elevator pressurization.

As can be seen from Figure 2, elevator pressurization systems have a tendency to produce very high pressure differences across the elevator doors at the ground floor, and an enclosed elevator lobby can reduce this pressure difference. The GFL system often has a vent between the enclosed lobby and the building with the intent of preventing excessive pressure differences across the

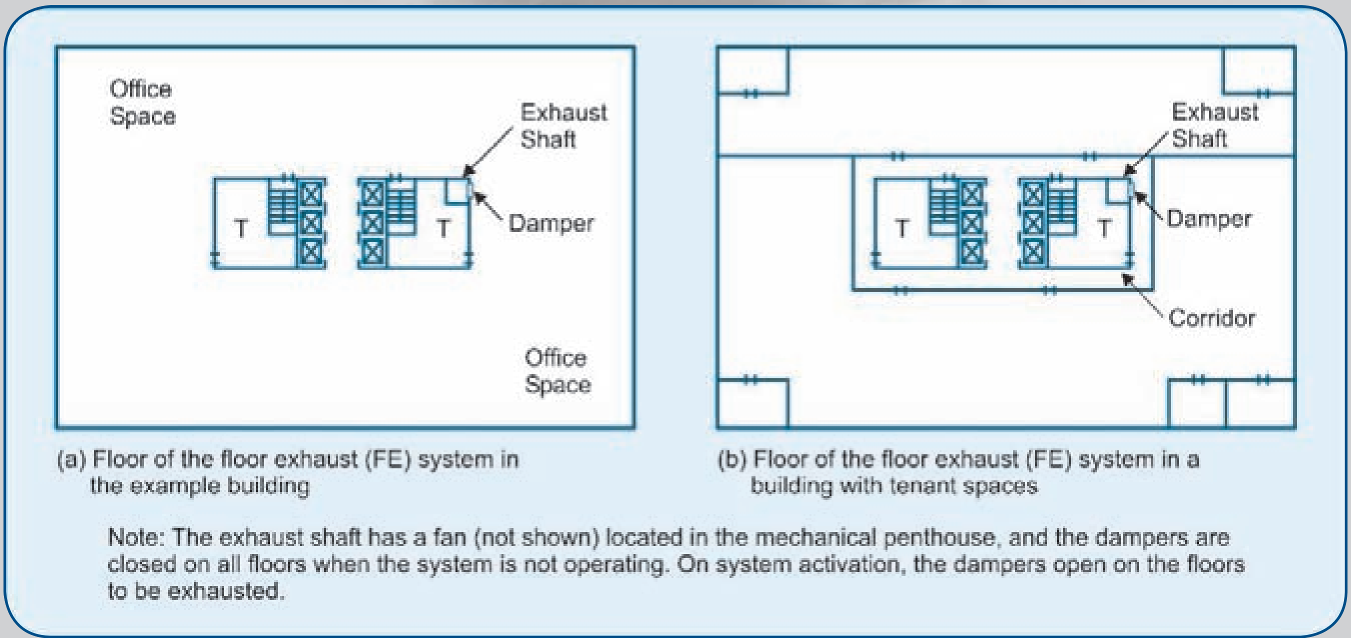


Figure 4. Typical floor plans of buildings with the floor exhaust (FE) system.

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doors between the enclosed lobby and the building.

The criteria of Table 1 apply to the GFL system with some modifications. There is no established criterion for the maximum pressure difference across the lobby doors, but the pressure should not be so high as to prevent the doors from remaining closed. This value depends on the specific doors and hardware. For the CONTAM simulations, a maximum pressure difference for the lobby doors was chosen as 0.35 in H_2O (87 Pa), but this value might be different for some applications. Because of the enclosed ground floor lobby, the minimum pressure difference criterion does not apply to the elevator doors on the ground floor.

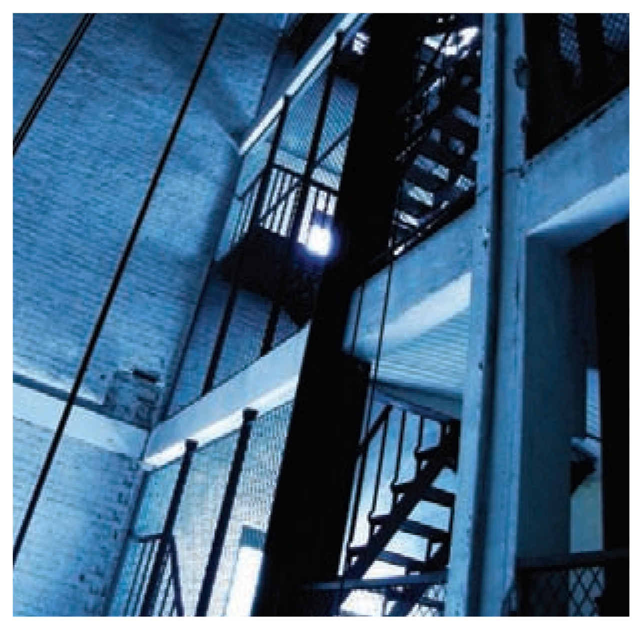

Figure 5 shows the ground floor of the example building with the GFL system. The pressure difference across the lobby door and the elevator door depends on the area of the vent, and this vent needs to be adjustable to allow for balancing during commissioning. CONTAM simulations of the GFL system in the example building showed that the criteria can be met with loose exterior walls, but not with tighter walls. The air supplied to the shafts was nearly the same as that needed for the basic system and the EV system. For the example building, the floor-to-floor leakage can have a significant impact on the performance of a GFL system. This leakage consists of the leakage of the floor and that of the curtain wall gap.

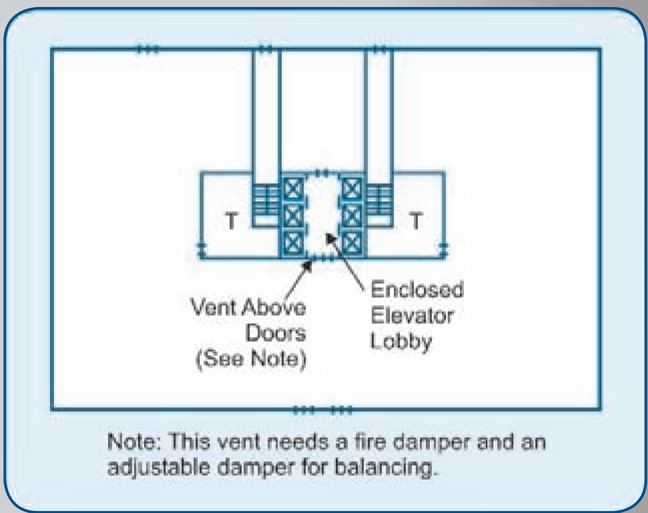

Figure 5. Ground floor of the example building with the ground floor lobby (GFL) system.

John H. Klote, Ph.D., P.E., FSFPE, is with John H. Klote, Inc. Michael J. Ferreira, P.E., is with Hughes Associates, Inc. James A. Milke, Ph.D., P.E., FSFPE, is with the University of Maryland.

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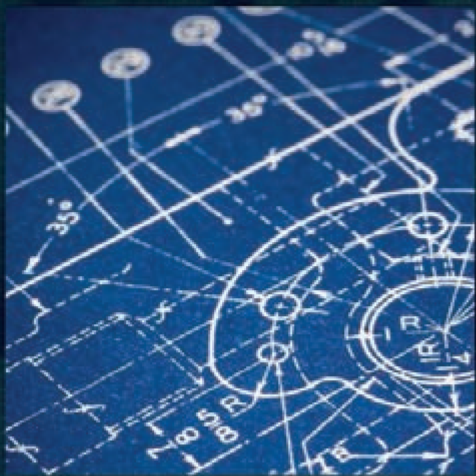
FIRST RESPON CHALLENGES IN VERY TALL BUILDINGS

By Joe McElvaney, P.E.




Tall buildings provide some unique challenges to first responders. These challenges arise not only due to the height of the building, but also because of the layout of the site, complexity of the structure, and the mixed uses found within the space. These structures can have the population of a small city, and they can include all the hazards and occupancies of a city.

The term "first responders" has a broad meaning that may include, but is not limited to, police, fire, emergency medical units, or even utility companies. All first responders have different levels of understanding and abilities to respond to an incident in a tall building. These different levels of understanding result from the demographics of their location, their training, and their equipment. When designing fire safety for a very tall building, the design team should meet with the first responders to determine limitations that they

DER

may have for different types of incidents or events.

There will be different types of incidents or events that may occur during the life of a very tall building, including during construction. These incidents/events can either occur naturally or can be caused by people, whether intentionally or unintentionally.

Many incidents or events can cause a major impact on the function of the structure, require a large amount of resources from first responders, and may possibly cause an impact to services in other parts of the community.

The building owners, along with the design team, should review the different types of possible incidents or events to determine which safeguards will be installed or provided to reduce the risk. First responders should provide information on the level of service they are capable of providing with their own resources.

It is necessary for the first responders, owners, and

design team to work together from the design concept continuously through construction and the life of the building. This will allow the team members to discuss potential design changes that come along and to move forward to meet construction timelines.

Depending on the type and location of an incident, at times first responders may be able to handle an incident without assistance or safeguards being provided. It should be noted that there may be incidents or events that the local first responders may not be able to address, and they may even require outside help from other organizations.

INCIDENT COMMAND AND CONTROL

The owners, building staff, and design and construction teams should meet with the local first responders to determine what type of management/command/control systems will be used if an incident does occur in the structure. How first responders, owners, and building staff teams interact during an incident will be critical to limit property damage and minimize injury and loss of life. Most first responders in the United States use some type of Incident Command System (ICS).

Even before the construction phase of a structure is completed, the first responders may wish to develop a working relationship with the building fire safety director, security director, and building engineering director.

Even before the construction phase of a structure is completed, the first responders may wish to develop a working relationship with the building fire safety

director, security director, and building engineering director. These three staff positions will play a key role in any incident due to their knowledge and familiarity with the building's systems and controls.

COMMUNICATION

During an incident, the ability to communicate between the first responders, building occupants, owners, and facility employees is critical. The communication between these groups can include the fire alarm paging system or the firefighter phone stations located within stairways, elevators, and elevator lobbies, which all connect to the fire alarm system in the building's fire command center.

Most first responders will use some type of radio communication system. However, due to the amount of steel and concrete within the structure, radios may not work correctly without some type of repeater system. This repeater system must be coordinated with all first responders so that the correct equipment and frequencies are installed. *The International Fire Code*[1] (IFC) and the *Fire Code*[2] (NFPA1) have code requirements for communication systems.

Most first responders will use some type of radio communication system. However, due to the amount of steel and concrete within the structure, radios may not work correctly without some type of repeater system. This repeater system must be coordinated with all first responders so that the correct equipment and frequencies are installed.

BUILDING ACCESS

The design team should consider providing access roads and doors that allow first responders into the building. Once inside, first responders will need easy access to the fire command center, security control room, stairways, and elevator systems. Ideally, once they arrive, they should be met by facility staff to provide any type of necessary assistance.

Security devices may be installed throughout the

> Security devices may be installed throughout the building. Therefore, first responders will need keys or other means to unlock all doors for free access and to reduce the risk of trapped occupants. During the 2003 Cook County Administration high rise fire in Chicago, IL, six occupants died; one of the leading factors in these deaths was locked stairway doors.[3]

building. Therefore, first responders will need keys or other means to unlock all doors for free access and to reduce the risk of trapped occupants. During the 2003 Cook County Administration high rise fire in Chicago, IL, six occupants died; one of the leading factors in these deaths was locked stairway doors.[3] On the flip side, during some terrorist scenarios, the first responders may ask the facility's staff to lock down the building and control the movement of occupants.

Reliable and robustly built vertical transportation (elevators) can facilitate first responders to gain access to upper floors in a safe and timely manner. The IBC and the *Building Construction and Safety Code*[4] (NFPA 5000) both have requirements for vertical transportation to provide a reliable and safe system for first responders to use during an incident/event.

FIRE CONTROL / COMMAND CENTER

Both the IBC and NFPA 5000 have requirements for fire control/command centers. The first responders, owners, and design and construction team should

consider the location, layout, and space for the center. In tall buildings, the center will need adequate space, equipment, and constant staff monitoring. The center will be the nerve center of all incidents.

Some of the systems that should be located inside the center can be found in table 1.

Fire alarm panel	Security alarms / access control systems
Security cameras	Smoke management / control panel
HVAC fan control systems	Stairway pressurization systems
Fire pump status	Fire phone system
Vertical transportation system status, recall and locking down	
Mass notification paging system	
Normal and emergency power supply status and remote start	
Radio communication / repeater system status	

Table 1. Fire Control / Command Center systems

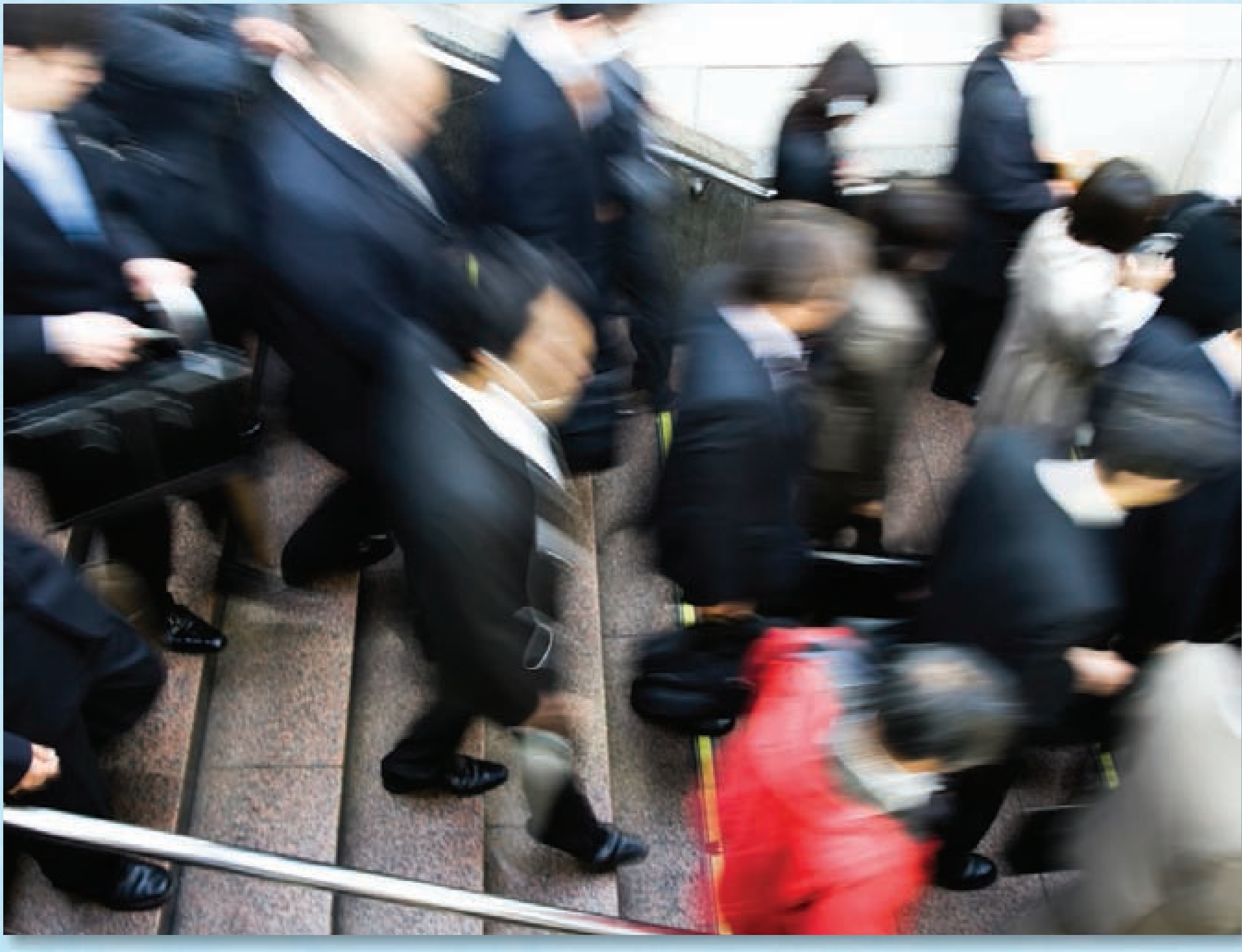
MEANS OF EGRESS

The means of egress for tall buildings can be complex. Trying to move several hundred occupants from upper floors down to the first floor via stairways or even elevators will take time. At the same time that occupants are traveling downward, first responders may be traveling upward.

The design team should meet with the local first responders to understand operations procedures that could impact the means of egress. It is common practice for fire departments in the United States to use stairways as a staging point for an attack on the fire floor. There are several reasons for this, which include the fire-rated and smoke-protected construction of the stairways and the location of the fire department standpipe outlets.

FIRE & LIFE SAFETY PROTECTION SYSTEMS

Very tall buildings will have fixed fire and life safety protection systems in place. These fixed fire and life



safety protection systems may include fire sprinklers, standpipes, fire pumps, emergency generators, firefighter air replenishment systems, onsite water supply, fire alarm systems, communication systems, smoke control systems, and emergency power to name a few. These systems can both mitigate the incident and support the first responders' actions.

The fire sprinkler and standpipe systems will most likely have fire pump(s) installed. These systems can also have some type of pressure reducing valves. The valves have caused trouble for the first responders. The One Meridian Plaza fire in Philadelphia, PA, on Feb. 23, 1991, resulted in the deaths of three firefighters. Some of the factors that resulted in their deaths were the loss of normal power, emergency power, and problems with pressure settings on pressure-reducing valves in the standpipe.[5]

Emergency Plans

The design professional and ownership should develop emergency action plans to facilitate actions by the local first responders. Some of these plans may include evacuation, lockdown, or shelter in place based on the possible incidents or events that the design team and first responders agree should be addressed. Training and drills of these plans are important to test the function and to identify changes based on the outcomes of these drills.

Joe McElvaney is with the Phoenix (AZ) Fire Department.

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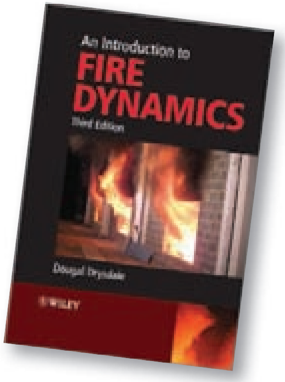

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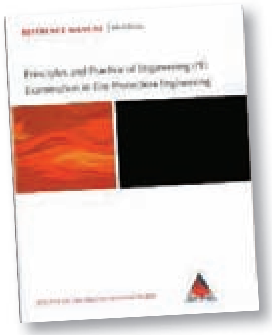

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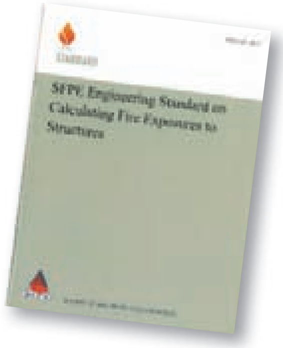

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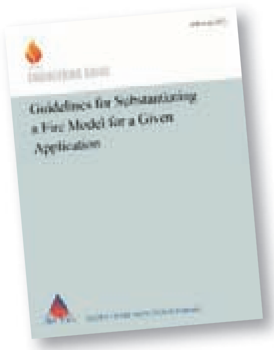

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Eurofire 2013
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Info: www.eurofireconference.com

October 27–November 1, 2013
SFPE 2013 Annual Meeting: Professional Development Conference and Exposition
Austin, TX, USA
Info: www.sfpe.org/SharpenYourExpertise/Education.aspx

BRAINTEASER [Problem/Solution]

Problem

How many students must be present in a classroom for there to be a 50% probability that two or more of them share a birthday (month and date, neglecting February 29 birthdays)?

Solution to Last Issue's Brainteaser

A motionless ice skater who weighs 50 kg throws a ball that weighs 0.25 kg forward at a velocity of 50 m/s. If the friction between the ice skater and the ice is negligible, at what velocity will the ice skater move?

Since momentum must be conserved, the initial momentum must equal the final momentum. Because the skater and ball are initially at rest, the momentum is zero. Therefore, the final velocity of the skater is:

$$0 = m_b v_b + m_s v_s = 0.25\text{kg} \times \frac{50\text{m}}{\text{s}} + 50\text{kg} \times v_s$$

The velocity of the skater is 0.25 m/s in the opposite direction that the ball is thrown.

PRODUCTS [LITERATURE]

Addressable Pull Station

Potter announces the release of the Addressable Pull Station (APS) series. The APS comes in a Single Action model or Double Action model. The Double Action model includes a front cover for added protection against unwanted alarms. With the ability to mount in a single gang box or the Potter P32-BB surface mount back box, the APS conforms to many situations. It functions within a temperature range of 32°F to 120°F; is compatible with all Potter PFC-6000, PFC-8000, and P-Series Panels; and is ADA compliant.

www.pottersignal.com
—Potter Electric Signal Co., LLC

Rectangular CV-S Explosion Vent

Fike announces the rectangular version of its CV-S Explosion Vent. Designed to provide a non-fragmenting opening when protecting industrial processing equipment, the CV-S provides superior protection in applications such as air-material separation, drying, conveyance, and processing operations. It is available in sizes ranging from 9 x 12-in. up to 44 x 69-in., including metric and custom sizes.

www.fike.com
—Fike

NOTIFIER's New Website

NOTIFIER has launched a new website to offer easier accessibility to its fire alarm and emergency communications product information for system designers and inspectors, as well as the specific, solutions-based information sought after by facility managers and first responders. The streamlined interface allows content to be easily searched and sorted, equaling fast access to pertinent data with fewer page views.

www.notifier.com
—NOTIFIER

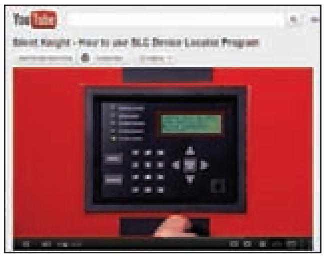
Self-Contained & Fixed Water Supply Systems

Pre-engineered fire suppression systems are available in both Self-Contained (SC) and Fixed Water Supply (FW) design. Both are FM Approved for Special Application Fire Protection. The Fixed Pipe Spray system is suitable for fire protection of special hazards that involve flammable liquids. Applications include emergency generators in hospitals and high-rise buildings, chemical storage facilities, fuel transfer stations, and more.

www.acafsystems.net
—ACAF Systems/PFS-Fire Suppression Group, LLC

Fire Alarm Video Training

Silent Knight by Honeywell has expanded the free fire alarm training and technical support it offers by developing a series of "How-To" videos, covering the most common topics addressed by its Technical Support Team. Easy to find and easy to view on mobile devices, Silent Knight's How-To videos demonstrate, step-by-step, how to program a fire alarm control panel for elevator recall, troubleshoot ground faults, and more. Each video runs less than three minutes in length and is free to view on www.silentknight.com and YouTube.



www.silentknight.com
—Silent Knight

UL Listed and FM Approved Dry ESFR Sprinkler

Viking's new patent-pending VK502 sprinkler, which is cULus Listed and FM Approved for use in wet pipe systems only, is well-suited for cold storage facilities where the system piping is installed in a heated space above the freezer area. In these applications, the VK502 sprinkler can reduce the installed cost of a fire sprinkler system by providing ceiling-only protection, without the additional costs associated with a dry or pre-action system, including an in-rack sprinkler system, detection system, air maintenance system, low point drains, and other components.

www.vikinggroupinc.com
—Viking Corp.

SOCIETY OF FIRE PROTECTION ENGINEERS

2013 SFPE Annual Meeting

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Engineering Technology Conference

This two-day conference highlights presentations and cutting-edge practices in fire protection engineering. This year's keynotes are:

> Raymond Grill, P.E., FSFPE, USA - *"The Role of Fire Protection Engineering in Sustainable Design"*

> James Golinveaux, USA - *"Significant Advancements in Water Based Fire Suppression for Storage Occupancies"*

> Stephen Kerber, P.E., USA - *"Evolution of the Residential Fire Environment"*

> Erica Kuligowski, Ph.D., USA - *"The Current State of Egress in Fire Engineering Design"*

> Ai Sekizawa, Japan - *"Challenges in Fire Safety in a Society Facing a Rapid Aging Population"*

> Piotr Tofilo, Poland - *"Fire Engineering Tools: Past, Present and Future"*

Professional Development Seminar

Following the conference is the SFPE Professional Development Week, which encompasses a series of seven seminars taught by the profession's leading experts. Seminars available are:

- ***New!*** Evaluation for Fire Safety Engineering
- Sprinkler Design for the Engineers
- Emergency Communications Systems: Planning, Design, and Use
- Speech Intelligibility for Emergency Communications Systems
- Advanced Fire Dynamics Simulator and Smokeview
- Protection of Storage Occupancies
- ***Revised!*** Principles of Fire Protection Engineering

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FIRE PROTECTION Engineering

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