

# FIRE PROTECTION Engineering

2<sup>ND</sup> QUARTER 2010 Issue No. 46

## Sustainable Design

and Fire Protection  
Engineering

**Performance-Based Design in Green Buildings**

**Green Construction and Fire Protection**

**Research on Electrical Fires**

**Design of Fire Alarm and Signaling Systems for a Long Life**



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



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From the **TECHNICAL DIRECTOR**

## SFPE's Fellows and Honorary Members

**S**FPE has two membership grades that are intended to recognize individuals who have distinguished themselves during their careers: the grades of Fellow and Honorary Member.

The grade of "Honorary Member" was originally created to acknowledge individuals who had made significant accomplishments and achieved a significant stature in the profession. Percy Bugbee — who served on the staff of the National Fire Protection Association for 48 years and was SFPE's first member — was installed as the first honorary member in 1970. Ten more individuals were appointed to the grade of Honorary Member before the grade of Fellow was created in 1977.

The grade of Fellow was created to recognize SFPE members who had achieved significant accomplishments and stature in fire protection engineering and who had rendered exceptional service to SFPE. By creating the grade of Fellow, SFPE was in line with other professional engineering societies who had earlier created that grade. "Accomplishments" would include significant involvement in projects, inventions or patents; unpublished and public talks; any scientific or engineering papers or theories, tests, concepts and demonstrations; impacts on fire protection regulations or technical standards. In the context for Fellows, "stature" meant professional awards received, committee appointments, leadership positions, etc.

To ensure that the grade of Fellow was reserved for the most deserving members, the number of Fellows was limited to 10% of total SFPE membership. Additionally, Fellows were required to have been Professional Members (formerly "Members") for a minimum of 10 years.

The grade of Honorary Member was retained after the grade of Fellow was created for two reasons: (1) to honor those Fellows who performed beyond the criteria for Fellows, and (2) to recognize and honor those outside the society who

had made significant contributions to the profession.

However, since 1977, the distinction between Honorary Members and Fellows became blurred. In some cases, people who would not qualify for Fellow were nominated to the grade of Honorary Member, which was contrary to the original intention of Honorary Member being a higher grade than Fellow.

In early 2010, the Board of Directors carefully considered the grades of Fellow and Honorary Members, and decided to limit the grade of Honorary Member to people who could not qualify to become a Fellow. This was done to clarify that Fellow is the highest grade of membership in SFPE. This change is also consistent with the use of the Honorary Member grade by other organizations, where Honorary Members are people who are not rank-and-file members of the organization, but contribute significantly nonetheless.

Fully implementing this change will require a change to the constitution, which will give each Fellow, Professional Member, Associate Member and (existing) Honorary Member the opportunity to vote on this proposed change.

Lists of individuals who presently hold the grades of Fellow and Honorary Member can be found at <http://www.sfpe.org/About/HonorsandAwards.aspx>.

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

*Fire Protection Engineering* welcomes letters to the editor. Please send correspondence to [engineering@sfpe.org](mailto:engineering@sfpe.org) or by mail to *Fire Protection Engineering*, 7315 Wisconsin Ave., #620E, Bethesda, MD 20814.

### Corrections

1. An incorrect web link was included in the news release titled, "Commercial Property Insurer FM Global and Home Fire Sprinkler Coalition (HFSC) Form Partnership to Study Environmental Effects of Home Fires," on page 6 of the First Quarter 2010 issue. The correct link is [http://www.fmglobal.com/press\\_release/2009/HSFC\\_sprinkler\\_090409.html](http://www.fmglobal.com/press_release/2009/HSFC_sprinkler_090409.html)

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Dear Editor,

The series of articles titled "Existing Buildings: From Rehabilitation Codes to Performance-Based Design" in the 1st Quarter 2010 issue (No. 45) provide an important suite of information to interested parties seeking answers to fire protection engineering questions.

From a historical viewpoint, it is of interest to note that virtually every (model) code-related reference in the four articles includes technical bases derived, to some extent, from the original HUD Rehabilitation Guidelines published in 1980. From a fire safety perspective, Volume 8 of those guidelines ("Guideline on Fire Ratings of Archaic Materials and Assemblies") provided then – and continues to provide – a single authoritatively referenced source for fire performance information describing anticipated fire endurance of construction elements in older buildings undergoing renovation. Since originally published, that document has been adopted either as an appendix or as a reference document in literally dozens of regional-model existing building codes, NFPA codes and standards, and federal documents related to existing or historic building treatments. Likewise,

the original protocol recommended for assessing the fire endurance of particular elements or assemblies remains relevant for anyone doing a reconnaissance of such buildings.

In considering this original guideline, credit should be given to Professor Brady Williamson, who developed the technical and organizational concepts underlying the original 1980s HUD Rehabilitation Guideline No. 8, as well as architects David Hattis and Bill Brenner of NIBS, who managed the development of the volume in question. While still a curly haired grad student in the late 1970s, I had the interesting experience of abstracting the literally hundreds of test results contained in the original guidelines!

Readers wanting to view or download a version of the original "Guideline on Fire Ratings of Archaic Materials and Assemblies" as updated in 2000, can find that information at <http://www.huduser.org/portal/publications/destech/fire.html>.

Joseph B. Zicherman, Ph.D.  
Fire Cause Analysis



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By Casey Grant, P.E., FSFPE

Concepts involving fire protection and those involving environmental sustainability share the common goal of making the world a better place. The environment is a key realm of focus in today's mainstream discussions of sustainability — included alongside debate on social and economic sustainability.

Definitions of the term “sustainability” found in the common literature are generally based on the ability to “endure” or to “maintain”. One useful definition is included as part of an earlier report to the United Nations, indicating that sustainability involves “meeting the needs of the present without compromising the ability of future generations to meet their own needs.”<sup>1</sup>

Similarly, fire protection strives to preserve and maintain. It inherently provides the characteristic of “endurance” for people, buildings, structures, operations, processes and other features of civilization. By addressing basic fire safety objectives (i.e., life safety, property protection, operational continuity, etc.) in the current and immediate context, it also promotes these same concepts into the future.

Focusing on environmental sustainability shows the commonalities with fire protection. The fire protection community has already faced serious concerns about preserving the environment, and has faithfully risen to address these challenges. Perhaps most notably is the phase — out of production of fire protection Halons. During the 1980s, the world was confronted with the predicted<sup>2</sup> perils of depleting the Earth's protective stratospheric ozone layer.<sup>3</sup> The magnitude of this situation brought countries together to sign world treaties like the Montreal Protocol that restricted the production of useful industrial gases, including certain fire protection gaseous extinguishing agents.

At that time, the fire protection community rallied in the face of this crisis.<sup>2</sup> Many individuals and organizations became proactively engaged in helping make the transition from environmentally harmful chemicals used for fire protection to more environmentally friendly replacements. Today, it is possible to use alternative fire protection agents and approaches that are fully sensitive to their environmental impact based on characteristics such as ozone depleting potential and global warming potential.<sup>4</sup>

What are some of the new environmental challenges facing the fire protection engineering profession today, and anticipated for tomorrow? This was the focus of the Fire Protection Research Foundation's recent 25th anniversary symposium, “Fire Protection and Safety: Preparing for the Next 25 Years.”<sup>5</sup> In addition to looking at changing demographics and technological advances, the event addressed the concerns associated with environmental resources that once were seemingly endless — clearly no longer the case.

The “Next 25 Years” symposium highlighted the emerging importance of the intersection of environmental sustainability and fire protection in decision-making for the built environment. At the symposium, stakeholders identified a broad range of key issues

such as: water shortages; new hazards introduced by alternative energy-based systems; restrictions on chemical substances used to retard or suppress fire development; and shortages of naturally occurring materials with inherent fire protection features.

One of the clear messages that came from this unique glimpse into the next quarter century is that unrestricted development of unwanted fire will have a catastrophic impact on the environment. Fire protection plays an important role in providing an environmentally sustainable future. It has had this role all along, and the importance of this role will increase.

In programs such as Leadership in Energy and Environmental Design (LEED) from the U.S. Green Building Council, it is necessary to explicitly account for the sustainability impact of doing nothing about fire protection. This is thankfully being addressed with renewed focus, as found in one recent study at FM Global on the positive environmental impact of home fire sprinklers.<sup>6</sup> This work clearly demonstrated a significant reduction in overall adverse environmental impact in the event of a home fire with sprinklers, based on a dramatic reduction in the release of greenhouse gases, the amount of water used and run-off, and the degree of fire damage.

The “green” movement needs to better account for the inherent preservation role provided by built-in fire protection measures and techniques. Arguably, the fire protection engineering profession is already doing this as it addresses the anticipated “life span” of a building (such as one with a performance-based design). For example, with applications involving historic structures and similar cultural resources, the desired sustainable life span is forever.

The environmental sustainability challenges facing today's civilized world are, in some ways, daunting. The fire protection engineering community is posed to be an important ongoing partner for meeting these challenges, helping to make this world a better place for future generations.

*Casey Grant is with the Fire Protection Research Foundation.*

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- 2 Taylor, G., “Achieving the Best Use of Halons,” *Fire Journal*, 81, 3, p. 69, 1987.
- 3 Andersen, S., “Halon and the Stratospheric Ozone Issue,” *Fire Journal*, p. 56, May/June 1987.
- 4 NFPA 2001, *Standard on Clean Agent Fire Extinguishing Systems*, National Fire Protection Association, Quincy, MA, 2008.
- 5 “Fire Protection and Safety: Preparing for the Next 25 Years,” Fire Protection Research Foundation, Quincy, MA, November 2008.
- 6 Wiecek, C., “Environmental Impact of Sprinklers,” FM Global, Norwood, MA, 19 January 2010.

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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.

## Cal Poly Announces New Graduate Degree Program in Fire Protection Engineering

The Cal Poly Academic Senate and President Warren J. Baker recently approved a new master's degree program in Fire Protection Engineering (FPE) - one of only three such programs in the United States and the only one on the west coast.

Based in the College of Engineering, the multidisciplinary program will be administered by Cal Poly Continuing Education and University Outreach. The FPE program will be open to students starting Fall 2010 both on campus and online, in order to accommodate working professionals. "Full-time students should be able to complete the 45-credit degree in one-and-a-half to two years," says Dr. Fred Mowrer, FPE acting director and visiting professor.

"The job of fire protection engineers is to analyze how buildings are used, how fires start and grow, and how fire and smoke affects people, buildings and property," he says. "Professionals in this field find innovative ways to lower costs and increase safety." Their work includes designing sprinkler and alarm systems, evaluating buildings for fire risk and prevention, and conducting fire safety research on consumer products and construction materials.

"Fire protection engineers are in high demand; through surveys and our initial outreach, we encountered a lot of enthusiasm for this new program," Mowrer notes. "We intend to take advantage of this support by calling on professionals to serve as mentors for student projects."

For more information, go to <http://ceng.calpoly.edu/articles/cal-poly-announces-new-graduate-degree-program-fir/>.

## Top-Paid Majors Among College Class of 2010

Engineering majors dominate the list of top-paid bachelor's degrees, according to a new report from the National Association of Colleges and Employers (NACE).

NACE's Winter 2010 *Salary Survey* shows that engineering disciplines account for eight of the 10 most highly paid degrees. (Table 1.)

"While a variety of factors play a role in determining salaries, new graduates with degrees in the technical fields tend to benefit from their relatively low supply. There is more competition for their skills, driving up their salary offers," says Marilyn Mackes, NACE executive director.

In general, candidates with technical degrees have an advantage in the job market," says Mackes.

Table 1: Top-Paid Bachelor's Degrees

Major	Average Salary Offer
Petroleum Engineering	\$86,220
Chemical Engineering	\$65,142
Mining & Mineral Engineering (incl. geological)	\$64,552
Computer Science	\$61,205
Computer Engineering	\$60,879
Electrical/Electronics & Communications Engineering	\$59,074
Mechanical Engineering	\$58,392
Industrial/Manufacturing Engineering	\$57,734
Aerospace/Aeronautical/Astronautical Engineering	\$57,231
Information Sciences & Systems	\$54,038

Source: Winter 2010 *Salary Survey*, National Association of Colleges and Employers. Data represent offers to bachelor's degree candidates where 10 or more offers were reported.

For more information, go to [www.nacweb.org](http://www.nacweb.org).

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# FIRE PROTECTION ENGINEERING AND SUSTAINABLE DESIGN

By Simon Dent



In the 21st century, sustainable building design is an increasingly popular and important client requirement as well as a growing focus for professional engineering firms. For the fire protection engineer, integrating sustainable, or “green,” building design aspirations presents the challenge of resolving conflicts between architectural vision and code expectations for fire safety.

At the heart of fire protection engineering is meeting the challenges of clients’ innovation. It is often the case that the fire protection engineer contributes to a broad spectrum of building solutions that significantly affect many other members of the design team.

By discussing the challenges that fire protection engineering must overcome to support sustainable building design, this article seeks to embellish on a simple philosophy – that the fire protection engineer’s use of performance-based design can both liberate the design team from code restraints, which might otherwise hinder the building’s sustainability rating, and serve to address the more holistic aspects of true sustainability.

...the fire protection engineer contributes to a broad spectrum of building solutions that significantly affect many other members of the design team.

#### **SUSTAINABLE BUILDING DESIGN: A MULTIDIMENSIONAL CHALLENGE**

In order to understand the implications of sustainability for fire safety, it is first necessary to understand what is really meant by “sustainable building design.”

In the first instance, a sustainable building is the physical end product of a design philosophy to improve the “performance” of the built environment by increasing the efficiency of the resources used in building during its lifecycle: construction, operation and demolition. Such performance is typically measured through a range of international environmental performance-rating systems for buildings.

# Case Study 1: Stockland Head Office

## Sydney, Australia



Figure 1. Open atrium

### THE BRIEF

The client's objectives for their new head office were to:

- Create connectivity in their business to break down internal silos.
- Showcase excellence in environmentally sustainable design for a tenancy in an existing building.
- Meet time and budget constraints.
- Minimize disruption to other tenants in the building.

### PROJECT APPRECIATION

Stockland's new head office is an eight-story tenancy on levels 22-29 of an existing 32-story office building in Sydney's central business district. The original building was a typical 1980s high rise, with a central core and floors separated from each other.

To respond to the business and environmental needs of the client, the architect developed a concept for interconnecting the eight stories with an open atrium, circulation stairs and two fire isolated escape stairs.

### LIMITING THE VISION

To minimize fire and smoke spread, the Building Code of Australia (BCA)<sup>1</sup> allowed the provision of only two stories to be interconnected via open stairs. The code alternative was to design an enclosed atrium requiring glazing and wall wetting sprinklers to separate the floors from the void. This did not meet the desire for real interconnection in the tenancy.

### THE INNOVATION

To allow an open atrium and stairs, as shown in Figure 1, various options were explored using performance-based design. Options included smoke exhaust and the use of vertical fire curtains surrounding the atrium on six floors; however, there were issues with cost and practicality.

It was finally decided that the design would feature a horizontal fire curtain. The curtain serves to seal off the atrium in the event of fire by incorporating a fire-rated flexible fabric that is carried on thin wires across the void. The concept used curtains at levels 25 and 27, essentially reintroducing the fire compartmentation given by the previous floors. Figure 2 shows an elevation view of the design. Vertical curtains were used to close around the accommodation stair. Risk assessment techniques were used to demonstrate that a 3-level interconnection achieved an acceptable level of performance. The risk assessment also addressed failure of the operable curtains.

### COMMUNITY, ENVIRONMENT AND SOCIAL CONSIDERATIONS

The project showcased what could be done with existing building stock, both in achieving an exciting new work environment and in achieving excellence in environmental performance.

Reuse of a building is far more environmentally responsible than development of a new one, but it can be a significant challenge. The environmentally sustainable design for this tenancy, as well as the business objectives for Stockland, hinges on the creation of the open atrium. Without the fire protection engineering design to allow the open atrium, these objectives simply could not be achieved.

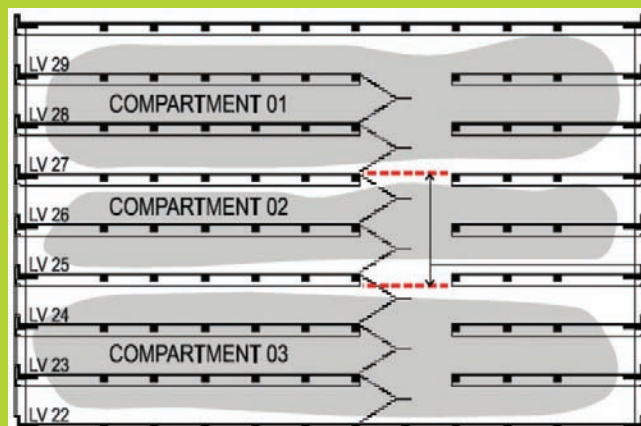


Figure 2. Elevation view



Widely recognized rating systems include: BREEAM, the Building Research Establishment Environmental Assessment Method most commonly used in the UK and increasingly internationally; LEED, The Leadership in Energy and Environmental Design Green Building Rating System developed in the United States; and Green Star, a similar rating system used in Australia.

All of the systems are fairly similar in their approach, with scores for the incorporation of sustainable design under areas such as energy, water, pollution and waste. The higher the total building score the more sustainable the design is considered to be.

In the second instance, a truly sustainable building is also a socially sustainable one; that has a positive social impact on the local environment for the duration of the building's existence. Wider issues such as societal needs, maintenance of heritage, provision of social amenity, accessibility for all and future-proofing of a building so that it continues to be useable for a longer lifespan than a more conventionally designed building can all be considered.

### **BUILDING SUSTAINABILITY AND THE FIRE PROTECTION ENGINEER**

Clients' design aspirations and tenant demands increasingly lean towards the provision of large open

floor plates, the incorporation of open atria and the interconnection of spaces and stories. These approaches maximize a building's bright and airy feel of daylight and natural ventilation while being harmonious with the principles of sustainability.

This desire for open planning alone presents the fire protection engineer with a concept design that is at odds with most international building codes that seek to limit large open compartments and the interlinking of floors. Achieving a "good" or "excellent" rating is often required for funding, good corporate governance, or for attracting tenants and premium rental returns;

therefore, the design team seeks to achieve quantified reductions in the use of resources such as energy and water. Fire protection engineers, as part of these design teams, must rise to the challenge of contributing to these reductions without significantly compromising the client's aesthetic requirements, or the resulting level of fire safety.

Natural lighting from large open spaces and glass facades can provide benefits in reducing energy consumption while increasing population well-being and productivity when compared to artificial lighting alternatives. Despite the restrictions of building codes, engineered solutions can make these designs (which also require less use of fire compartmentation) feasible. Through the assessment of the fire load within the space, fire protection engineers can assess the smoke movement through interlinking spaces and develop



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Flexible working and the increased focus on maintaining a healthy work life balance is also presenting new challenges and opportunities.

technical solutions to address this while also tailoring the solutions towards a low energy, natural ventilation strategy. Additionally, the engineered provision of elements such as active smoke or fire curtains can provide the code-required barrier between, for example, an atria mezzanine and an adjacent escape route.

In order to quantifiably reduce a building's resource use, fire protection engineers also need to think about the resource demands of products necessary to achieve the required fire safety performance.

Despite refurbishment projects' obvious relationship to the sustainable philosophy of re-use, recycle, they present the greatest challenge to providing adequate levels of

performance for both fire and sustainability. These buildings also present a challenge to code officials, as the buildings rarely comply with the current standards. For refurbishment, the best approach is performance-based engineering – understanding how the building currently performs and finding appropriate solutions working with the building's current provisions to achieve acceptable levels of safety. Considering embodied energy, it is far more sustainable to reuse existing buildings. Through good design, it is possible to do so far into the future.

### **SOCIALLY SUSTAINABLE FIRE ENGINEERING**

Aside from the client-driven challenges, there are other aspects that relate to sustainability that are likely to become stronger influencing factors for designs of the future – such as the actual population of the buildings.

A global trend towards aging populations and longer working lives means sweeping code assumptions that building occupants are generally mobile are becoming less appropriate. Typically, greater provision is made where, for example, it is known that a building is designed to accommodate a high proportion of wheelchair users. (continued on page 18)



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## Case Study 2: California Academy of Sciences California, USA



Figure 3. Exterior view

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### THE BRIEF

The client's objectives for their Academy were to:

- Design a working research facility with the capability for unlimited storage of specimen samples. The samples were to be contained within combustible preservative within movable storage cabinets (compact shelving).
- Create a unique rainforest exhibition, effectively a "building within a building" incorporating multiple levels of interconnectivity.
- Safeguard 18 million samples of plants, animals, fossils and artifacts – essential tools for comparative studies on the history and future of the natural world.

### PROJECT APPRECIATION

The 41,000 m<sup>2</sup> sprinklered building shown in Figure 3, features an undulating 1.01 ha living roof. Other important architectural features include a perimeter steel canopy supporting photovoltaic cells, a large glass skylight supported by a tensile net structure and a 28 m diameter glazed dome, housing a rainforest exhibition. The new \$484 million CAS opened to the public in September 2008.

## LIMITING THE VISION

In the United States, performance-based fire safety is generally accomplished under the guise of the prescriptive building codes "alternate materials and methods of design" clause. In the CAS, more than a dozen such performance-based design equivalencies were proposed and accepted.

For example, the NFPA suite of codes<sup>2</sup> do not normally permit multiple levels to be atmospherically interconnected without smoke exhaust. However, interconnectivity between multiple levels was a client requirement for the rainforest exhibition dome. Achieving smoke exhaust from the rainforest dome would be architecturally undesirable and physically difficult to implement, as the dome itself is located within the larger CAS building.

The ceiling of the main exhibit hall required special treatment in order to avoid the cavernous echo that might occur with such large spaces. In this case, 0.5 meter x 0.5 meter square panels were suspended approximately 2 meters below the concave main exhibit hall roof to help dampen the echo. Under the curved roof, the panels needed to appear "free floating" or disconnected from each other. This resulted in a 12 cm gap (approximate) between each panel. In the event of a fire underneath, this free-floating collection of ceiling panels with associated gaps would not permit a normal ceiling jet to form. The plenum space above them was the entire area of the exhibit hall, which meant that a hot layer could take significant time to develop. Because of this geometry, there was a concern that sprinkler operation would be significantly delayed.

The client's requirements for a working research facility also provided a great challenge. The required design has no similar precedents and was therefore not addressed under generic code guidance.

Normally, due to the hazard type (preservatives with >70% alcohol content), the code would require an automatic sprinkler system with secondary containment of combustible spills and fire suppression water. This would prove a big burden in terms of drainage implications.

## THE INNOVATION

For the research facilities, high pressure water mist systems were investigated. The design required a peer review and full scale fire testing. Fire tests were performed to prove the theoretical performance of the mist system design. The results were a success.

The proposed suppression system successfully incorporated a greatly reduced water flow rate – thus the design precluded the need for special drainage and containment systems.



The client's requirement for a multilevel rainforest exhibition could not be achieved through the normal use of smoke exhaust. Using performance-based design tools and computer-aided fire and egress analysis, the fire protection engineers were able to verify the safety of the egress strategy within the rainforest exhibition without smoke exhaust.

Fire Dynamics Simulator<sup>3</sup> was used to model a likely fire scenario – the results of which were compared to an egress analysis model to ascertain an appropriate evacuation time within tenable limits. The approving authorities reviewed the results and approved the rainforest design. The fire protection engineering analysis saved the architectural integrity and satisfied the client aspirations for an immersive rainforest experience.

FDS modeling was necessary to determine whether the sprinklers within the exhibition hall would activate within a reasonable amount of time. A solid ceiling model was compared to the proposed ceiling. The resulting strategy included the spacing of the sprinklers in a more dense arrangement to have the confidence that they would activate within the same time frame as that of a standard design. This work saved the architectural integrity of the entire ceiling.

The engineering work provided a safe environment, maximized space savings and benefited the building functionally and aesthetically. It provided savings with regard to initial installation costs and future service and maintenance costs projected against the building's life cycle.



(continued from page 15)

The issue of obesity, and the challenges it poses to fire safety are perhaps felt most acutely in hospitals and treatment centers.

Flexible working and the increased focus on maintaining a healthy work life balance is also presenting new challenges and opportunities. As flexible working becomes a more popular approach, businesses are increasingly designing fit-outs without dedicated desks, with occupant's hot-desking or using flexible spaces for their activities. This, combined with the

understanding that many offices are generally only occupied to 70% capacity with people on leave, out at meetings, etc., provides an opportunity for businesses to actually lease less space than they would if everyone had a traditional desk. This may result in more people being allocated to work in a building than say the exit width can accommodate, although the actual population at any point in time should be no greater than can be evacuated safely. The challenge for the fire protection engineer is to test whether or not that is true and possibly to design for more people than simple floor area calculations would imply. This is particularly relevant where a building may cater for trading floors, or changing its use from an office to education, as is happening in many city centers.

Increasing flexibility and minimizing business loss also improves sustainability. Sprinkler protection of buildings, although using resources, can be seen as inherently improving sustainability both for flexibility and as they reduce the potential size of polluting fires. Residential sprinkler protection, particularly in higher risk occupancies, can be argued to be socially sustainable as they reduce risk of loss to life and property and protect some of the most vulnerable members of society.

Some of this may appear to lead to overly conservative designs and hence not be sustainable; however, if future flexibility can be increased, the lifespan of a building can be increased and hence its sustainability. All of these decisions should be made by the client, and the fire protection engineer can help provide their clients with information and options.

*Simon Dent is with Arup.*

#### References:

- 1 Building Code of Australia, Australian Building Codes Board, Canberra, 2009.
- 2 NFPA 101, *Life Safety Code*, National Fire Protection Association, Quincy, MA, 2009.
- 3 McGrattan, K., et al. Fire Dynamics Simulator (Version 5) User's Guide, NIST Special Publication 1019-5, National Institute of Standards and Technology, Gaithersburg, MD, 2009.

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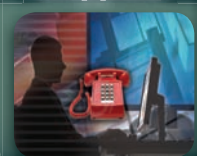
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A chain-link fence is visible in the background, with a sign attached to it. The sign has a red oval with the words "ELECTRICAL FIRES:" in white, and a white rectangular area below it with the words "RESEARCH NEEDED TO IMPROVE SAFETY" in black.

# **ELECTRICAL FIRES:**

## **RESEARCH NEEDED TO IMPROVE SAFETY**

**By Dr. Vytenis Babrauskas, FSFPE**

The NFPA's National Electrical Code (NEC<sup>1</sup>) may be the most technically detailed code—on any topic—that exists in U.S. practice. It has served well for the 110 years of its existence, especially in the area of electric shock hazard. While electrocutions still do occur, they usually require “a chain of human errors,” something that a code generally cannot eliminate.

The other role for NEC is in fire safety. Here, the safety record has certainly improved over the decades, but there remains room for further improvement. A few years ago, this author had the opportunity to comprehensively examine the state of the art of the knowledge underlying electrical fires. This first-ever systematic review was published in 2003 as part of the *Ignition Handbook*.<sup>2</sup> The review indicated that while some topics had received considerable study, many other aspects of electrical fires are still not well enough understood. It is the purpose of this article to consider some of the salient gaps. In addition, some existing, but not well-publicized, research has already identified some safety concerns that should be addressed by appropriate actions.

## STATISTICS

The system of obtaining fire statistics in the United States, based on NFPA 901<sup>3</sup> and the U.S. Fire Administration's NFIRS,<sup>4</sup> generally works well for identifying the broad problem areas. But it is very limited in the quality and accuracy of information that it can produce when it comes to fires caused by electrical or mechanical equipment.

To see why, it is necessary to consider how these statistics are obtained. NFIRS data are supplied by individual fire departments. Once the fire is extinguished, the fire department fills out a form describing the details of the event, and most fire departments use the coding system contained in NFPA 901 and NFIRS.

It is important to understand *who* fills out the form. The delegated individual can either be a fire company officer or the department's fire investigator. Except for the largest cities, it will be rare indeed that this individual would have any detailed knowledge of electricity or electrical fires. The national statistics<sup>2</sup> (Table 1) reported that around 33% of electrical distribution fires are attributed to “fixed wiring.”<sup>7</sup> This is by far the largest single cause of electrical fires, with the next-largest category, “light fixture, lampholder or sign” accounting for only about 16%.

These statistics are almost certainly biased and incorrect. Fixed wiring, while it has various potential failure modes, is generally robust, in comparison to connections in various devices (e.g., outlets) or cords used by occupants.

It is easy to see why such statistics would be reported. If the individuals delegated with the task of providing the NFIRS information do not have good knowledge of both electricity and the modes of faults and failures, one can hardly expect them to provide detailed, reliable information on the topic.

This is not a criticism of fire departments in this regard. In most jurisdictions, the main investigation task for the fire department is to determine if arson has been committed. If it was not, their responsibility typically ends. Since it is exceptionally rare for arson to be committed by tampering with electrical systems, fire department investigatory expertise should not be expected in electrical matters.

Progress could be made on this issue, without requiring a major change in fire department training or investigation procedures. In actuality, fire investigation in the United States is typically a three-tier system. The initial investigation is conducted by the local fire department. In all except trivial losses, the next investigation is normally performed by a private fire investigator sent out by the insurance company that has insured the property. This investigator typically has more extensive training and better resources for conducting the investigation.

In addition, it is not uncommon for a private investigator to devote several days to investigating a fire that the fire department investigated in a few hours. If the loss

Table 1. Average annual losses in the United States for structure fires involving electrical distribution equipment, arranged by type of equipment involved in ignition<sup>2</sup>

Equipment	Fires
Fixed wiring	19,100 (32.7%)
Light fixture, lampholder or sign	9,600 (16.4%)
Cord or plug	8,600 (14.7%)
Switch, receptacle or outlet	5,700 (9.8%)
Lamp or light bulb	4,600 (7.8%)
Fuse, circuit breaker or other overcurrent protection device	3,400 (5.8%)
Meter or meter box	1,200 (2.1%)
Transformer	1,200 (2.1%)
Unclassified electrical distribution equipment	2,200 (3.8%)
Unknown-type electrical distribution equipment	2,800 (4.7%)
<b>Total</b>	<b>58,300</b>

Table 2. Physical mechanisms causing electrical fires, as reported in the published U.S. fire statistics (average per annum, 2002-05)<sup>5</sup>

Factor contributing to ignition in reported structure fires	Fires	Percent
Unclassified electrical failure or malfunction	36,300	7
Unspecified short circuit arc	21,400	4
Short circuit arc from defective or worn insulation	11,400	2
Arc or spark from operating equipment	4,000	1
Arc from faulty contact or broken conductor	3,600	1
Short circuit arc from mechanical damage	3,400	1
Water caused short circuit arc	1,600	<1
Fluorescent light ballast	800	<1
<b>Total (All electrical failure or malfunction)</b>	<b>82,500</b>	<b>16</b>

Table 3. Physical mechanisms causing electrical fires, ranked according to importance by expert judgment

Mechanism	Importance
Poor connections	<div>most</div> <div>↓</div> <div>least</div>
Arcing across a carbonized path	
Arcing in air	
Excessive thermal insulation	
Overload	
Ejection of hot particles	
Dielectric breakdown in solid or liquid insulators	
Miscellaneous phenomena	

is large, then generally the third tier comes into play, whereby electrical engineers, metallurgists or similar professionals examine the evidence in great detail. The third tier is invariably associated with lawsuits, and it cannot readily be expected that these detailed results would be disseminated. The NFIRS system could readily be changed to make use of the second-tier information. A system could be set up whereby insurance companies that have sent out fire investigators to do a detailed investigation feed the information obtained back to the fire department, which, in turn, uses this as the basis for the NFIRS report, instead of the fire-cause information derived

during the fire department's own, much briefer investigation.

## RESEARCH ON MECHANISMS

In order to best make progress, it will be helpful to have a good knowledge of the underlying physical mechanisms that lead to fire, rather than solely categorizing fires by the type of device that has failed. Published statistics on this point are, again, dubious (Table 2). The eight categories listed in Table 2 are the *only* categories into which the national NFIRS fire data system recognizes as electrical "Factors contributing to ignition."

Most specialists consider that short circuits are not a major cause of fires

(Table 3). Instead, the primary mechanisms for causing electrical fires are poor connections and arc tracking, with overloads being a much-lower third cause. Poor connections and arc tracking are, in fact, completely missing from NFIRS. In addition, contributory factors that must be considered are mechanical damage and aging. "Overloads" are to be construed broadly and are meant to include not just exceeding the nominal ampacity of a circuit by excessive load but also problems that cause the effective ampacity to be decreased, e.g., interfering with cooling by excessive thermal insulation.

The review undertaken in the *Ignition Handbook*<sup>2</sup> indicated the available technical knowledge on electrical fire mechanisms is spotty. In some areas, for example, the aluminum wiring problem or "last-strand" failure of power cords, extensive research has been done and the failure modes have become understood quite well. But in other areas, research has been so limited that good guidance cannot be given. This article will examine some salient areas that are either notably short on research or where research failed to lead to needed actions: arc tracking, mechanical damage, aging, and reduced ampacity.

## POOR CONNECTIONS

Poor connections (Table 1) is one of the areas where basic physics has been identified,<sup>2</sup> due largely to research conducted in Japan and by the Consumer Product Safety Commission (CPSC). The physics involved is complex, and CPSC does not have any sustained project to advance the knowledge further. More recent progress has been made by research<sup>6</sup> conducted at the Eaton Corp., but public-sector or university research is notably scant.

## ARCING ACROSS A CARBONIZED PATH

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which must not conduct electricity. The bulk of modern electrical insulators are plastic, and these are susceptible to a failure mode whereby they stop being a good insulator and become a semiconducting material. This process can take place when the material is excessively heated, or carbonized.

The carbonization can occur due to external thermal heating, or due to current flow itself. The latter becomes possible if a wet, polluted insulator surface allows small amounts of current to start flowing along the surface of the insulator; the latter phenomenon is more specifically identified as “wet-tracking.” The fact that fires can occur due to arc tracking has been known since the pre-World War II era, yet research available on the topic is limited.

For house wiring and wiring in appliances and equipment, the most common plastic is PVC (polyvinylchloride). Japanese research<sup>2,7</sup> identified a unique failure mechanism: wet-tracking induced under originally dry conditions (Figure 2). Most electrical-wiring grades of PVC contain a calcium carbonate filler. When initially dry, but subjected to sustained, yet only modestly elevated temperatures (around 120 °C), PVC begins to decompose and reactions with calcium carbonate cause a hygroscopic reaction to occur along the surface. If continued, this can then lead to wet-tracking and possibly to an electrical fire. Thus, PVC is a unique material that can fail by wet-tracking even when it is located in a dry environment.

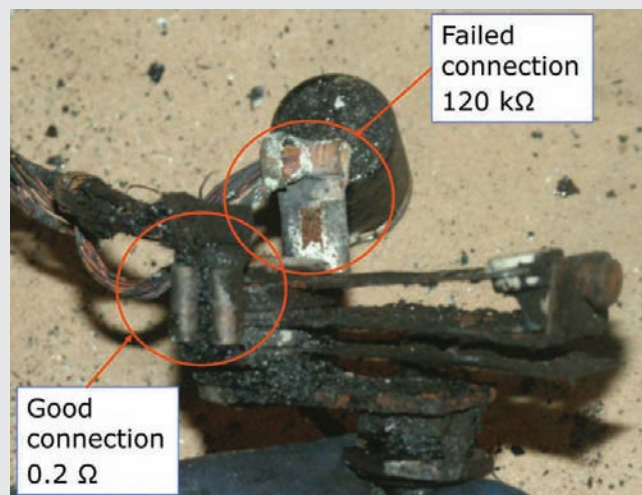


Figure 1. Poor connection at a “push-on” connection led to overheating and ignition of a plastic-bodied electrical heater (Photo: Vytenis Babrauskas).

Additional Japanese research showed that PVC wire insulation is very susceptible to wet-tracking even at the Japanese supply voltage of 100 Volts, which is slightly lower than the 120 V used in the United States. This is of serious concern because standard test procedures used for assessing wet-tracking (IEC 60112<sup>8</sup> and UL 746A<sup>9</sup>) give misleading results for PVC, incorrectly indicating that it can withstand much greater voltages without tracking failure. This appears to be due to the physical configuration of the test method, which does not resemble construction of actual cables. Tests conducted on actual cables demonstrated that PVC-insulated cables have very poor resistance to wet-tracking.<sup>7</sup> The IEC Technical Committee in charge of IEC 60112 has been notified of this problem, but has not taken any action.



Figure 2. Initial stages of wet-tracking on a PVC plug, induced by dry exposure to an elevated temperature (Photo: Kiyomi Ashizawa).

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Figure 3. Charred cables (3 runs of 14 AWG, carrying 120% of ampacity; the stud cavity is insulated with polyurethane foam); cables arced when re-energized (Photo: Mark Goodson)

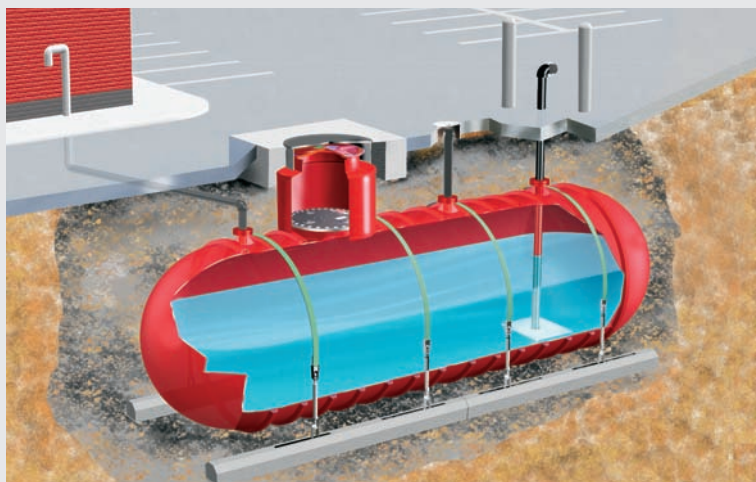
## MECHANICAL DAMAGE

It is no surprise that mechanical damage can lead to failures and fires with electrical components. One of the few U.S. studies where more detailed statistics on electrical failures were obtained identified that "mechanical damage" was the foremost cause leading to fires originating in both branch-circuit wiring and in cords and plugs.<sup>10</sup> Yet, such statistics do not tell how these fires occur. Mechanical damage can cover a large number of different phenomena, including both manufacturing defects and user abuse. A few have been studied in detail,<sup>2</sup> primarily by Japanese researchers. These include parallel arcing across a damaged line cord, "last strand" failure of power cords, and severing of wire conductors by a penetrated staple. Yet others are notably lacking

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in research. This includes factors such as progressive creep and nicked or gouged insulation.

This situation is especially of interest since the thickness of electrical insulation in 120 V circuits is determined by serviceability considerations, not by electrical breakdown considerations. Minuscule insulation thickness

would suffice at these voltages, were it not for the need to provide durability of the insulation over time. Yet, studies on this point are unavailable.

## AGING

A study by CPSC<sup>11</sup> identified "deterioration due to aging" as being

the factor leading to electrical distribution fires in 13.8% of the cases. These determinations were conducted by CPSC field-office personnel, who presumably have some electrical knowledge and skills.


But, are such determinations realistic or correct? In fact, there are no guidelines that would allow an individual—even a highly experienced electrical engineer—to correctly categorize a fire as being due to this cause. A detailed review<sup>2</sup> indicated that research on aging of electrical wiring has been nearly non-existent. Recently, NFPA's Fire Protection Research Foundation (FPRF) completed a research project<sup>12</sup> on the subject of "Aging of Residential Wiring" and a related study,<sup>13</sup> "National Electrical Grounding Research Project." This research is an important first step, but the data on aging of wiring collected by FPRF were primarily better statistics and the work did not encompass physics and chemistry that would allow the failure mechanisms to be more fully understood.

Even the very concept of aging of wiring is fuzzy and poorly founded. Aging of any device implies that, after a certain length of time, its service life will be expired and it must be replaced if functionality is to be maintained or a hazardous condition avoided. Thus, the concept would require that, if electrical wiring or an electrical device is over X years old, it must be removed and replaced.


Manufacturers of smoke alarms have in recent years taken the posture that smoke alarms over 10 years old should be replaced. This type of strategy is generally unknown for other types of electrical devices. And, even for smoke alarms, there has been no technical basis for the 10-year period. For wiring, this would require that an endpoint be rationally established and wiring exceeding this limit be mandated to be replaced. But at the present, since research is lacking, there would be no basis to make such a determination.


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For electrical wiring, inextricably intertwined with aging is the concept of temperature classes. Any physical material has a maximum temperature which, if exceeded, can result in precipitous failure. The electrotechnical community, specifically IEEE and UL, have established a methodology for classifying insulation materials into temperature classes;<sup>14, 15, 16, 17, 18</sup> internationally, IEC uses different standards, but with the same philosophy.

A wide range of these classes exists, but the common ones are 60°C, 75°C, 90°C and 105°C. There are a number of problems with the scheme, but a major problem is that endpoint failures have not been rationally studied. In most cases, a number of tests are used to establish the temperature class (in some cases, however, classification is based solely on "experience"), but none of them determine ignition or even gross electrical failure under conditions reasonably representative of in-use conditions. Some of the tests relied upon are very indirect, i.e., mechanical testing for the ultimate elongation at the breaking point; it is by no means clear that their results can be correlated to the initiation of fire.

Correct determination of the maximum temperature to which an insulation is permitted to be subjected is of major importance for both safety and functionality. Thus, it is very troubling that research validating the IEEE/UL/IEC methodology is lacking. The basic scheme originated in a 1948 paper by Dakin.<sup>19</sup> It represented the best-available research for 1948; however, much has changed in the last 60 years. Even PVC as the insulating material for building wiring did not come into use until after 1948.

In these intervening decades, there have not been any significant studies completed that would verify the soundness of this methodology. In 1974, Ontario Hydro conducted tests<sup>20</sup> on a variety of commercial

PVC-insulated cables. The cables were rated at 90°C or 105°C, but in each case the results were that after roughly one month of aging at 71–77°C, the cables were deemed to have functionally failed. Consequently, the report concluded that these 90°C and 105°C-rated cables must not be used at temperatures that exceed 71°C.

Thus, the only available study that attempted to validate the temperature-class scheme not only did not confirm Dakin's methodology, but found that serious errors on the unconservative side were being made. It is further troubling that these unconservative results emerged after only a month's worth of aging. In actual use, wiring

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must safely function for decades, not month-long periods. Thus, true long-term aging may well reveal a more problematic situation than showed up in the Ontario Hydro testing. Of equal concern is a more recent study<sup>21</sup> where the authors examined NM cables subjected to 90°C temperature and found failure at 4,020 hours, or about half a year. Equally problematic is that in the IEC version of the temperature class rating procedures,<sup>22</sup> it is explicitly stated that the lifetime only needs to be 20,000 hours, which is only 2.28 years.

## REDUCED AMPACITY

The ampacity of wire or cable is the current that it is allowed to safely carry. Calculating ampacity requires a detailed engineering effort, because it is affected not only by the construction details of the wire or cable but also by the environment. The ampacity ratings published by NEC are reliable, but only if the usage conditions correspond to the calculation premises. Often, this may not be true.

The temperature attained by a conductor is governed by the interplay between the heat produced (due to flow of current) and the heat lost (due to convective cooling). The latter, however, depends not only on details of the cable but also on anything that affects convective cooling, e.g., presence of other adjacent conductors and presence of thermal insulation.

Most are aware that it is unsafe to stick electric cords under carpets, mattresses or similar environments since they may overheat. Electricians who install NM-type house-wiring cables generally have no basis to know that they may be creating an overt fire hazard. This hazard normally arises because thermal insulation is used in a wall or ceiling cavity where the cabling is located (Table 3).

Goodson et al<sup>23</sup> became concerned upon finding houses under construction, where NM cables suffered charring damage. They then

conducted a study where they measured the short-term temperatures obtained on cables in wall cavity spaces. They noted that the standards for circuit breaker performance do not require tripping if the sustained load is less than 120% of the rating. Thus, they considered that the appropriate current flow to consider for establishing the thermal hazard is 120% of the breaker rating.

Using 90°C-rated NM cables, a single run of cable in an uninsulated cavity space registered 114°C, which is well above the 90°C limit (even setting aside Stricker's finding that a 90°-rated cable may fail at 71°C). As insulation was added to the cavity spaces and as additional runs of NM cable were placed adjacent to each other—as fully permissible in the NEC—the situation got progressively worse. With three parallel runs of cable and fiberglass thermal insulation, for example, a temperature of 211°C was reached.

Goodson et al were not the first researchers to be alerted to this problem. Already in 1980, Evans<sup>24</sup> at NBS studied the temperatures developed on cables covered by fiberglass thermal insulation. His study was less extensive and involved only single runs of cable, but he too reported that actual temperatures exceeded the rated 90°C value.

*Vytienis Babrauskas is with Fire Science and Technology Inc.*

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By Craig E. Hofmeister, P.E.

The building design community's movement towards sustainable or environmentally friendly building designs can result in unique fire protection and life safety challenges, especially in relation to traditional building code compliance. The design and construction industry has embraced sustainable design principles over the last 10 years and building owners, as well as government entities, have required the development of facilities that meet specific performance goals, such as certification to the United States Green Building Council's (USGBC) Leadership in Energy and Environmental Design (LEED) rating system.

While the focus on better use of natural resources, refinement of construction processes, and integration of the building development into the surrounding landscape are obviously noteworthy goals, the design elements often necessary to meet those goals can be in conflict with longstanding fire protection and life safety code requirements. Sustainable design is a broad concept that can impact fire protection design in several ways — ranging from the manufacturing processes used to develop fire protection systems' equipment to the development of "clean" suppression agents to the support of the building design process to meet specific sustainable design goals.

This article will focus on how the fire protection engineer (FPE) can participate in and support the building design process for a sustainable design. The solutions to the prescriptive code challenges can range from relatively simple common-sense alternatives to more detailed performance-based design analyses. The code compliance issues are often similar to those which the FPE has developed solutions for in the past; they are now just put in a green wrapper.



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The design of a green building often incorporates an abundance of glass and similar translucent materials in order to promote natural light transfer through the building as well as provide landscape views to building occupants.



### BACKGROUND

The sustainable building design concept is a focus on increasing the efficiency of resource use while reducing impact on human health and the environment throughout the building's lifecycle. In general, this includes optimizing and reducing natural resource use, integrating the building within the local landscape, and a focus on building siting and operation, and optimizing transportation and similar community infrastructure use. As such, green building certification processes, such as the USGBC LEED certification, typically utilize several categories to evaluate the overall building design and operation. The LEED certification process includes points based upon categories including site sustainability, water efficiency, energy and atmosphere, materials and resources, indoor environment and quality, and innovation and design. The building can then be certified at various levels, including certified,

silver, gold or platinum, based upon the number of points gained in the evaluation process.

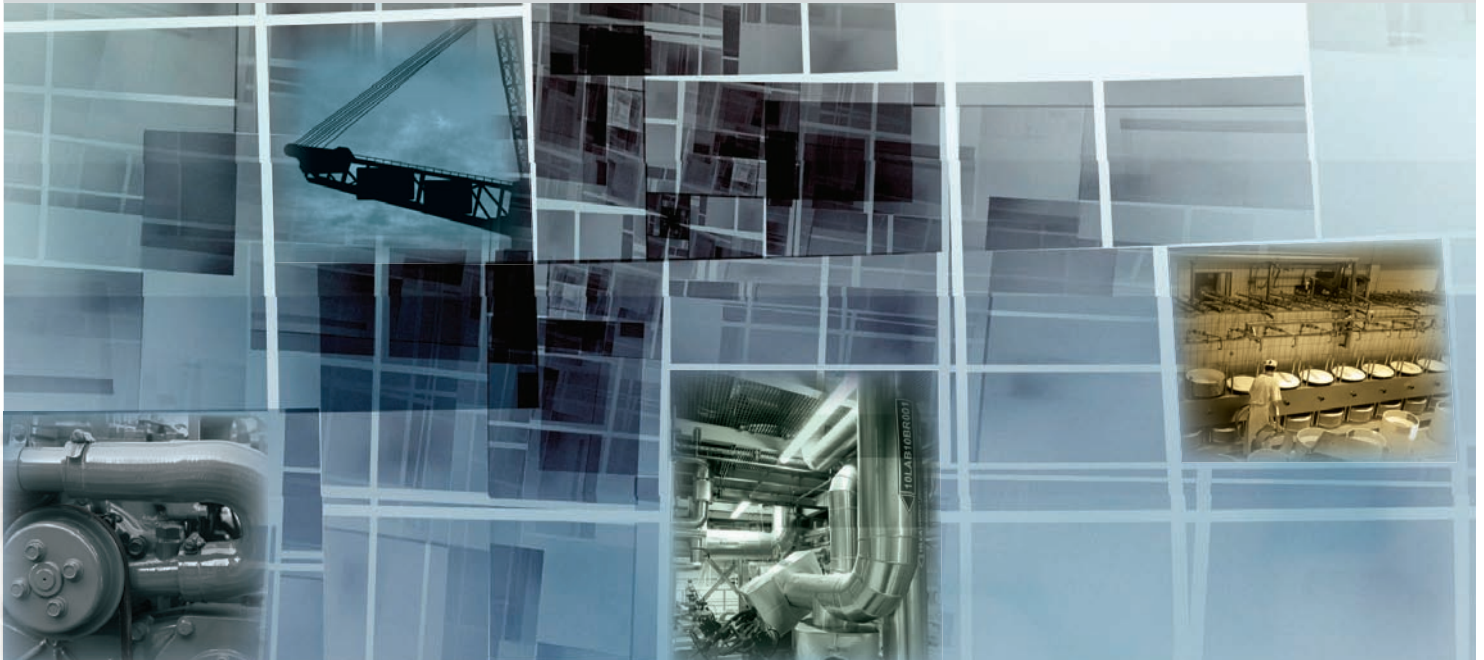
### THE CHALLENGES

In support of the green building certification processes, the FPE has often been asked the question, "What points can fire protection gain the project for green building certification?" Unfortunately, the simple answer is usually "none," or perhaps more accurately "none directly." However, the same concepts and design elements that are used to meet the building's sustainable design goals are often in conflict with prescriptive code requirements. Therefore, the FPE can develop alternative or performance-based options to help the architect and design team meet the sustainable design goals for the project, and in turn, influence the certification process. The following will outline several areas of potential prescriptive code issues and/or general fire protection and life safety concerns and discuss some potential analysis options to maintain a consistent level of fire protection and life safety for the building design.

### FIRE-RATED CONSTRUCTION

In general, the fire resistance construction requirements for a building are dictated by the building's size, use and protection features to determine the basic construction type in accordance with the applicable building code. Larger commercial buildings typically require a fire resistance rated structural frame as well as additional fire resistance rated assemblies for separation of different use groups or specific building features (such as atriums, exit components, etc.).

This basic design premise results in large, open building spaces, which span multiple floor levels, often classified as atriums, and a desired use of materials such as glass and unprotected steel for assemblies that are required by prescriptive codes to main-

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Figure 1. MASDAR Corporate Headquarters Building (Image courtesy of project design architect Adrian Smith Gordon Gill)

tain a fire resistance rating. A notable example of this design concept is the MASDAR Corporate Headquarters Building in Abu Dhabi, United Arab Emirates as seen in Figure 1.

The striking design includes several integral cone building elements

intended to moderate natural ventilation for the space as well as provide natural light transfer throughout many levels of the building. The cone elements are part of the structural frame of the building, which would require a fire resistance rating based

upon the applicable building code. Several of the cone elements also constitute atrium spaces, which would also require fire resistance rated separation on several levels.

Traditional methods of providing the required fire resistance rating would clearly mitigate the intent of the design, and therefore a performance-based approach was deemed appropriate. In this case, a specific review of the use, fuel loading and potential fire hazards was conducted to develop conservative severe-case fire scenarios for the spaces, and working with the project structural engineer, an analysis incorporating the design fire exposures, materials and structural loading conditions was conducted to develop an appropriate protection scheme for the specific building elements.

While the above building design is certainly distinctive, the more common use of traditionally non-rated

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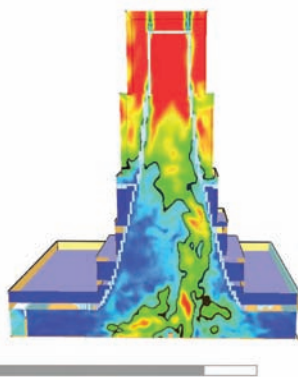
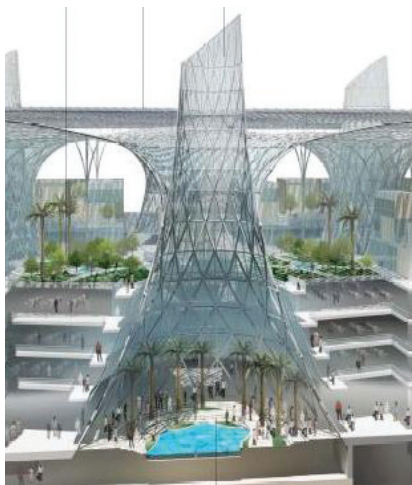


Figure 2. Example of the design and a fire model simulation for the MASDAR Corporate Headquarters Building (Images courtesy of Adrian Smith Gordon Gill architects and RJA)

materials in applications that may require a fire resistance rated assembly in accordance with the applicable code is becoming commonplace in green building designs. Further, more innovative

ideas, ranging from undulating concrete floor/ceiling assemblies to optimize radiant heating/cooling systems, to encapsulating landfill waste (such as plastic bottles) within structural elements are being

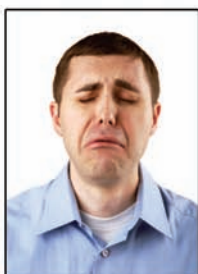
proposed to further the sustainable design principles. It likely will be incumbent on the FPE to develop methods to analyze and assess these unique design ideas.

## FIRE PROTECTION SYSTEMS DESIGN AND INSTALLATION

Another challenge in green building designs can often include the design and installation of fire protection systems, such as automatic sprinklers, fire alarm and smoke control. When discussing sustainable design and fire protection systems, many thoughts jump immediately to whether reclaimed water, such as stormwater or pumped groundwater, can be used for a sprinkler/standpipe system or whether the use of alternative suppression agents, such as "clean agent" systems, will have an impact on the design goals.

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While each of these are valid areas of analysis and come with their individual benefits and causes of concern, an often more basic challenge can be the design and installation of the systems based on the green building design features. The challenge can range from the performance-based design of atrium smoke control systems to the placement of sprinklers and/or devices based upon obstructions, local temperature conditions, and even simply affixing devices to glazing.

Additionally, such detailed analysis can also be of benefit to review the potential for natural smoke venting schemes, in support of the sustainable design concept of reducing mechanical equipment and energy usage.

The MASDAR Corporate Headquarters Building is again an example of the potential benefit of a detailed performance-based smoke control analysis. Several of the large cone elements are classified as atrium spaces, requiring smoke

temperature conditions.

The fire modeling simulations allowed a detailed assessment of smoke movement and occupant tenability within the spaces and ultimately a workable natural ventilation scheme that resulted in the elimination of much of the mechanical smoke control equipment for the project.

Another example outlining several more basic fire protection systems installation issues was the design of the Sara Lee Knit Products Corporate Headquarters Building. A design sketch of one of the atrium spaces is shown in Figure 3.

In this case, the use of automatic extending and retracting sunshades created dynamic obstructions to sprinklers and detection devices, both for roof configurations as well as along curtain walls. The shades could potentially cause obstructions in the extended, partially extended, and even the closed configurations, due to the shade support equipment.

In addition, the project originally included unique undulating poured concrete floor/ceiling assemblies, intended to maximize radiant heating and cooling surface areas, which could potentially obstruct sprinkler spray patterns based on the depth of the "waves."

In effect, the sprinkler and fire alarm detection device placements needed to be reviewed on a location-by-location basis to assess the potential obstruction under a number of different conditions. The fire alarm device locations also needed to be reviewed based upon simple issues such as affixing the devices to glazing and the potential impact of strobe flash through or reflection from the glazing.

Lastly, the abundance of glazing and the use of natural ventilation panels in the design warranted a detailed review to assess whether specific local areas could result in elevated temperatures approaching sprinkler or device activation or decreased



Figure 3. Sara Lee Knit Products Corporate Headquarters Building (Image courtesy of project design architect Thomas Phifer Partners)

Many green building designs include atrium spaces to enhance light transfer and natural ventilation throughout the building areas. Further, the atrium spaces are often of a unique design configuration as opposed to more traditional "box" type atrium spaces to optimize the design goals. The use of fire modeling and performance-based design techniques can be of direct benefit to provide a detailed assessment of simulated smoke movement and the potential impact on egress and tenability conditions within and surrounding the unique space configurations.

control based upon the applicable code requirements. The unique cone design offered an opportunity to review a natural smoke ventilation design for the spaces. Similar to the fire rated construction analysis, conservative fire scenarios were developed for the atrium and surrounding spaces. A detailed smoke modeling analysis was conducted considering such parameters as interior and exterior temperature conditions, exterior wind conditions, etc. Figure 2 shows an example of the design and a fire model simulation of the cone



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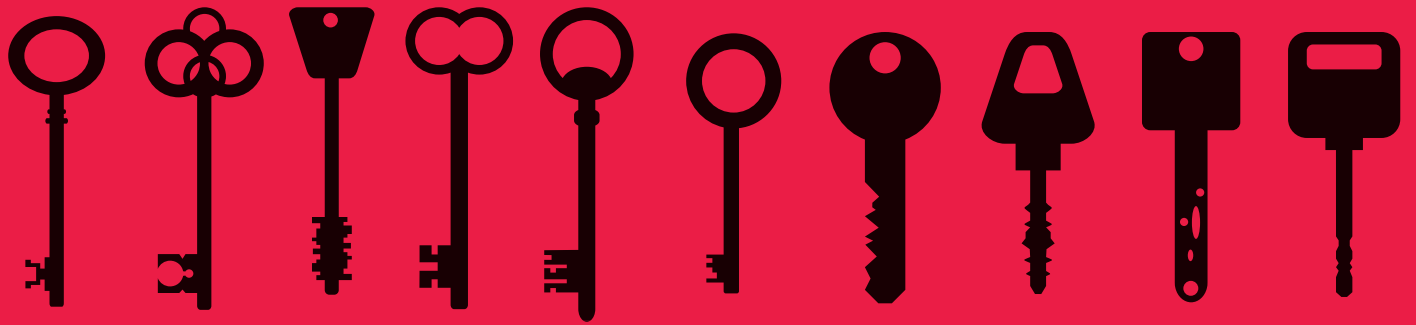
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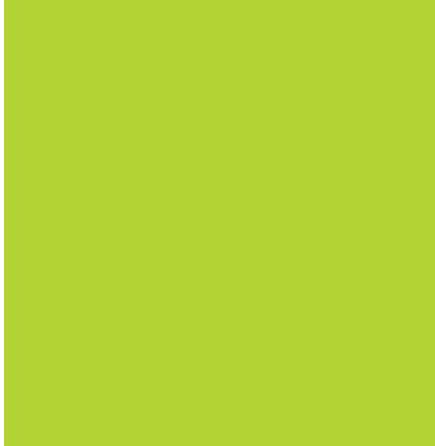
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# green construction and fire protection

By Dominick G. Kasmauskas



**T**here are several possible negative environmental events occurring at a fire scene (whether a single-family home or a factory).

Toxic materials may spew into the atmosphere, debris may be added to landfills, and a significant amount of fire-fighting water may be used. This water, whether turned into steam or as runoff, may flow into aquifers, waterways or reservoirs.

There may be an inherent water conservation benefit from having automatic fire suppression. There may also be a positive impact on the atmosphere. Similarly, fires have an impact on the carbon footprint associated with buildings.<sup>1</sup> There are many questions regarding exactly where automatic fire protection fits into the green community, and although not all of the questions have answers, these and other questions need to be raised.

- 30% of waste output (136 million tons annually)
- 13.6% of potable water consumption

Fire sprinklers have been stopping fire growth and minimizing greenhouse and toxic gas production for over 130 years. However, they are presently not given any credit in the USGBC's Leadership in Energy and Environmental Design (LEED) certification program.

Fire in buildings contributes to the production of CO<sub>2</sub> and potable water consumption. While the impact of building fires are considered in the code process, they are not addressed in the green process.

Buildings that do not have automatic fire protection can be expected to generate a greater volume of burned materials, which will eventually be thrown into landfills.

New products must be produced to replace the burnt structural material and replace lost commercial

the roofer is not just going to patch the hole. The roofer is going to inspect the damage and replace a significant area beyond the damage — or possibly the entire roof — to be able to warranty the work and new material. Exposed neighboring structures may also have radiant heat damage.

Fuel and energy are also consumed by fire apparatus operating at a fire scene, and most fires require multiple fire vehicles. Most fire apparatus use diesel fuel. Diesel fuel not only contributes greenhouse gasses to the atmosphere, but also toxins.<sup>3</sup>

Automatic fire protection can have a positive impact on the environment. The positive impact can be measured in the avoidance of future negative effects. Just as fire protection can mitigate the effects to local economies after an unwanted fire, fire protection can also positively affect the environment and assist in energy conservation.



## THE BUILT ENVIRONMENT IMPACT AND THE NEED FOR "GREEN"

According to the U.S. Green Building Council (USGBC), the built environment has a major impact on the environment. In the United States alone, buildings account for:<sup>2</sup>

- 72% of electricity consumption
- 39% of energy use
- 38% of all carbon dioxide (CO<sub>2</sub>) emissions
- 40% of raw materials use

equipment, process materials and furnishings. Energy is consumed to manufacture, transport and install the needed replacements. Additionally, not just the burnt material is discarded from a structure involved in a fire. Other materials may also need replacement either due to code or design requirements for the new part of the structure or by insurance and liability-driven issues for the contractor in order to guarantee the new work.

For example, if a roof is damaged by the fire and firefighting operations,

## FIRE SPRINKLERS AND LEED

Portions of the LEED certification process address the impacts of "material & resources" — such as re-use, recycled content and use of regional materials. However, mechanical, electrical and plumbing components are specifically excluded. Therefore, fire protection system components are exempt from LEED point calculations for materials being used in the project.

Many materials used in the sprinkler industry (e.g., pipe, hangers, fire

sprinklers, valves, etc.) are made using recycled materials. CPVC is recyclable.

There is some precedent for using the "innovation in design" section of the LEED checklist to obtain one credit by using fire sprinklers. This section can gain one point more toward the desired level of LEED Certification for exceptional performance above the LEED requirements. To gain this credit, the LEED AP® would need to document and apply the strategies and measures of the fire sprinkler concept, including stating the environmental and health benefits.

### CREDITS REGARDING FIRE PROTECTION

A project cannot obtain the LEED credit in chapter 4 for having a clean agent fire protection system. Credit is available for not using a HCFC or CFC system in the project. A project can use a CFC system and still obtain a LEED platinum rating; however, this individual credit cannot be claimed in the point scheme.

Having automatic fire protection recognized in the future may not come without some trading. If LEED is to recognize fire sprinklers, the impact of using water during flow tests that must be captured in gray water must be considered. The impact would be reduced if all testing water was supplied from a gray water source.

### FIRE PUMPS

There is a potential environmental impact of testing of diesel fire pumps and the energy use of electric fire pumps during tests. Many large building projects will use fire sprinklers and the associated equipment needed for a properly operating system. Many projects where a point might be available for automatic fire protection could be smaller projects that would not require a fire pump.

While diesel fire pumps have an associated environmental impact, they could reduce the number of fire apparatus responding and operating at unwanted, uncontrolled fires

furnished with modern items, one with fire sprinklers and one without. The results show fewer water usage and less gases released in the fire-sprinklered burn as compared to the non-fire-sprinklered burn.<sup>5</sup>

### FUTURE EFFORTS

The fire sprinkler industry plans to work with the USGBC to develop a credit for fire sprinklers in future editions of LEED based on the environmental benefits of sprinkler systems.

A possibility for later consideration is a new credit for material and resources.

*Dominick G. Kasmauskas is with the National Fire Sprinkler Association.*

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in structures. NFPA 25<sup>4</sup> requires a weekly test of at least 10 minutes for diesel fire pumps. An item that should be considered is whether electric fire pumps would be preferable over diesel fire pumps. Electrical fire pumps do not emit exhaust.

### AVAILABLE DATA

The Home Fire Sprinkler Coalition and FM Global teamed up in October 2009 and burned two identical 4.5 m x 6 m (15' x 20') living rooms fully



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A project engineer would never intentionally design a building sub-system to be obsolete a year or two after completion – unless the whole project was a temporary venture. What factors must an engineer consider to ensure the longevity of a fire detection, alarm or signaling system? And, what is the useful life of a typical fire alarm or signaling system?

The answer to the second question is directly related to the first. For a properly designed system, its life cycle is defined only by possible changes in the required mission or by component failures and replacement availability.<sup>1</sup> To varying degrees, engineers can design to reduce component failures and provide for possible changes in a system's intended mission. There are many fire alarm systems still in service today that are 30 or more years old. They might not be as sophisticated as today's systems, but they continue to reliably perform their intended functions.

Like sprinklers, today's fire alarm and signaling systems are often designed for a specific mission. Building codes, fire codes and life safety codes have requirements for the use of fire detection, alarm and signaling systems in certain occupancy or use groups. The requirements in the codes are coordinated with other prevention and protection

There are several ways that an engineer can help ensure that a system designed to meet today's needs has the infrastructure to be adapted to meet changes in its intended mission without requiring a total replacement.

2003. Changes in occupancy and changes in owners' goals might also trigger changes to a fire detection, alarm or signaling system.

There are several ways that an engineer can help ensure that a system designed to meet today's needs has the infrastructure to be adapted to meet changes in its intended mission without requiring a total replacement. One of the best ways to provide a flexible infrastructure for a fire detection, alarm or signaling system is to ensure that there are an adequate number of circuits, properly distributed and of sufficient wire size, to permit changes and growth.

Most new fire detection and alarm system designs use addressable control units and addressable detectors for all but very small systems. In NFPA 72<sup>2</sup> terms, an addressable circuit is called a "Signaling Line Circuit" (SLC). Control unit manufacturers design their equipment to allow a single SLC to have as many as 200 addressable devices in various combinations of initiating devices and control devices (relays for example).

Design engineers would not normally specify the number of SLCs required for a project. Instead, they would show the number of initiating devices and specify the number of control points, and then allow the contractor or manufacturer to determine the required number of circuits.

However, to ensure room for changes and future growth, engineers should specify that SLCs not be loaded more than 80% – or some other limit. This could still result in 100 or more devices on a single SLC that passes through multiple fire areas of a building. While technically feasible, that is not good practice. Therefore, the engineer should specify that either separate circuits be used or that isolation modules be used to limit number of devices that might be out of service due to a fault at any one location. Some local codes might also impose similar limits.

Signaling line circuits also have a "growth" advantage in that they are permitted to be "T-tapped" – unless Class A circuits are specified. Class A circuits can remain fully



Figure 1. Combining Protection to Balance Risk

requirements to achieve some level of life safety and property protection contemplated by the code. (See Figure 1.)

In some cases, code changes are made retroactively and would require either a new installation, if one did not already exist, or a change to an existing system. A good example are the code changes that took place to require sprinkler and alarm retrofits in many places of assembly as a result of the Station Night Club fire in

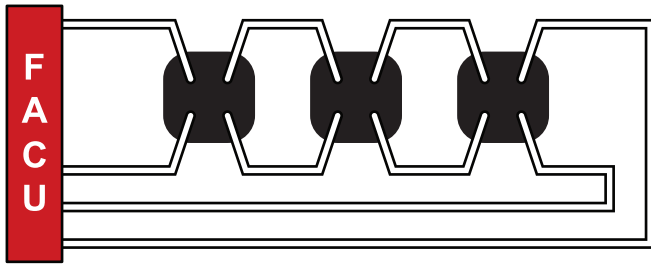


Figure 2. Class A Signaling Line Circuit

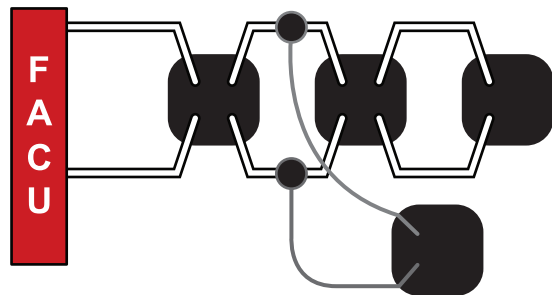


Figure 3. Class B Signaling Line Circuit with a Single "T-Tap"

operational even with a single wire break. On the other hand, a Class B circuit would not be operational beyond the open circuit. (See Figures 2 and 3) Class B SLCs, unlike other types of Class B circuits, are permitted to be "T-tapped" as shown in Figure 3 because they monitor the integrity of the wire by communicating with the devices. (Circuit classes will be described in greater detail in a future installment of this series.)

While it is possible to maintain Class A circuit integrity when adding to a system in an existing installation, it is generally less expensive to "T-tap" an SLC. Also, Class A circuits are not necessarily more operationally reliable than Class B circuits. Class B circuits can be more reliable, depending on the number of "T-taps," the wiring type, the type of fault and the number and location of isolation modules.

As with SLCs, Notification Appliance Circuits (NACs) should have a load limit specified by the designers. NACs are more likely to require changes during the life of a system. Therefore, a lower load limit of 70% or so is recommended. Design engineers should also specify that no one NAC serve more than one fire or smoke zone – even if the system is set up for general alarm. This would permit future "zoning" or selective communications options to be implemented by changing or reconfiguring the control equipment, which is easier and less expensive than rewiring a building.

Regardless of the specific load limits for the initial installation, the wire size for each circuit should be based on 100% loading so that it can properly handle future additions. Future changes to circuit length should also

be incorporated in the initial installation by up-sizing the wires. For NACs, the wire size can be increased one or two sizes without any downside consequences – the only limit being the cost. However, for SLCs, the smallest wire size that meets the load and distance requirements is best. This is because larger wires have a greater capacitance, which degrades digital signaling and slows communications speeds. In most cases, No. 18 or No. 16 AWG (0.823 mm<sup>2</sup> or 1.31 mm<sup>2</sup>) wires are sufficient for SLCs. The panel manufacturer can provide resistance and capacitance limits.

Many facilities now install Emergency Communications Systems (ECS) to provide notification and information to occupants for more than just fire emergencies.<sup>2</sup> The backbone of an ECS is the use of voice for the audible part of the system. This can have a growth advantage over conventional direct current audible appliances.

Conventional NACs used for horns are direct current circuits and are limited by the available current – typically one to two amps per circuit. NACs used for speakers are limited only by the available wire size and amplifier size. Thus, if properly planned, they have greater potential for future growth. The disadvantage is that separate circuits must be provided for visible signaling appliances. However, since the need for ECS is increasing, providing voice capability even when not required results in a more flexible system. In many installations, the cost can be offset by using the ECS for day-to-day communications and paging needs as permitted by NFPA 72.

Engineers should also address future component failures and replacement availability. The first step is to choose and specify the correct type of equipment for the environmental and situational conditions. In certain situations, mechanical protection, listed for use with the particular detector or notification appliance, might be required.<sup>2</sup> The availability of parts over time varies among different manufacturers and for different product lines. Engineers should work with manufacturers and distribution chains that have a track record for maintaining parts availability.

A system that can last forever and meet all future needs does not exist. However, by requiring certain features and upgrading from minimum requirements, engineers can design and specify systems that will be more likely to meet or contribute to future needs.

#### References:

- 1 "Mission Effectiveness and Failure Rates Drive Inspection, Testing, and Maintenance of Fire Detection, Alarm and Signaling Systems," *Fire Protection Engineering*, Bethesda, MD 20814, Summer 2002.
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### May 24-26, 2010

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### June 7-10, 2010

2010 NFPA Conference & Expo  
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**Info:** [www.nfpa.org/categoryListWSCE.asp?categoryID=1600](http://www.nfpa.org/categoryListWSCE.asp?categoryID=1600)

### June 8-9, 2010

11th International Fire Prevention Symposium  
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**Info:** [www.interschutz.de/60448](http://www.interschutz.de/60448)

### June 16-18, 2010

8th International Conference on Performance-Based Codes & Fire Safety Design Methods  
Lund University, Sweden

**Info:** [www.sfpe.org](http://www.sfpe.org)

### July 5-7, 2010

The 12th International Conference on Fire Science & Engineering (Interflam)  
University of Nottingham, United Kingdom

**Info:** [www.intercomm.dial.pipex.com/html/events/interflam10cfp.htm](http://www.intercomm.dial.pipex.com/html/events/interflam10cfp.htm)

### July-October 2010

2010 Fire Protection Engineering P.E. Exam Online Review Seminar

**Info:** <http://www.sfpe.org/Education/2010OnlineStudySeminarforFPEPEExam.aspx>

### September 29-30, 2010

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**Info:** <http://www.firesinvehicles.com/en/Sidor/default.aspx>

### October 3-8, 2010

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**Info:** [www.sfpe.org](http://www.sfpe.org)

### October 20-23, 2010

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**Info:** <http://grupos.unican.es/GIDAI/>

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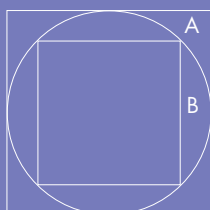
## BRAINTEASER >

## Problem / Solution

### Problem

**A** square is circumscribed within a circle, which is in turn circumscribed within another square as shown below.

Which area is larger – area “A” or area “B”?



### Solution to Last Issue's Brainteaser

A train is one kilometer long. If the train is traveling 33 km/h, how long will it take for the train to completely pass through a 10 km tunnel?

The train must travel a distance of 11 km to completely pass through the one kilometer tunnel. The train will travel 11 km in  $\frac{11 \text{ km}}{33 \text{ km/h}} = \frac{1}{3}$  hour or 20 minutes.

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The Van Duyn Home & Hospital (VDHH) Residential Health Care Facility is comprised of a seven floor building, where all residents live, and two smaller outbuildings for auxiliary services. The challenge was to warn and protect its residents with varying degrees of physical incapacity, some suffering from Alzheimer's or dementia.

Syracuse Time & Alarm Co., Inc. (ST&A), a local systems integrator, worked with VDHH and the contract engineer to design a new fire protection system network covering the entire facility.

Plans called for a fire alarm emergency voice audio communications system with the flexibility to meet future plans for facility expansion. ST&A utilized the E3 Series® Expandable Emergency Evacuation system, manufactured by Gamewell-FCI, as the heart of the new fire protection network.

The new combined fire alarm and

emergency communications system features selective paging for mass notification. For enhanced survivability, decision making is done by the fire alarm control panels on each floor; all system components are wired in a loop (Style 7) to prevent breaks, faults or other disruptions from halting system operations.

In compliance with the latest NFPA 72 emergency communications codes, VDHH's system is programmed to follow a three-level hierarchy and fire alarm functions are to override general paging, which includes distribution of any prerecorded emergency messages.

Ancillary functions such as VDHH's resident wandering system are also superseded by the fire alarm. Residents with dementia wear bracelets that activate door locks when approached. In the event of a fire alarm, the wandering system is automatically disabled. The flexibility of the E3 Series Expandable Emergency Evacuation System provides the VDHH with all the unique requirements necessary to effectively protect its facility and more importantly its residents.

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In a fire retardant treated wood roof system, the panelized wood sections speed

the erection process and add strength, dimensional stability, and high diaphragm capacity to the roof. The ability to pre-frame large roof panelized units reduces cost, cuts construction time, and enhances job site safety since fewer man-hours are spent on the roof. Panelized roof systems are one of the safest systems to erect because most of the work is accomplished on the ground during fabrication of the large pre-framed roof panels. Once the large panels are lifted into position at the proper roof elevation, only one or two workers are required on the roof to complete the final purlin attachments and diaphragm nailing.

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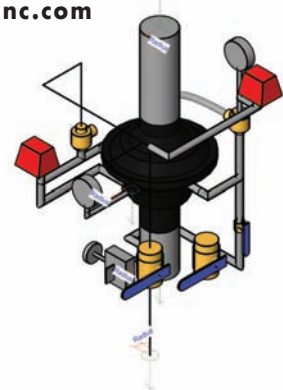
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# FIRE PROTECTION Engineering

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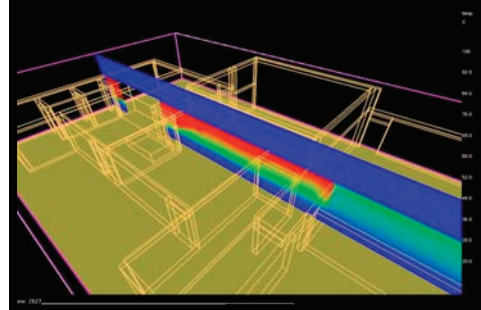
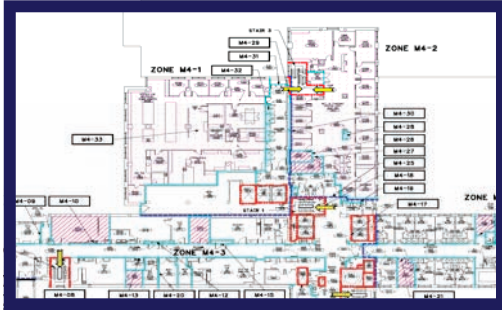
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