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# Engineering

3RD QUARTER 2014

Issue No. 63

# HIGH-RISE TIMBER BUILDINGS

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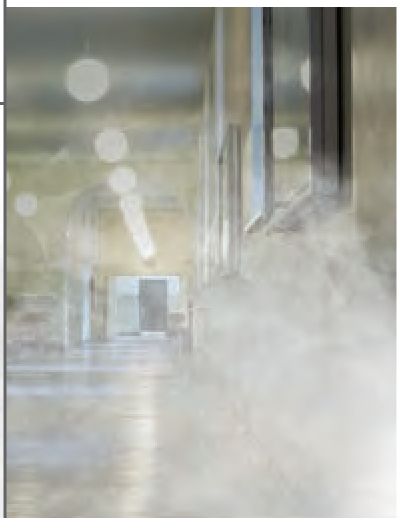

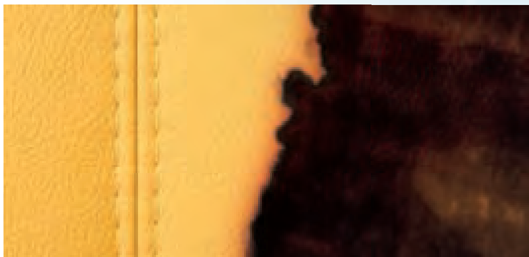

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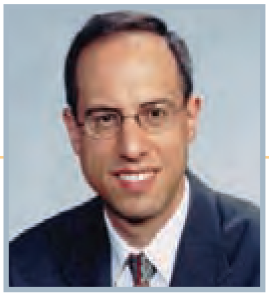
ON THE COVER: Contemporary apartment building made of wood, Hamburg, Germany.



From the TECHNICAL DIRECTOR

# "Who Will Design Fire Protection of the Future"

The title of this column is not a rhetorical question, but rather it was the title of a presentation that was given on the occasion of SFPE's 25th anniversary in 1975. A summary of the presentation can be found in SFPE Technical Report 75-5, which can be downloaded from *http://tinyurl.com/SFPETR75-5*. (SFPE "Technical Reports" were a precursor to SFPE's peer-reviewed journal.)

In the subject paper, Dr. John Rockett of the National Bureau of Standards (Now the National Bureau of Standards and Technology) made a number of projections about how fire protection engineering might evolve. Since this paper was written almost 40 years ago, it's interesting to see how closely Dr. Rockett was able to foresee the future.

Rockett divided practicing fire protection engineers into three categories: those who performed risk assessments and ratings for the insurance industry, consultants, and those involved in codes and standards development or research. At the time, Rockett observed that 70% of all fire protection engineers fell into the first category, with the other categories representing 20% and 10%, respectively. (Now, the latter two categories would arguably not be mutually exclusive.)

Rockett's first prediction was that the percentage of fire protection engineers who work in the insurance industry would decline, while the percentage involved in consulting would increase. While the insurance industry is arguably the driving force behind establishing fire protection engineering as a profession, Rockett proved prescient here. The percentage of fire protection engineers who work in the insurance industry has declined to 14%, according to the 2012 survey[1] of SFPE's members.

Rockett also predicted that as the share of fire protection engineers who worked in the insurance industry decreased, so too would the sophistication of their work. Rockett was incorrect with this prediction, as fire protection engineers who work in the insurance industry do work that is no less sophisticated than that done by other engineers.

He suggested that residential fire detection systems, which in 1975 were only beginning to be introduced into homes, would be one of the last technological changes. While sprinkler systems were certainly not novel in 1975, perhaps Rockett would have considered their use in homes novel at the time.

Another significant prediction of Rockett's was that buildings of the future would be more highly engineered. He did not use the term "performance-based design," although that was clearly what he meant by "more highly engineered." He suggested that, due to the higher design costs, such approaches would primarily be used in "more densely occupied properties."

He was partially correct here, although his posited timeframe – 10 years – was certainly short. Almost 40 years later, performance-based design is generally only used on higher-end projects, where building owners or developers seek to incorporate innovations that would not be possible under the prescriptive code.

With the transition to a more highly engineered approach, Rockett foresaw the need for additional specialties to be applied in fire protection engineering. In addition to the need for professionals who are well versed in fluid flow and heat transfer, Rockett foresaw the need for professionals with expertise in areas such as physiology, toxicology and psychology. Here again he was correct.

In 1975, computer programs were already available to assist with hydraulic calculations of sprinkler systems. Rockett observed that, while it was possible to perform accurate hydraulic calculations, determining the effect of sprinkler flows on a fire was much more difficult. Rockett suggested that this situation would be resolved "in a few years." Nearly four decades later, it is still quite difficult to predict the effects of fire suppression, although computer modeling has made great progress and shows promise for additional progress.

Reference:

1 2012 Profile of the Fire Protection Engineer, Society of Fire Protection Engineers, Bethesda, MD, 2012.

**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* or by mail to *Fire Protection Engineering*, 7315 Wisconsin Ave., Ste. 620E, Bethesda, MD 20814.

# VIEWPOINT > *To Achieve High Performance Sustainable Success, Greater Emphasis is Needed on Performance-Based Codes*

**By Kevin Rodenkirch and Benton Johnson, P.E.**

Over the past decade, sustainable design requirements have begun to make their way into building codes. However, as this shift has occurred, it has become apparent that the codes' prescriptive requirements often limit the use of high performance sustainable designs that incorporate strong technical solutions.

In general, building codes outline today's standards, but don't flexibly accommodate future design innovation. The most forward-thinking sustainable design solutions, therefore, will go no further than the design development table – to both incorporate them into a project and meet building codes is often too costly, too redundant, or too cumbersome.

The proposed use of mass timber to construct mid- and high-rise buildings is a perfect example of a sustainable solution that cannot easily be realized until building codes change. Most prescriptive codes prohibit the use of heavy timber in construction that exceeds certain heights, number of floors, and/or floor areas.

Building timber towers, however, would help mitigate growing population and environmental degradation concerns. Since 1990, the United States' population has grown by approximately 3 million people per year.[1] The largest centers of growth within the U.S. are metropolitan areas; worldwide, urbanization in some of the fastest growing regions is happening at a far greater rate.[2]

Housing will drive a large portion of future construction, and it is important that the planning that goes into it – including the standards set within the building industry – provides buildings that will be safe, livable, efficient, and sustainable. One must be critical of how buildings are designed, constructed, and operated going forward. This includes reassessing the stipulations of building codes.

Beyond building codes, there are a number of standards and rating systems that can help to guide this process, including the "2030 Challenge" (see http://www.architecture2030.org). The 2030 Challenge promotes better design strategies and the use of on- and off-site energies in order to achieve operational carbon neutrality in buildings by 2030. However, it doesn't consider buildings' embodied carbon footprints, and designers need to consider embodied carbon footprints because they cannot be improved over the life of a building.

Virtually all materials and systems have a net positive carbon footprint. Wood is the exception to this rule: it is approximately 50% carbon by weight and also acts as a carbon sink, absorbing carbon emissions from the surrounding environment. This is what makes mass timber such an appealing structural material for mid- and high-rise residential construction.

When used in lieu of traditional structural materials, such as concrete or steel, mass timber would significantly reduce a mid or high-rise building's embodied carbon footprint. When these savings are combined with operational carbon savings, a mass timber building would most likely achieve far greater carbon footprint reductions than a comparable building made from structural concrete and/or steel.

Unfortunately, current building codes restrict the height of timber structures when categorized as heavy timber structures. They also prohibit the use of combustible structural materials when structures are classified as high-rise buildings. To make solutions like timber towers possible, building codes must shift from being prescriptive to performance-based.

The path to code compliance through performance-based design needs to become a more widely recognized and viable option for designers. If the industry can accept the fact that innovation comes in many forms, not all of which will fall within prescriptive requirements or traditional means of design and construction, the doors will be open to incorporate the best and most innovative high performance systems, materials, and applications into real buildings. This will allow the industry to not only meet current goals, but continue to exceed them well into the future. Design development taking place across the globe indicates that high performance design possibilities are nearly limitless. More performance-based building codes will let them go from research to reality.

*Kevin Rodenkirch and Benton Johnson are with Skidmore, Owings & Merrill, LLP*

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1 *Annual Estimates of the Population for the United States, Regions, States, and Puerto Rico*, U.S. Census Bureau, Washington, 2013.

2 *Urban and Rural Areas 2009*, United Nations, New York, 2009.

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# LETTER to the EDITOR >

**Dear Editor:**

I read with interest the article by John F. Devlin, P.E. on "Passenger Rail Systems Fire Safety: An Overview," in particular the emergency ventilation information. This is a major life safety problem during fire conditions and emergency operations in tunnels. I have worked over 35 years in the FDNY and operated at numerous fires in subway track tunnels and stations under smoke conditions that could not be readily relieved.

A ventilation point often used was the emergency exits in the NYC subway system that are positioned in between most stations. These emergency exits are generally enclosed and lead from the street level to the catwalk ledge above the tracks. These provide not only access but possible ventilation points.

During one prolonged incident when a train lost control and crashed in the 14th Street Union Square station in Manhattan, many rescue tools required generator power, and their usage created significant quantities of carbon monoxide. Ventilation fans were set up to exhaust air at the emergency exits while supplied by fans from the train station area. This greatly improved conditions and allowed members to operate without the use of SCBA.

SCBA usage was often necessary in tunnel areas where homeless people lived and slept. Fires in rubbish-heavy areas were often difficult to reach and find; members were often pressed to search for fire and victims alternating between using their mask and breathing in the toxic environment in order to ensure they would have enough air to exit and locate the fire/victims. There were very difficult decisions to make for officers directing these units, and they did not have many alternatives until the fire was located and fans could be positioned. There were no subway system fans that could be used for emergency ventilation. The only fans we used were the ones we provided.

As the author pointed out: "Emergency ventilation is a significant contributor to achieving fire safety in a tunnel train way and enclosed station during a fire condition." Tunnel ventilation solutions are an absolute major issue in a highly populated subway systems and worthy of Fire Safety Engineers immediate attention.

Howard J. Hill

*Dear Mr. Hill:*

*You raise an important point. Many existing fixed guideway transit and passenger rail systems, like New York City Transit Authority, are not provided with permanent emergency ventilation facilities. An emergency rescue operation as you have indicated may itself create potentially detrimental environmental conditions in a tunnel trainway or enclosed station. NFPA 130 requires the rail authority, in collaboration with the emergency response agencies, to address various possible emergency scenarios. Procedures for implementing temporary emergency ventilation facilities must be recognized and considered for non-fire emergencies.*

*John F. Devlin, P.E., Aon Fire Protection Engineering Corp.*

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## University of Maryland Department of Fire Protection Engineering Appoints First Clinical Professor

The University of Maryland's Department of Fire Protection Engineering (FPE) has appointed the department's first endowed Clinical Professor, Kenneth E. Isman (B.S. '86, fire protection engineering). The Clinical Professor's role is to bring hands-on field experience to the undergraduate curriculum and strengthen ties with industry.

Isman's appointment was made possible by FPE's Legacy Campaign for a Professor of the Practice. Launched in 2012 by a group of FPE alumni, departmental and A. James Clark School of Engineering leadership, the campaign has raised almost $1.3 million toward its $2.5 million goal. Financial support from Clark School Dean Darryll Pines enabled Isman's hiring and arrival this August, while the campaign is still ongoing.

From 1987 to 2014, Isman was an engineer with the National Fire Sprinkler Association (NFSA), where he ultimately rose to the position of Vice President of Engineering. He is a Licensed Professional Engineer in the State of Connecticut and is an elected Fellow of the Society of Fire Protection Engineers (SFPE). He has served on over a dozen NFPA technical committees and is a noted author, lecturer, and speaker.

**For more information, go to *fpe.umd.edu/legacy-campaign***

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

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# HIGH-RISE TIM

# BER BUILDINGS

By David Barber and Robert Gerard, P.E.

Over the past decade, the design industry has been increasingly looking toward timber as a building material for the construction of tall buildings. This interest is partly due to the development of new engineered timber products and the potential economic benefits of prefabricated timber elements and composite building systems. However, a recent emphasis on the importance of green and sustainable architecture and an understanding of the potential sustainability benefits of tall timber buildings can be seen as the primary motivator for many architects, owners, governments, and other building stakeholders wanting to design with timber.

## SUSTAINABILITY BENEFITS – THE ADVANTAGES OF A TIMBER BUILDING SYSTEM

Owners, managers, designers, and some government agencies have been placing a greater importance on sustainability in building construction and operation, as buildings are a major contributor to greenhouse gas emissions in their construction and operation.[1] This has led to increased interest in the use of timber in buildings, as timber can be considered an attractive material for green building construction.

The use of timber in building construction can positively contribute to sustainable building practices in many ways:

- Timber is considered a renewable resource and the forests supplying timber can offer a natural carbon sink;
- The resource extraction and manufacturing phases of timber products demand a very low amount of energy relative to more conventional structural materials used in construction; and
- Innovative timber systems designed for prefabrication and disassembly allow for reuse of the material and a more resource-efficient product life cycle than typical demolition and down-cycling.

In addition to the sustainability benefits, timber has other positive attributes relative to other building material types:

- Possibility of offsite prefabrication and minimized onsite work allowing for high-quality certified production, independent from weather and a rapid erecting progress;
- Reduction of building weight, resulting in savings in foundation works when compared to other construction materials;
- Ease of alteration onsite; and
- Increased flexibility in architectural design options.

## TYPES OF TIMBER CONSTRUCTION – THE NEXT GENERATION IN TIMBER DESIGN

Timber products, assemblies, and methods of construction have evolved over time. Conventional experience with timber buildings is typically limited to low- and mid-rise residential and commercial buildings. These buildings generally utilize light timber frame construction and are limited in size and open area. This is different from heavy timber frame construction that is increasingly being used for mid- to high-rise residential and commercial applications.

While light and heavy timber framing are used for different applications, the primary differentiator between the construction types is the section size of the timber members used in construction. Although there is currently no universally accepted definition of "light" and "heavy" timber, timber can be considered as heavy where its minimum dimension of solid wood exceeds approximately 80 mm (3").[2]

In general, light timber frame construction is composed of a greater number of small-section stud members to form wall and floor assemblies, typically enclosed within cladding to form wall or floor framing elements. Light timber frame construction is typically used in low- and mid-rise residential buildings and is often used in buildings up to five- and six-stories, typically above a reinforced concrete ground floor. Framing methods include "platform" and "balloon," or stick-framed construction.[4]

Heavy timber frame construction is composed of a lesser number of large-section engineered products to form the building superstructure. While this includes solid sawn lumber sections, modern timber buildings generally use engineered timber products. Relative to solid sawn lumber, engineered timber products offer greater strength and design flexibility and have enabled greater ambitions in architectural and structural design.

The use of heavy timber frame construction allows for greater design flexibility (relative to light timber frame construction) including longer unsupported spans, open-plan areas, and taller construction. The two predominant forms of heavy timber construction include post and beam construction and panelized construction.

Characteristics of light and heavy timber frames are discussed in a number of design guidance documents.[2,3,4,5]

## Post and Beam Construction

Post and beam construction utilizes a range of different products. This includes traditional products such as solid sawn lumber, and contemporary engineered products such as glue-laminated wood, laminated veneer lumber and cross-laminated timber.

Solid sawn lumber consists of large-section timber members that are cut down to size. Given the size of the elements, solid sawn lumber is typically used as structural column and beam framing members. Glue laminated wood (glulam) is an engineered product that consists of smaller pieces of wood, nominally 2 in x 4 in (50 mm x 100 mm), which


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are adhered, or laminated, together. This produces a structural element that is stronger than solid sawn lumber as it is more homogenous and reduces the impact of knots and other imperfections. Similar in size and structural application as solid sawn lumber, glulam elements are commonly used as structural beams and columns.

Laminated veneer lumber (LVL) is composed of multiple layers of thin wood veneers, approximately 3 mm (1/8") thick, which are laminated parallel to each other under heat and pressure. Slicing the timber into thin veneers and laminating them together reduces the effect of imperfections in the wood, resulting in improved structural performance compared to solid sawn timber members.[6]

### Panelized Construction

Panelized construction consists of solid timber panels as the primary structural elements. These panels are composed of an engineered product referred to as "cross laminated timber" (CLT).

Cross laminated timber is an engineered product that consists of multiple layers of stud members that are laminated perpendicular to each other to achieve strength in multiple directions. Multiple perpendicular layers are built up to create CLT panels for use as structural elements.

CLT panels can be vertically oriented as load-bearing walls and shear walls, or horizontally as load-bearing floors or roofs. The use of CLT panels for structural wall and floor elements is typically used for mid- and high-rise residential construction as load-bearing walls and floors. Walls typically consist of three- to five-layer panels, whereas floors consist of five or more layers for greater stability. CLT panels can be designed to create internal and external partitions within the structure that makes their use practical for housing units in residential buildings. One of the primary benefits of CLT panels is the use of offsite prefabrication. Holes and notches in panels can be pre-cut prior to arrival to site. This minimizes work onsite, reduces construction time and costs, and increases the accuracy of structural components and quality of workmanship.

## CHALLENGES FOR TALL TIMBER BUILDINGS

The recent emergence of tall timber buildings presents several primary challenges for the design, approval,

and construction of these new and innovative structures.

## Perception of Fire Risk

One of the primary challenges for tall timber buildings is a concern that they might present greater risks compared to high-rise, non-combustible structures. This could be motivated by historical precedent for catastrophic fire cases, recent fire incidents in timber structures, or even a general misunderstanding of the fire performance of heavy timber as a building material.

Identifying the fire performance of light and heavy timber members is an important distinction. Experience with timber in fire could be limited to small section members, characterized by kindling and light timber framing. Research has shown that heavy timber elements exhibit different fire performance compared to light timber.[7] The section size of heavy timber members achieves an inherent fire resistance that protects the element due to the formation of a charring layer. This results in improved fire performance for heavy timber members relative to light timber.

## Gaps in Knowledge

Over the past 15 years, research and testing has been performed to better understand the fire performance of timber structures. However, opportunities for further research remain. Providing greater understanding of these gaps in knowledge is intended to better characterize the fire performance of timber structures and clarify fire risks. Research and testing could lead to performance benchmarks and design tools that would allow a designer to characterize fire performance, engineer fire protection strategies, and demonstrate safe design.[8]

### Contribution of exposed timber to room fires

Previous fire testing has shown that exposed timber has the potential to contribute to the fuel load in compartment fires.[9] Fire tests have shown that delamination can occur in exposed CLT panels.[10] This delamination may result in an increased burning rate for a limited period of time and also can result in an increased char rate for the exposed solid wood as it is instantly exposed to the compartment temperatures.

A better understanding of the contribution of exposed timber to room fires has the potential to better account for the contribution, identify if and when delamination might occur, and engineer strategies to meet the specific risks. Further, research also can evaluate the potential for self-extinguishment in exposed timber applications.

**Connections between timber components and timber composite assemblies**

As new timber technologies are developed to meet architectural ambitions and structural demands, it is important to consider the fire performance of these new structural assemblies and, in particular, the connections that transfer load between structural elements.

A high level of confidence in structural fire performance will be required to demonstrate that safety is achieved. This could require advanced modeling analysis or fire testing to demonstrate safe design. Design solutions must be balanced by structural-efficiency, cost-effectiveness, aesthetics and, importantly, fire performance.

**Penetrations for services**

Understanding penetration behavior is critical to demonstrate that compartmentation is achieved for fire safety in timber buildings. The combustible nature of fire-rated structural elements presents unique challenges compared to non-combustible structures. Charring behavior must be considered for appropriate fire-stopping solutions to be developed to meet the fire performance requirements.

Two possibilities to solve this challenge include the development of fire test standards that account for combustible bases or substrates, and proprietary products for walls and floors in timber buildings.

## Gaining Approval

While there is a growing global precedent for tall timber buildings,

the building regulatory process in the U.S. has yet to approve the design for a high-rise timber building. The current prescriptive guidance in the *International Building Code*[11] restricts combustible construction to approximately five to six stories, well below the practical limit of approximately eight-plus stories for heavy timber buildings.

In the current regulatory environment, approval for a high-rise timber structure would require the proposal of an alternative solution to the building code. This requires a designer to provide technical justification that the alternative solution meets the intended level of safety required by the prescriptive code requirement. This is a high burden of proof that relies on a comprehensive understanding of timber fire performance, an engineered fire protection strategy, and possibly fire testing, to justify safe design.

A significant amount of ongoing research is aimed at filling the gaps in knowledge and leading to a better understanding of the fire safety challenges in tall timber buildings. A particularly valuable tool is fire testing to clarify fire performance issues and validate analytical tools for fire engineering design and alternative solutions.

### TYPES OF TIMBER BUILDINGS – GLOBAL PRECEDENTS IN TALL TIMBER BUILDINGS

Europe is one of the first continents to embrace the use of new timber technologies in mid- and high-rise buildings. Sweden, Germany, and the United Kingdom, among others, have constructed tall timber buildings of seven-stories or more. Most recently, Australia has completed the tallest modern timber building in the world.

As experience and familiarity improves and a greater number of buildings are completed, the benefits of timber construction are becoming increasingly apparent, not only due to the sustainability benefits, but also due to the speed and ease of construction.

The structure of an eight-story building in Bad Aibling, Germany, took only three weeks to complete. The U.K.'s nine-story Stadthaus apartment building took 23 weeks less than a comparable standard concrete project. London's Stadthaus also provides an interesting example of innovation facilitated by carbon reduction legislation. In June 2013, the Forté Building, a 10-story CLT residential complex in Melbourne, Australia, became the tallest occupied timber building in the world.

The development of tall timber buildings has recently expanded to North America. A six-story office building called the Bullitt Center is under construction in Seattle, Washington.

## FEASIBILITY STUDIES – THE FUTURE OF TALL TIMBER DESIGN

Timber is becoming an increasingly desirable construction material as many architects and designers understand the potential sustainability and construction benefits of timber buildings. Traditional schemes for timber structures as low-rise (two-stories or less) and mid-rise (three- to five-stories) are now being extended with schemes for new high-rise buildings (six-stories or greater).

Innovative technologies, such as the emergence of CLT and other engineered timber products, create the potential for timber buildings to be designed to taller heights and maintain the stability and safety of conventional construction materials, all while reducing the environmental impact.

A 2010 partnership between Arup consulting engineers and Rhomburg, an Austrian architecture firm, undertook a research study for a 20-story office building called Life Cycle Tower (LCT). The study aimed to design and detail a heavy timber commercial office building to demonstrate that high-rise buildings can be constructed in timber without compromising safety. The research project was realized with the construction of an eight-story office building called LCT One in Dornbirn, Austria in 2012.

One of the most well-known cases for tall timber construction was published in 2012.[12] "The Case for Tall Wood" challenges the use of steel and concrete as essential materials in tall building construction. The study demonstrates the environmental benefits of timber buildings, while highlighting the design challenges and identifying how these can be achieved through science, engineering, and design. "The Case for Tall Wood" promotes the use of a mass timber structural solution that can be competitive with concrete construction for buildings up to 30 stories in height.

Skidmore, Owings and Merrill (SOM) published a study, "Timber Tower Research Project."[13] The study demonstrates the feasibility of a new structural mass timber system that can be designed to be competitive with reinforced concrete construction

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in buildings from 10 to 30 stories in height, while reducing the embodied carbon footprint by approximately 60 to 75%. The system proposes the use of performance-based design.

*David Barber and Robert Gerard are with Arup.*

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# A Passive Smoke Control Design

By Tiffney A. Cates Chen, P.E.

The new Engineering, Aviation, Computer & Mathematical Sciences Building (EACMS) will be located on the campus of the University of Maryland Eastern Shore (UMES) in Princess Anne, Maryland. Completion of building construction is expected by July 2015, and the building is expected to be open to students for the 2015 fall semester. The building was designed to comply with the 2012 International Building Code[1] (IBC) and the *Life Safety Code*[2] (LSC) as adopted by the State of Maryland. The EACMS building will be three stories in height, consisting of classrooms, lecture halls, laboratories, machine shops, office space, and food services. Each story is approximately 15 ft (4.6 m) high and the clearstory above the third floor extends approximately another 10 ft (3.1 m).

A three-story atrium rises from the ground level to the clear-story above the third floor, for an approximate height of 55 ft (17 m). The open space of the atrium measures approximately 245 ft (75 m) long (east to west) and 20 ft (6 m) wide (north to south) on the second and third floors.

Walkways are provided on the second and third floors around the outer edge of the atrium, which protrude into the clear space of the atrium. There is an additional walkway on those floors, which connects the north and south walkways through the center of the atrium. There is another opening that penetrates the second and third floors in the south hallway as well as an unenclosed stairway in the north hallway. (See Figure 1.)

## DESIGN APPROACH

The three-story atrium requires a smoke control system in accordance with the IBC and NFPA 101. A natural smoke exhaust system will be utilized to exhaust smoke from the top of the atrium so that tenable conditions are maintained from the bottom of the atrium to 6 ft (1.8 m) above the highest walking surface. Fire Dynamics Simulator (FDS) Version 5 modeling has been used to evaluate the worst reasonably anticipated conditions within the atrium and to evaluate the effects of natural smoke exhaust on tenability within the space. Building areas that were not contiguous to the atrium were not included in the model.

## DESIGN CRITERIA

### Design Fire Scenarios

Four (4) design fire scenarios were identified as reasonably expected to occur within the three-story atrium:

- a spill plume on the ground level in the center of the three-story atrium underneath the walkway,
- a spill plume on the ground level underneath the stairs in the north hallway,
- an axisymmetric plume on the ground level between the studio and meeting rooms on the east side of the atrium, and
- a spill plume on the second floor next to the opening in the floor in the south hallway.

Each design scenario consisted of a constant heat-release rate fire. By specifying the fire to have a constant

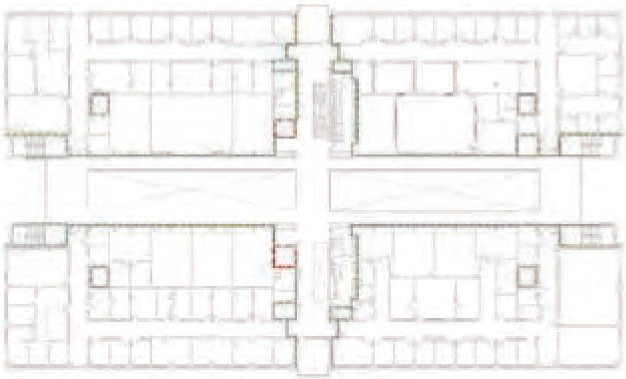


Figure 1: Third Floor Plan

heat output (and, therefore, a constant smoke output) from the beginning of the scenario, a more conservative estimate of conditions within the atrium was modeled.

A 5-megawatt (MW) (4740 Btu/s) fire was used as the design fire size for all four design scenarios. The design fire size was chosen based on relatively low rates of heat release from a fire occurring within the building corridors, which is typical of a light hazard occupancy. In accordance with Figures 3-1.18 and 3-1.102 in the SFPE Handbook, a 2 MW fire is more likely to occur within the building; however, to be conservative a fire size 2.5 times greater than this was modeled to demonstrate that the natural smoke exhaust system is capable of venting a 5 MW fire. See Figure 2 and Figure 3.

Each fire scenario was modeled with no wind, a 30 mph (13.4 m/s) wind, and a 60 mph (26.8 m/s) wind blowing north, south, east, or west. A sensitivity analysis was conducted for 27 scenarios. The mesh resolution was increased to 2.5 ft (0.75 m) per side for the sensitivity analyses to determine if increasing the model resolution would noticeably alter the results. Based on the models that were run using the 2.0 ft (0.61m) per side mesh resolution, both models performed similarly.

## Tenability Criteria

Visibility and air temperature were evaluated to determine occupant tenability in each of the design fire scenarios. Tenable conditions had to be maintained for a period of at least 20 minutes in accordance with the IBC. A minimum visibility distance of 30 ft (10 m) was used as the threshold above which egress is impeded through the smoke layer, as suggested by Purser.[4]

Two maximum temperature criteria were examined in each of the design fire scenarios. A sustained maximum temperature of 169°F (76°C) during a 20-minute exposure is deemed acceptable.[4] Additionally, Purser suggests that a maximum temperature of 392°F (200°C) can be tolerated for up to a minute; accordingly, exceeding this temperature was considered a failure to maintain tenable conditions.

## SMOKE EXHAUST MODELING

Figure 4 illustrates the building exterior as it was modeled in FDS. (Note that areas not contiguous to the atrium were not included in the model.)

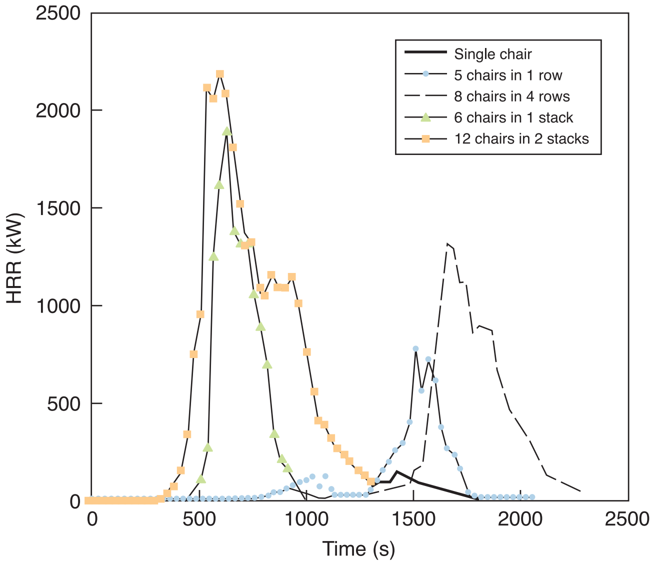


Figure 2: HRR of stackable chairs, polypropylene with steel frame, no padding[3]

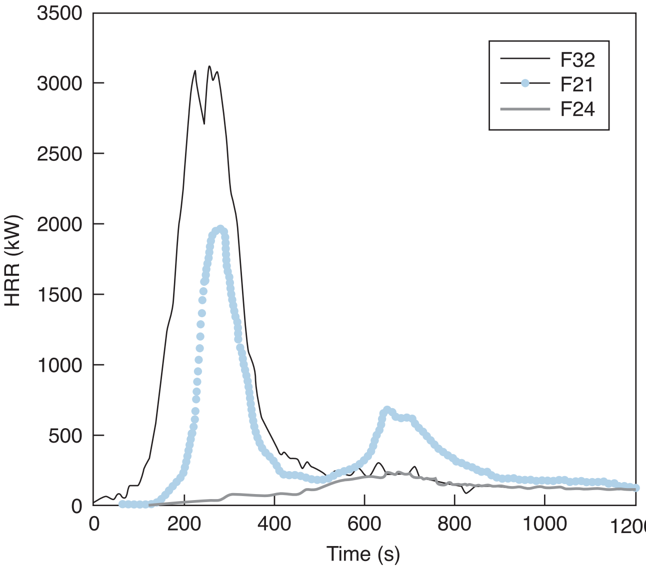


Figure 3: HRR of several upholstered furniture items tested at NIST[3]

The building designers wanted the smoke vents to be awning-type windows that did not fully open to 90° in order to provide the greatest protection against precipitation entering the building during operation of the atrium smoke control system. Due to the limitations of FDS, the awning that was created to model this new window was comprised of an obstruction that extended one cell out from the wall and one cell down, creating an upside down "L" shape. This effectively represents the same obstruction as a true awning window in that it forces the smoke to flow out from the edges of the awnings.

In many design scenarios, sprinkler effects on the fire were not modeled due to the complexity of sprinkler/fire interaction and to obtain more conservative results in regards to performance of the smoke control system.

Sprinkler activation is required for some scenarios when testing stack effect conditions. In these cases, and where sprinkler activation is required to maintain tenable conditions because the temperature rises above the 169°F (76.1°C) limit, the modeled sprinklers were placed 2 ft (0.61 m) below the ceiling and spaced 20 ft (6.1 m) apart.

Although the actual building sprinkler installation complies with NFPA 13, the modeled sprinklers were located lower than the NFPA 13 prescribed 12 inch

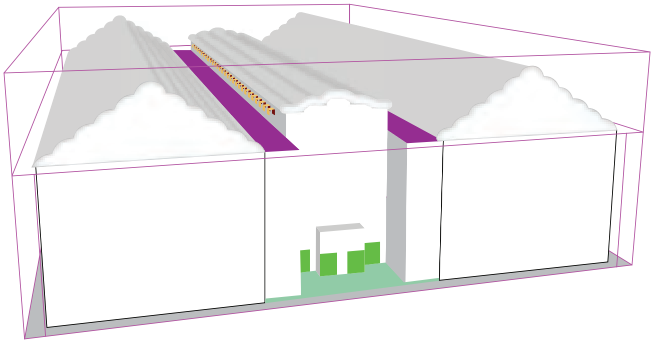

Figure 4: EACMS Fire Model Geometry

(30 mm) maximum to conservatively delay sprinkler response time and maintain consistency with the 2 ft (0.61 m) cube grid cell size used in the model. Sprinklers were specified with an activation temperature of 155°F (68°C) and an RTI of roughly 100 $(ft \times s)^{1/2}$ [50 $(m \times s)^{1/2}$], which would simulate ordinary temperature, quick response, extended coverage sprinklers in a light hazard occupancy. Table 1 shows the quickest activation times for each of the fire scenarios that were run in the models.

The smoke exhaust system was designed based on calculation methods from NFPA 204.[5] The make-up air is provided

by two sets of 6 ft x 8 ft (1.8 m x 2.4 m) double doors at each of the four entrances and two extra vents by both the east and west entrances. The actual venting area is provided by 48 windows along the clearstory of the atrium, which are 4.5 ft x 4.5 ft (1.4 m x 1.4 m) for a total of 972 square feet (90.3 square meters). Including a vent coefficient of 0.35, the total effective venting area becomes 340 square feet (31.6 square meters). Numerous different scenarios (nine at each fire location) were created in order to compare the effects of wind (both velocity and direction).

The atrium smoke control system is activated via three beam detectors along the roof of the atrium. Two of the beam detectors run east-west along the full length of the atrium and are located a few feet (about a meter) below the atrium roof. A third beam detector is located a few feet (about a meter) below the third floor ceiling and runs north-south to detect smoke that may be in the north or south hallways. These detectors activate when they reach 25% light obscuration. A 45-second delay after detector activation was provided to account for fire alarm signal processing time and to provide time for the vents and doors to fully open.

Slice files provided two dimensional illustrations of visibility and temperature values throughout the atrium. The slice file shown for each measurement is taken at 38 ft (11.6 m) above the ground level, which is 6 ft (1.8 m) above the highest walking surface. Any reduction in visibility, increase in temperature, and/or increase in asphyxiant gases below this level will begin to substantially affect the egress ability of a given population.

## Modeling Results Summary

The results of each fire scenario, including smoke exhaust and sprinkler activation times, are summarized in Table 1. The values are from the no-wind scenarios for each fire location; the interior and exterior temperatures are both 68°F (20°C).

| Fire Location | Fire Type | Exhaust Activation | Sprinkler Activation | Visibility | Temperature |
|---|---|---|---|---|---|
| Center | Spill Plume | 11.5 seconds | Does not activate | Never below 92 ft (28.2 m) | Never above 113°F (45°C) |
| Under Stairs | Spill Plume | 30 seconds | 217 seconds | Never below 46 ft (14 m) | Never above 149°F (65°C) |
| Between Studio and Meeting Rooms | Axisymmetric Plume | 6 seconds | 19.5 seconds*, 89 seconds** | Never below 68 ft (20.9 m) | Never above 122°F (50°C) |
| 2nd Floor By South Opening | Spill Plume | 17 seconds | 69 seconds*** | Never below 39 ft (12 m) | Never above 221°F (105°C) |

*Activation time may be due to placement of sprinkler in relation to fire.
**In the same model, another sprinkler activated after 89 seconds.
***Sprinklers are located on the third floor in the south hall.

Table 1: Fire Modeling Results Summary

## RATIONAL ANALYSIS

### Stack Effect

Stack effect describes the tendency for air to move within a building, when interior and exterior temperatures are different. Normal stack effect describes the condition where the interior building temperature is hotter than the outside air, causing interior air to move upward. Reverse stack effect describes the condition where air tends to flow downward in a building because the interior of the building is cooler than the outside air.

In addition to running each scenario where the interior and exterior temperatures are both 68°F (20°C), each scenario was simulated to account for normal and reverse stack effects. To simulate the worst case scenario for the summer, the exterior temperature was modeled at 100°F (37.8°C) while keeping the interior at 68°F (20°C). To simulate the worst case scenario for the winter, the exterior temperature was modeled at 0°F (-17.8°C) while keeping the interior at 68°F (20°C).

Both stack effect conditions alter the way in which the natural ventilation system performs; normal stack effect conditions tend to lower visibility and temperature, and reverse stack effect conditions increase visibility and temperature. Nevertheless, results of the modeling indicate the atrium smoke control system is able to maintain tenable conditions even under these conditions.

### Wind Effect

For the EACMS Building, any wind during a fire scenario is expected to improve the smoke control system efficiency. Primarily, the wind would aid the natural ventilation by pushing the smoke around the atrium and eventually out through the vents in the clearstory. The primary negative effect that wind could have in a naturally ventilated system is that it could prevent smoke from leaving the building if wind comes in through the smoke vents.

Due to the height of the penthouse roofs, 70 ft (21.3 m) compared to the 62 ft (18.9 m) atrium roof, any perpendicular flow (wind in north or south directions) is forced above the atrium roof and is not able to come back down to the atrium roof height. Further, having vents on both sides of the long axis of the clearstory minimizes the effect of wind pushing smoke back into the building.

| Fire Location | Fire Type | Exhaust Activation | Sprinkler Activation | Visibility | Temperature |
|---|---|---|---|---|---|
| Center | Spill Plume | 11.5 seconds | N/A | Never below 71 ft (21.7 m) | Never above 92.3°F (35.5°C) |
| Under Stairs | Spill Plume | 29.5 seconds | N/A | Never below 56 ft (17 m) | Never above 119°F (48.5°C) |
| Between Studio and Meeting Rooms | Axisymmetric Plume | 6 seconds | N/A | Never below 53 ft (16 m) | Never above 118°F (48°C) |
| 2nd Floor By South Opening | Spill Plume | 16.5 seconds | 73 seconds* | Never below 38 ft (11.5 m) | Never above 194°F (90°C) |

*Sprinkler is located on the third floor in south hallway.

Table 2: Fire Modeling Results Summary, Normal Stack Effect

## RESULTS

In all of the standard temperature simulations, the visibility did not drop below 30 ft (9.1 m) at any point. In all but two fire scenarios, under the south opening on the ground level and next to the south opening on the second floor, the temperature did not rise above the 169°F (76.1°C) value acceptable for exposures up to 20 minutes.

This temperature above the 20-minute limit was contained to the south hallway, and at no point did the temperature approach the 392°F (200°C) upper limit. Sprinkler activation was evaluated in the two cases where the temperature exceeded the 169°F (76.1°C) limit, and it was found that sprinklers would be expected to activate in both cases within one minute. After sprinkler activation, it is assumed that the temperature in this area drops sufficiently to provide tenable conditions for the remainder of the simulation.

The effect of the exterior temperature also impacts the effectiveness of the smoke control system. Under normal stack effect conditions, where the exterior is colder than the interior, the smoke control system performance varies in comparison to equal interior and exterior temperature conditions. The minimum visibility experienced decreased for a number of the fire scenarios. This can be attributed to the smoke plume being cooled by entraining colder air, causing the smoke to become less buoyant. This leads to greater smoke accumulation on the top floor, but the smoke is cooler, by about 20°F (-6.7°C), in almost every scenario.

Under reverse stack effect conditions, where the exterior is hotter than the interior, the smoke control system performance is the opposite of the case of normal stack effect. Instead of entraining cold air in the smoke plume, hot air is entrained, which prohibits the plume from losing as much heat and allows it to become more buoyant. This increased buoyancy enhances the natural ventilation. However, the smoke layer temperature increases by about 20°F (-6.7°C) in almost every scenario.

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| Fire Location | Fire Type | Exhaust Activation | Sprinkler Activation | Visibility | Temperature |
|---|---|---|---|---|---|
| Center | Spill Plume | 11.5 seconds | N/A | Never below 98 ft (30 m) | Never above 131°F (55°C) |
| Under Stairs | Spill Plume | 29.5 seconds | N/A | Never below 49 ft (15 m) | Never above 167°F (75°C) |
| Between Studio and Meeting Rooms | Axisymmetric Plume | 6 seconds | N/A | Never below 84 ft (25.7 m) | Never above 149°F (65°C) |
| 2nd Floor By South Opening | Spill Plume | 18.5 seconds | 70 seconds* | Never below 36 ft (11 m) | Never above 248°F (120°C) |

*Sprinkler is located on the third floor in south hallway.

Table 3: Fire Modeling Results Summary, Reverse Stack Effect

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# FLAME RETARDANTS: Background and Effectiveness

**By Marcelo M. Hirschler, Ph.D.**

Fire safety can be achieved by means of active or passive fire protection. Passive fire protection involves using materials or products with superior fire performance so as to either minimize the probability of ignition or, if ignition does occur, minimize the damaging effects of the resulting fire. Flame retardants offer one way of providing passive fire protection.

When a combustible material (often a polymer) is used in applications where fire safety is important, the lack of intrinsic fire safety must be addressed to provide passive fire protection. There are four possible approaches, the first two involving flame retardants.

- Adding flame retardants (i.e., using additive flame retardants)
- Creating new materials with better fire performance though syntheses of variations of the material (i.e., using reactive flame retardants)
- Blending or otherwise compounding the material with other materials with better fire performance (i.e., creating blends or mixtures)
- Encapsulating the material or separating it from potential exposure to the heat insult (e.g., using barriers).

Typical applications where fire safety is critical include consumer products (such as upholstered furniture or mattresses), electrical and electronics (such as wire and cable, circuit boards, computer or appliance housings), and building products (such as interior finish, insulation or roofing materials).

It is always possible to choose non-combustible materials for any or all of these applications, but such a choice would typically limit either the esthetics or the comfort of the product in question. For example, combustible foams are typically used as paddings for upholstered furniture because they provide comfort and resilience. Foams could be replaced by steel or concrete, but that would provide much lower comfort. Interior finish (such as wall linings) can be wood or decorative wall coverings, or it can be gypsum board or concrete, but the latter option involves a clear loss of appeal.

Flame retardants are materials intended for incorporation into combustible materials to improve their fire performance or to meet fire test requirements. Many studies have shown that flame retardants can improve ignitability and/or reduce flame spread. Clearly, fire will not occur if no ignition happens: thus, a delay in ignition will improve fire safety. However, fire hazard assumes that ignition has occurred and studies have shown that flame retardants also have a beneficial effect on heat release, which is the most important fire property.

## WHAT ARE FLAME RETARDANTS?

Flame retardants are not a new invention: since the 18th Century, it has been found that the addition of some specific chemicals would help improve one or more fire properties. The earliest published example is a 1735 Wyld patent[1] (copy available at *magazine.sfpe.org*) to improve the flammability of textiles and of paper by using "a mixture of alum, vitriol and borax." In the same century, flame retardant coatings were used in "lighter than air balloons" launched by the Montgolfier brothers in France in 1783.[2,3] Much earlier, the ancient Egyptians and Greeks used solutions of "alum" (an aluminum-based salt) as flame retardant coatings for wood construction during times of war.

The seven chemical elements that, when contained within materials incorporated into polymers as additive or reactive flame retardants, have the greatest effect in improving fire performance are: bromine, chlorine, phosphorus, nitrogen, aluminum, antimony, and boron.[3] Flame retardant chemicals (more commonly known as flame retardants) often include one or more of these chemical elements, and their effectiveness is usually a direct function of the fraction of the active element present in the flame retardant.

Synergy (i.e., improvement in effectiveness beyond what would have been expected from the added effects of the individual components) often occurs when combining additives containing more than one of these chemical elements. For example, materials containing antimony as the only one of the above elements are almost invariably of little utility in terms of flame retardance unless used in combination with ones containing chlorine or bromine, or both.

Brominated flame retardants are probably the most efficient ones: a small proportion of a brominated additive or of a reaction that partially brominates the substrate polymer is often enough to cause a very significant effect on fire performance. The most common mechanism of action of brominated flame retardants is thermal breakdown to form free radicals that react, in the gas phase, and inhibit the chain reactions whereby the decomposition products of combustible materials propagate combustion. The mechanism involves converting very reactive free radicals into ones that are much less reactive.

Chlorinated flame retardants are also very efficient and can act in a similar way as brominated flame retardants, typically by decomposing to give off hydrogen chloride, with the same gas phase inhibition effect discussed above. However, chlorinated flame retardants also act in the condensed (or solid) phase by changing the decomposition mechanism and the burning rate.

One of the clearest indications of the beneficial effect of chlorine content on fire performance is the fact that polymers containing chlorine in their basic formula outperform polymers with the same structure and no chlorine. The typical example is PVC [polyvinyl chloride], which has much lower heat release and much better ignitability than polyethylene [PE]; the only difference in chemical structure between PE and PVC is that PVC has chlorine.

Flame retardants containing phosphorus may exert different modes of action, depending on the material used and the polymer (substrate) used. They may act in the condensed phase or in the gas phase or as a combination of both. For phosphorus-containing flame retardants, condensed phase action typically results in increased char formation, in some cases via a mechanism called intumescence.

The efficacy of such materials as flame retardants is often enhanced by materials containing halogens (chlorine or bromine) or materials containing nitrogen. This is sometimes done by developing materials that combine more than one such element within the structure or by using a series of additives as a system. Elemental phosphorus, as red phosphorus, is probably the only example of a flame retardant that is an elementary material. Its action is primarily in the gas phase and is strongly enhanced by synergists.

Intumescence requires three components (although the same material can have more than one role): a "carbonific" (supplying the raw material for char), a "spumific" (supplying evolving gases) and a "catalyst" (accelerating the process, often an ammonium phosphate). Certain compounds, either initially incorporated into or simply coated onto an organic polymer, either decompose or react with other materials in the condensed phase at high temperatures to give a protective barrier in which the gaseous products of polymer decomposition are trapped as they are formed.

An intumescent coating is then said to have been formed on the polymer surface. This non-flammable protective coating covers the polymer surface and helps insulate the flammable polymer from the source of heat and thus prevent the formation (or at least the escape into the gas phase) of combustible breakdown products; it may also insulate the gaseous oxidant (normally air or oxygen) from the surface of the polymer. Alternatively, direct application of a non-flammable layer on the surface of the polymer yields a non-intumescent coating.

Nitrogen-containing materials are rarely used as flame retardants on their own, but some polymers containing nitrogen (such as aromatic polyamides or natural materials such as wool or silk) have some inherent improved fire performance. The most common combinations are of materials containing nitrogen with those containing phosphorus or sulfur, often in the same molecule. One mechanism of action of these materials is the release of gases containing nitrogen, which dilute or cool the vapor phase and thus slow the combustion reactions. Flame retardant systems containing nitrogen can also be part of intumescent systems.

Alumina is the flame retardant that is most widely used, typically as a hydrated material (or aluminum hydroxide). It thermally decomposes to emit water, which then both cools and dilutes the vapor phase and makes combustion more difficult. It also acts as a filler, which decreases the amount of combustible material. Its action is primarily physical and usually requires very large amounts to be effective. Similar activity to hydrated alumina is obtained with magnesium hydroxide, but it decomposes at higher temperatures than hydrated alumina.

Antimony is primarily used as antimony oxide and it is an efficient synergist for halogenated materials (chlorine or bromine). Activity occurs principally in the gas phase, and it enhances the scavenging activity of the free radicals generated by the halogenated additives.

Boron is primarily used as either a substitute for antimony oxide (zinc borate) or with cellulosic materials, such as textiles or loose fill insulation (either borax or a borax/boric acid mixture). The mechanism of action is often a combination of the formation of glassy residues above the condensed phase, the enhancement of char production, and gas phase activity (including the release of water vapor). Boron has been used since the 19th Century.[3]

Many other elements can impart improved fire performance, on a limited basis. Typical examples are magnesium, sulfur (particularly as ammonium salts), and tin (as hydroxystannate or zinc hydroxystannate).

However, each flame retardant system (and modern ones may have multiple components) will be useful for a specific polymer system and a specific application. Thus, if a flame retardant system is very effective for a particular polymer when intended for a particular use, it may well not be useful for the same polymer for a different use or for a different polymer for the same use. Flame retardant systems must be tailored to fit both the material and the end use intended and the fire safety needs.

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## WHAT DO FLAME RETARDANTS DO?

Flame retardants are a tool that can have a favorable effect on every key fire property, including ignitability, flame spread, heat release, and ease of extinction; albeit they do not necessarily have all of these effects simultaneously in every case. Some examples follow associated with well-known products in actual use where the effectiveness of the appropriate flame retardant system has been well demonstrated or even incorporated into codes or regulations. It is not possible to assign a particular flame retardant to a specific application, since many different flame retardants can be used for a variety of applications and vice versa.

Wood behaves very differently if it has been treated with flame retardants to obtain fire-retardant-treated wood (FRTW). Standard wood panels tend to exhibit a flame spread index (FSI) of between 75 and 200 (in the ASTM E84[4] test), while FRTW panels exhibit an FSI of under 25 and are accepted in many more applications than standard wood panels.

Recent heat release work has shown that the peak heat release rate [in the cone calorimeter] for both low density and medium density particleboards decreases when flame is retarded.[5] Similar results exist for larch and thermowood pine.[6] In all the cases reported, the treated wood materials were also less easily ignitable.

Cellulose loose-fill is a product used for insulating attics, although it has relatively poor fire performance. Regulations and codes require the product to meet a critical radiant flux. This fire performance can only be achieved if the cellulose loose-fill is treated with flame retardants, often boron materials.

Cables installed in plenums have long been required by the *National Electrical Code* (NEC)[7] to be encased in non-combustible raceways. In the 1970s, fire hazard assessments showed that cables could be used safely in plenums without raceways if they met flame spread and smoke release requirements in a specific fire test designed for the application.[8]

After this was implemented in the NEC, it was found that suitable fire performance for plenum cable insulation and jacketing materials could be obtained with materials treated with flame retardants (often multi-additive systems). Small scale[9,10] and intermediate scale[10,11] heat release tests were conducted on the materials in these cables and on the cables themselves; the tests showed a significant decrease in flame spread and heat release associated with the flame retarded materials as compared to the ones that were not flame retarded. These are the materials typically used to make the cables used in plenums, meeting NEC requirements.

In the U.K., polyurethane foam used for upholstered furniture and mattresses has been required since the 1980s to meet a fire test.[12] The test requires that the foam (when covered by a standard fabric) not spread flame to the extremities of the test cushion. The typical way in which furniture and mattresses using polyurethane foam (the vast majority of them) have been built in the U.K. is by incorporating flame retardants into the foam.

Cone calorimeter heat release tests have shown that systems with a fabric and a flame retarded foam that meet BS 5852 crib 5 requirements exhibit much lower heat release rates than those that are not flame retarded.[13] Moreover, there is usually no ignition in those systems; as soon as the crib flame burns out, the fire ceases.

Full scale tests comparing an actual sofa containing BS 5852 crib 5 foam (purchased in the U.K.) with a sofa

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Figure 1: Sectional sofa with Non FR polyurethane foam ignited by BS 5852 ignition source 1 (match equivalent, 20 s) and same sofa after 4 min (close to flashover)[14]

Figure 2: U.K. sofa, with FR polyurethane foam complying with BS 5852 crib 5 before ignition and after exposure to BS 5852 ignition source 2 (lighter equivalent, 40 s)[14]

using a non-flame retarded (Non FR) foam (purchased in the U.S.) showed similar effects: the U.K. sofa did not ignite while the U.S. sofa ignited with a match equivalent ignition source and the sofa generated enough heat release to cause the compartment in which it was placed (with no other items) to go to flashover (See Figures 1 & 2).[14]

In this connection, it is worth discussing the test method used in California for assessing the flammability of upholstered furniture components, namely TB 117.[15] The test, in effect since 1975, is a mild open flame test on bare foam; polyurethane foam requires flame retardants to pass the test.

Tests conducted on two identical sofas (one using Non FR foam and one using CA TB 117 foam) showed that the sofa with TB 117 foam did not ignite with the ignition source that caused the Non FR foam to ignite quickly; a significantly more severe ignition source was required and a much longer time elapsed before ignition.

Once ignited, both sofas caused the compartment in which they were placed to go to flashover.[14] Recent work showed that when comparing two upholstered furniture mockups (See Figure 3) exposed to a severe ignition source (19 kW for 80 s, as per TB 133), a chair with a fire retarded cotton fabric and TB 117 foam ceased burning when the ignition source was removed while an identical chair with Non FR components was completely consumed.[16] (See *magazine.sfpe.org* for video.) It also was shown that CA TB 117 foam exhibits lower heat release than Non FR foam.[17]

The ultimate proof of the effectiveness of a system for fire safety is whether fire hazard is reduced, as assessed by parameters such as heat release rate, tenability, or time available for escape. A study in 1988[18] demonstrated that flame retardants lower fire hazard.

In that study, five products were constructed containing flame retardants (FR) and not containing flame retardants (NFR) but otherwise substantially identical products. The flame retarded formulations were chosen to

Figure 3: Mockup of single sofa used in comparative fire tests[16]

represent ones that were, at the time, commercially available and in common use, but which were anticipated to represent high quality performance.

In order to analyze the data for all products together, the full set of products were set, separately in an array in a room-corridor arrangement and exposed to a 50 kW burner. The FR products required the use of an auxiliary burner (120 kW) to avoid finding no flame propagation at all. The study showed that proper selection of flame retardants can improve fire and life safety by lowering total heat release (from 750 MJ to 200 MJ), toxic product release (by a factor of three), and mass loss (by more than half), while increasing time available for escape or rescue (from 113 s to 1789 s).

In summary, the FR products were associated with a much lower fire hazard. The authors stated that flame retarded products will not always be effective in lowering fire hazard, normally because the systems chosen are ineffective or the flame retardants are added at insufficient levels.

Note, for example, that the electrical cables were made with polyolefins (known for relatively poor fire performance) and that the polyurethane foam used for the upholstered furniture products was intended to perform better than foam intended for TB 117 use, but probably not as well as a BS 5852 crib 5 foam, and that the same fabric (a typical Non FR nylon) was used for both sets.

*Marcelo M. Hirschler is with GBH International.*

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# HARNESSING THE SUN:

## SOLAR POWER AND FIRE PROTECTION ENGINEERING

**By Casey C. Grant, P.E., FSFPE**

Solar power is one of today's good news stories. This is a rapidly growing segment of the alternative energy market, with new technology that is effectively and efficiently harnessing the energy of the sun.

The ever expanding population of today's world and an almost insatiable craving for energy are strong drivers in the quest for renewable power sources. Improved manufacturing of solar power technologies is greatly enhancing the ability to create and utilize solar power technology, resulting in more efficient and effective system installations. These systems are increasing in size, complexity, and overall number of installations.

Fire protection engineers have an important role to play with the ongoing proliferation of solar power systems. This technology is no different than any other new and innovative approach, and with its clear benefits it also introduces unanticipated and unintended consequences. These consequences are not insurmountable or beyond the ability to manage and handle.

Developments in the solar power field are proliferating at an ever increasing rate, raising new questions about safety and reliability. These developments are necessitating reexamination and modification of codes and standards and other instruments of the existing safety infrastructure. The expertise of fire protection engineers is important for the advancement of solar power technology – to prevent unwanted events before they occur or to mitigate any adverse events once they do occur.

The overall health of the solar power industry is increasingly strong. In the U.S., photovoltaic (PV) systems show strong promise for supporting future electrical energy needs. The year 2012 was a productive year for solar power with the capacity and number of facilities using this equipment significantly increasing.

Multiple marketplace indicators reveal the growing strength of this technology, such as: (i) the capacity of photovoltaic installations increasing by 80 percent in 2012 over the previous year; (ii) for six consecutive years, the annual capacity growth rate exceeded 40 percent; (iii) the compound annual growth rate over the last 10 years was 65 percent; (iv) the total installed capacity of utility installations increased two-and-one-half times; and (v) distributed installations (primarily on residential, commercial, and government buildings) increased by 36 percent.[1]

### THE POWER OF THE SUN

Solar power technology has proliferated in recent years, in part because of improved manufacturing methods that are making this approach realistically affordable and readily available. The three basic means of capturing the sun's energy are: passive solar (i.e., capturing the sun's energy in building design and construction); solar thermal (i.e., sunlight converted to heat); and photovoltaic (sunlight converted to electricity).

Of particular interest from a fire protection engineering perspective are solar thermal and photovoltaic

| Thermal Systems | Photovoltaic Systems |
|---|---|
| • Tripping/Slipping | • Tripping/Slipping |
| • Structural Collapse due to Extra Weight | • Structural Collapse due to Extra Weight |
| • Flame Spread | • Flame Spread |
| • Inhalation Exposure | • Inhalation Exposure |
| • *Hot Fluid Scalds* | • *Hot Fluid Scalds* |
| | • *Battery Hazards* |

Figure 1: Primary Hazards of Solar Power Systems[3]

systems. Solar thermal systems are those involving the heating of fluids in a circulating loop system, and certain solar thermal systems can add appreciable weight load to a structure. They also can introduce general hazards to emergency responders similar to other building systems, such as rooftop tripping or scalds from hot liquids. For all rooftop systems, consideration needs to be given to maintaining full access by fire fighters on the roof and on other sections of a building where they operate during an emergency situation.

Photovoltaic systems are different from solar thermal systems in that they directly convert sunlight into electrical energy. These systems share similar hazards with solar thermal systems, though with the additional consideration that photovoltaic panels are electrically "on" when exposed to sunshine or other light.

Power isolation during an emergency is a technical challenge; full and complete power shutdown is normally not a simple option when exposed to sunshine. Further, lighting other than sunlight has been shown to be sufficient to cause harmful electrical shock.[2] An additional complication involves systems equipped with battery storage, which continue to maintain current throughout the system when sunshine is not present.

The challenge of photovoltaic power isolation is, however, presently being addressed by

new innovative electrical system approaches, such as module level electronics that can provide electrical isolation on the level of the solar cells, modules, or panels. While these approaches demonstrate significant promise for new installations, emergency responders lack widespread knowledge of which systems include such types of isolation technology. Thus, from their perspective, significant questions remain concerning the ability and time frames for this technology to infiltrate the current inventory of widely installed photovoltaic systems.

Figure 1 illustrates a side-by-side comparison of the primary hazards of solar power systems for emergency responders and others.

## IN SEARCH OF LOSS DATA

To facilitate a review of loss information, structural fires involving solar power systems can be evaluated as one of three basic types depending on the point of ignition. These are: (1) an external exposure fire to a building equipped with a solar power system; (2) a fire originating within a structure from other than the solar system; or (3) a fire originating in the solar power system as the point of ignition.[3]

Detailed loss information to support each of these scenarios is lacking due to the relative newness of this technology and the length of time required to collect credible data. Traditional fire loss statistics, such as NFIRS (National Fire Incident Reporting System) handled by the U.S. Fire Administration and FIDO (Fire Incident Data Organization) administered by the National Fire Protection Association, do not at this time provide the necessary level of detail to distinguish the relatively recent technologies of solar power systems.

There is quantifiable data on the number of structure fires in the U.S. each year. For example, in 2012 there were 480,500 structure fires resulting in 2,470 deaths, 14,700 injuries, and $9.8 billion in direct property loss. Of these fires, residential structures accounted for 381,000 fires, 2,405 deaths, 13,175 injuries, and $7.2 billion in direct property loss.[4] While the actual percentage of overall buildings with solar power systems and those involved with fire is unknown, there is a general expectation of how the data will likely trend in the future. As solar power systems continue to proliferate, the likelihood of them being involved with a structural fire will similarly increase.

Despite the lack of statistical data, several case studies of individual fire events can supplement the understanding of fires involving solar power systems. Several of these fires have exhibited certain noteworthy characteristics, such as an April 2009 fire in Bakersfield, Calif., where the rooftop system was the cause of the fire,[5] a May 2013 fire in LaFarge, Wis., where a fire in the building caused the rooftop photovoltaic system to energize the entire metallic roof during the fire,[6] and a September 2013 fire in Delanco, N.J., with a total loss to a commercial warehouse with a rooftop system of more than 7,000 panels.[7]

## FIRE PROTECTION ENGINEERING CONCERNS

Advanced manufacturing techniques have allowed solar technologies to expand beyond the traditional approach using panels that have been the mainstay for many of today's photovoltaic systems. For example, new photovoltaic fabrics and films can be installed in any orientation (e.g., on a vertical surface).

Once again, this raises questions relating to hazards and their performance in fire, such as how the system components hinder, resist, or contribute to exterior flame spread. Further, new, innovative building products include components such as photovoltaic roofing shingles and tiles, which are not readily obvious to firefighters and others that may need to be aware of their hazards.

The test methods necessary to assure proper performance of solar power system components are currently evolving. The constant introduction of new products and uniqueness of alternative system designs are challenging the current methods of testing. For example, present tests for fire resistance of roofing materials and assemblies may or may not be appropriate with a photovoltaic system installed on top. Further, a question exists concerning the long-term performance of the solar power system, recognizing that it is intended to operate properly and safely throughout its full lifespan with exposure to all intended climatic conditions.

The broader engineering community is asking questions on certain loss characteristics beyond loss from unwanted fire. These questions address considerations such as structural loads, ability to resist high winds, hail impact, and snow loads. These questions are being addressed in a research study conducted by the

Fire Protection Research Foundation to review installation best practices, identify knowledge gaps, and provide an all-hazards assessment.[8]

## EMERGENCY RESPONDER CONCERNS

Buildings and structures equipped with a rooftop solar power system, and in particular a photovoltaic system, are becoming more common. For firefighters, it is not an unimaginable event for any particular fire department to encounter a photovoltaic system when fighting a structure fire.

From the standpoint of emergency responders, photovoltaic systems generally fall into two broad categories: those small enough not to hinder firefighting tactics and strategy, and larger systems that adversely impact their firefighting approach. For relatively small systems, such as those found on single-family residential occupancies, firefighters can typically work around the system and any hazards during their operations. In contrast are systems that cover entire rooftops, leaving little firefighter access, or simply very large systems.

Large photovoltaic systems are thus garnering the attention of emergency responders and fire protection engineers alike. These large systems equate to solar power farms. Solar power farms may be installed at ground level within isolated and secure tracts of land, or they may be installed on the roofs of large commercial buildings. Examples are expansive photovoltaic systems installed on big box stores, where fire-fighting tactics and strategy become problematic.

The general advice typically given to firefighters for large solar power farms (such as those installed at ground level and not on a building) is to treat them the same as any other power generation facility in their jurisdiction. For a conventional power plant, or similar support installation such as an electrical transformer yard or sub-station, the advice to the local fire department has traditionally been to develop robust pre-plans and not enter secured high voltage areas without clear guidance from the power generation plant operators. With large photovoltaic systems appearing on rooftops, this presents a challenge to their normal tactics and strategies for fighting a building fire.

Two helpful research studies on this topic provide information for emergency responders faced with fighting fires in buildings equipped with solar power systems. The first was a study that pulled together background information on this topic.[9] The second was a more comprehensive research effort that provides empirical test clarification of the electrical hazards that photovoltaic systems provide to firefighters.[2]

## SOLAR POWER USE BY THE EMERGENCY RESPONSE COMMUNITY

Certain alternative energy applications are the power source of choice for some emergency management and emergency response applications, and solar power is a leader in this regard. The use of photovoltaic systems

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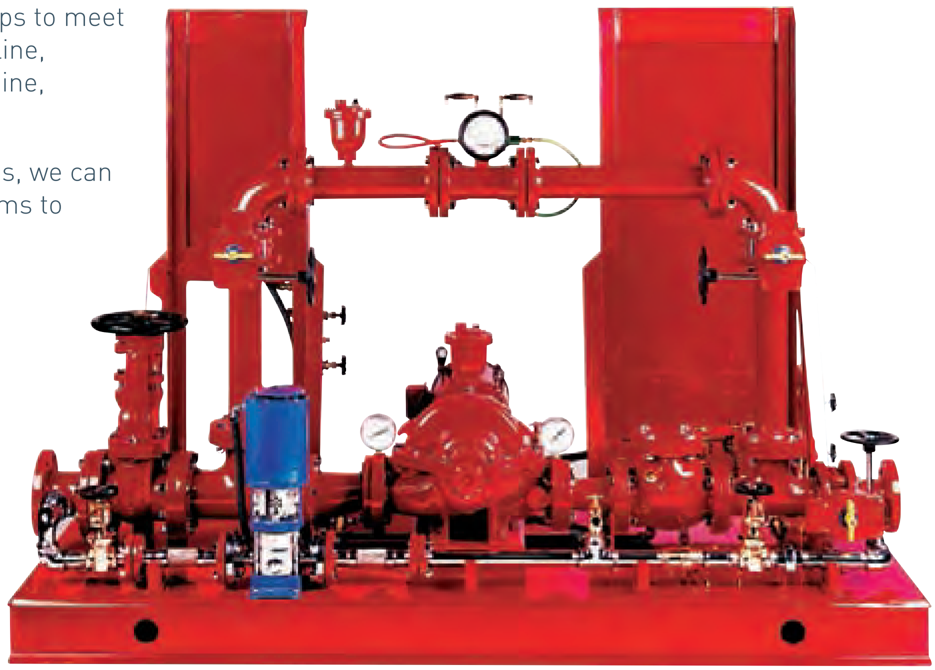

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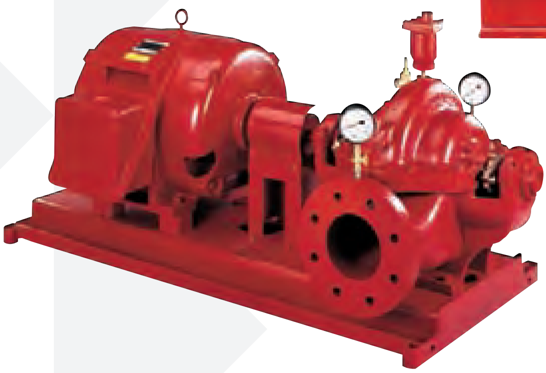

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for emergency preparedness and disaster planning is an obvious application of alternative energy independent of the normal electrical power grid.

Examples of the use of this technology abound as a mainstay for uninterrupted power supplies. Fire stations are an integral part of almost all communities, and these civic structures are possible candidates for solar power system applications. Over the last several decades, multiple examples exist of fire departments that have effectively installed solar power systems on their fire stations.[10,11] One example is an initiative to establish a photovoltaic back-up power supply in Boston for evacuation routes out of the city for critical traffic controls, gas station pumps, and emergency evacuation repeaters.

Fire service facilities in remote areas utilize solar power systems more by necessity than for cost savings or similar reasons. This is not unusual for installations in the urban/wildland interface, where commercial electric power from the local utility may not be available. The U.S. Forest Service has long used photovoltaic systems well in advance of today's popularity.

An intriguing approach in California is the installation of fire apparatus rooftop photovoltaic systems to accommodate deployment over long periods of time (e.g., a wildfire event), providing a dependable electrical power supply for radio operation and other critical electrical equipment. As an example, one fire department that has equipped its fire apparatus in this manner is the San Rafael Fire Department in the California Bay Region.[12]

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


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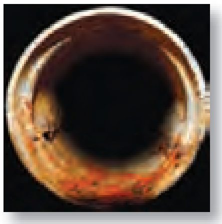
CASE STUDY

POTTER ELECTRIC SIGNAL

# POTTER ELECTRIC STUDIES EFFECTS OF USING NITROGEN GAS IN FIRE SUPPRESSION SYSTEMS

Internal corrosion of dry and pre-action fire suppression systems is a growing concern for the fire sprinkler industry. Corrosion in these systems causes failures resulting in property damage, production downtime, and increased maintenance costs. Additionally, corrosion impacts system hydraulics and reduces the efficiency of fire sprinkler system designs. Historically, dry and pre-action fire suppression systems have used compressed air as the supervisory gas to pressurize their piping. Compressed air, however, contains both oxygen and moisture causing the system piping to corrode. Nitrogen, acting as a supervisory gas in piping, is a well documented inhibitor of corrosion and has been implemented in industries such as gas and oil, pharmaceutical and the marine transit industry. Potter's Corrosion Solutions team performed a yearlong study analyzing the corrosion-inhibiting effects of 98% nitrogen gas when applied to both carbon steel and galvanized steel, in an environment simulating a dry pipe fire sprinkler system. The conclusions are as follows:



1. The use of 98% nitrogen in lieu of compressed air as a supervisory gas reduces corrosion in both galvanized and black steel systems regardless of whether or not trapped water is present. The corrosion reduction potential ranges from 48% to 91% when compared to compressed air.
2. Using 98% nitrogen gas in lieu of compressed air increases the life expectancy of a dry or pre-action system on an average of 5.3 times.
3. The use of galvanized steel instead of black steel results in higher metal loss rates when compared in equivalent environments.
4. The use of 98% nitrogen gas in a relatively dry, black steel environment has the lowest corrosion rate overall.

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CASE STUDY

POTTER ELECTRIC SIGNAL

# NEW POTTER FIRE ALARM SYSTEM HELPS RENOVATE LANDMARK HOTEL

Potter Electric Signal Company recently had products installed in a renovated version of the Crowne Plaza Ponchartrain Hotel in Detroit, Michigan. This Detroit landmark had been neglected for years and the existing fire system was completely outdated. Ownership changes and poor management resulted in a building that was no longer the symbol of class that it once was, and the people of Crowne Plaza, after purchasing the building in 2009, wanted to change that.

Once renovations began, it was clear that the simplest way to update the fire suppression system was to retrofit a new Potter P400 Fire Panel using the existing THHN wiring. It was an easy choice for the contractors to use an addressable panel that could communicate using the existing wiring rather than having to rewire the entire building with all new cable. Due to its retrofitting capabilities, Potter's P400 Fire Panel was chosen for the job.

The benefits of the Potter P400 Fire Panel didn't stop with its retrofitting capabilities; its ease of use and intelligent power capabilities made it an obvious choice as well. The outdated original system had a zone configuration with selective signaling (Floor above/Floor below) and was configured with audio voice evacuation capabilities. There were typically three zones per floor; one for water flow, one for common area or general alarm, and one for the guest room smoke detectors. This zoned configuration made it extremely difficult to determine the exact location of an alarm or trouble on the system. This also made performing the NFPA 72-required smoke detector sensitivity test a disruption to business, as well as time consuming and expensive.

The Potter P400's ability to distribute intelligent power and system expanders throughout the facility, on a simple 4-wire bus, made it very easy to configure the entire 1,290-point system including analog addressable room smoke detectors and sounder bases. With the analog addressable detectors and sounder bases connected to the Potter P400, the required sensitivity testing can now be easily accomplished by utilizing software from the main control panel. The Crowne Plaza Ponchartrain Detroit was opened for business on July 17, 2013 and has been successfully operating since.

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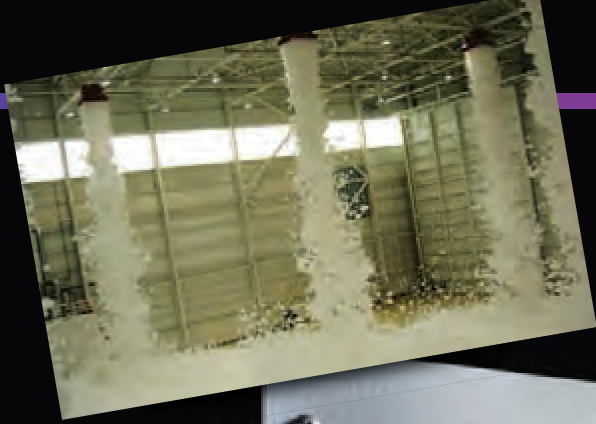
# The Problem: False Alarms



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CASE STUDY

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- Cost effective and environmentally safe replacement of Halon systems.
- 45-100% higher pressure capabilities than competitive systems for maximum design flexibility.
- By enabling longer piping networks, supply tanks can be moved outside the protected area, freeing up valuable IT floor space.
- Utilizes same piping as standard 360 psi systems.
- No additional Nitrogen tanks are required.
- Selector valves provide capability of protecting multiple IT rooms using a shared agent supply.
- cULus Listed and FM Approved.

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CASE STUDY

WHEATLAND TUBE

# KNOW THE RISKS ASSOCIATED WITH CPVC

The CPVC compatibility rules change constantly. But 100% steel remains 100% compatible with everything. From certification changes to safety risks, there are plenty of reasons to avoid CPVC and install 100% steel in your fire sprinkler systems. Wheatland Tube believes that knowing the facts is the best way to protect against undue liability and system failures.

Risk #1: Material compatibility issues are extremely difficult (if not impossible) to control. Exposure of CPVC to incompatible materials – even as basic as cologne – can cause environmental stress cracking (ESC), leaks and system failure during a fire. And because the list of incompatible materials keeps expanding, it's quite possible that a substance may be deemed incompatible immediately after the system is installed. Over time, this issue could increase costs to insure contractor work and the building.

Risk #2: Improper physical contact can never be fully prevented. Seemingly harmless actions, such as resting a datacomm line on CPVC, can cause system failure years later. But how can you prevent other workers, owners or occupants from doing these things? The risk of improper physical contact poses a threat throughout the CPVC system's life – beyond anyone's control.

Risk #3: Installing CPVC incorrectly can have serious consequences. Stringent guidelines must be followed when installing CPVC. Because the guidelines are extremely complex and continually evolve, the installer must commit to ongoing education and re-certification in order to avoid making installation mistakes such as:

- Incorrectly handling the product with hands or equipment containing residues of incompatible substances
- Installing in too-low temperatures
- Using too much, too little or the incorrect adhesive
- Applying the incorrect antifreeze
- Incorrect pipe support spacing
- No allowance for thermal expansion
- Forming connections that incorporate incompatible gaskets, steel piping coatings, pipe dope, Teflon® products, lubricants and more

**The assurance of 100% steel systems**

Many of the risks associated with CPVC are fully eliminated with 100% steel fire sprinkler systems. Installing 100% steel systems guarantees total compatibility, and you can rest assured that your fire sprinkler system will perform. Download the full briefing at *wheatland.com/knowtherisks*.

Wheatland Tube
A JMC STEEL GROUP

**Wheatland Tube**
700 South Dock Street
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## SFPE Job Board

**The Society of Fire Protection Engineers and Fire Protection Engineering magazine are pleased to offer an online Job Board featuring career opportunities in fire protection engineering.**

*jobs.sfpe.org* is designed for communicating the availability of employment opportunities in the fire protection engineering market. This highly-targeted job board is ideal both for those seeking to fill positions and those looking for employment opportunities in fire protection engineering.

**Job categories include:**

- **Consulting**
- **Government**
- **Insurance**
- **Research & Testing**
- **Fire Equipment Manufacturing & Installation**
- **Education**

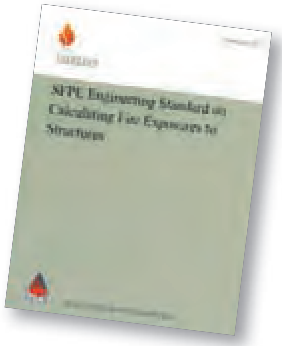
The SFPE job board is promoted in each *Emerging Trends* newsletter, on the *magazine.sfpe.org* website, and through the SFPE LinkedIn group. Whether you're looking to make a career move, or you need to fill a fire protection engineer opening, jobs.sfpe.org is just a click away.

**SFPE Corporate 100 members receive a $100 discount off of each job post, and Corporate 100 job posts are featured at the top of the job listings. Please contact Carol Yachanin for your custom coupon code: carol.yachanin@penton.com.**

# IS YOUR BOOKSHELF UP-TO-DATE?

***Visit www.sfpe.org/bookstore***

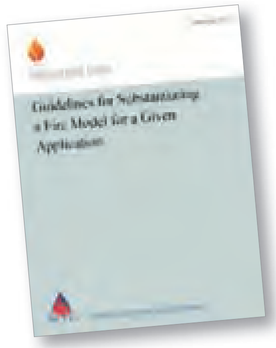
## SFPE Engineering Standard on Calculating Fire Exposures to Structures



Performance-based design of structural fire resistance entails three steps: (1) determination of the fire exposure to the structure, (2) calculation of the thermal response of the structure to the fire exposure, and (3) production of the structural response. This standard provides methods for the first of these steps. It also addresses fully developed fire exposures, which include fully developed fires within an enclosure and localized fires that are not affected by an enclosure. Fires within an enclosure are considered to be spatially uniform, while local fire exposures are not. Topics covered in this standard include determining whether a fire exposure should be considered as a local fire or an enclosure fire, prediction of fire exposures within an enclosure, prediction of heat fluxes from local fires, and documentation of the analysis. An extensive commentary provides background and guidance for the requirements in the standard.

SFPE Member Price: $58 plus P&H
Non-Member Price: $161 plus P&H

## Engineering Guide to Substantiating a Fire Model for a Given Application



The Engineering Guide to Substantiating a Fire Model for a Given Application provides a framework for determining and documenting the suitability of a fire model for use in a specific application. The framework in the guide is applicable to all types of fire models, ranging from algebraic calculations to zone or lumped parameter models to CFD or field models.

The guide addresses:

- Definition of the problem that is intended to be solved using modeling
- Selection of a candidate model
- Model verification and validation
- Uncertainty analysis

SFPE Member Price: $58 plus P&H
Non-Member Price: $161 plus P&H

## SFPE Reference/Answer Manual for the P.E. Exam in FPE, 4th Edition

The new 4th Edition of SFPE's Principles and Practice of Engineering (PE) Examination in Fire Protection Engineering covers all of the technical subjects on the National Council of Examiners for Engineering and Surveying exam specification. The Reference Manual includes sample exercises on concepts that may be encountered in the PE exam. Also included are objectively scored timed sample problems that are equivalent to PE exam problems in length and difficulty. The answers to all of these exercises and problems are published in a companion answer manual.

SFPE Member Price: $204 plus P&H
Non-Member Price: $507 plus P&H

# RESOURCES

## UPCOMING EVENTS

**September 8–10, 2014**
2014 Fire and Evacuation Modeling Technical Conference (FEMTC)
Gaithersburg, MD, USA
**Info: www.thunderheadeng.com/femtc-2014**

**October 1–2, 2014**
FIVE 2014: 3rd International Conference on Fires in Vehicles
Berlin, Germany
**Info: www.firesinvehicles.com**

**October 12–17, 2014**
SFPE Annual Meeting – Professional Development Conference & Exhibition
Long Beach, CA, USA
**Info: www.sfpe.org**

**October 22–23, 2014**
14th International Water Mist Conference
Istanbul, Turkey
**Info: www.iwma.net**

**Nov. 10–12, 2014**
10th International Conference on Performance-Based Codes and Fire Safety Design Methods
Gold Coast, QLD, AUS
**Info: www.sfpe.org**

**June 22–25, 2015**
NFPA Conference & Expo
Chicago, IL, USA
**Info: www.nfpa.org**

**September 28–30, 2015**
6th International Symposium Human Behaviour in Fire 2015
Cambridge, UK
**Info: www.intersciencecomms.co.uk**

# BRAINTEASER [ Problem / Solution ]

## Problem

**In this problem, x is an integer, and $9 < x^2 < 99$. What is the largest possible value of x minus the smallest possible value of x?**

## Solution to Last Issue's Brainteaser

A woman purchased four items from a store. She noticed that the product of the prices of the four items was the same as the sum of the prices of the four items. If three of the items cost \$1.50, \$3.00 and \$4.00, what was the cost of the fourth item?

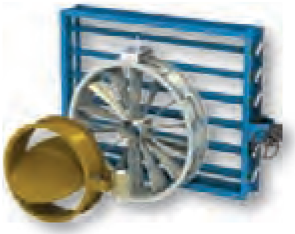
If the price of the fourth item is $x$, then:

$$\$1.50 + \$3.00 + \$4.00 + x = \$1.50 \times \$3.00 \times \$4.00 \times x$$

So, $\$8.50 + x = 18x$.

Solving yields $x = \$0.50$.

## Industrial Dampers



Greenheck industrial dampers are heavy-duty, flanged-style frame dampers with various blade styles and pressure classes designed to control airflow and provide shut-off in HVAC and industrial process control systems. Built under an ISO9001-2008 Quality Assurance Program and ideal for nuclear, tunnel, bio lab, and power generation applications, Greenheck's complete line of industrial dampers includes control, backdraft and pressure relief, UL-rated smoke, tunnel transit, blast, tornado, and bubble tight dampers.

**www.greenheck.com**
– Greenheck

## Phone-Based Mass Notification

Fire-Lite Alarms by Honeywell has released the Remote Telephone Zone Module (RTZM), designed to provide authorized users remote access to send out emergency notifications through a facility's Emergency Command Center (ECC) system via any phone. Secure system access and simple menu options ensure facility managers and security officials get appropriate emergency information and instructions to building occupants quickly – in real-time.

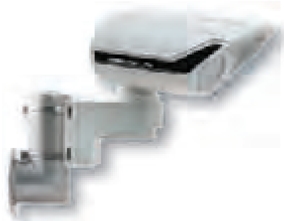
**www.firelite-ecc.com**
– Fire-Lite Alarms

## Touchscreen Fire Alarm Control Panels

The S3 Series Intelligent Fire Alarm Control Panel applies touchscreen technology to offer a simple, intuitive solution for small- to mid-sized fire alarm applications. Five programmable buttons enable a person with little or no experience to understand the cause of the alarm and how to operate the system in response to an emergency. In standalone or network configurations, the S3 Series complies with most fire alarm application requirements.

**www.gamewell-fci.com**
– Gamewell-FCI

## Security Detection



ADPRO by Xtralis perimeter, multi-site, and enterprise security solutions are suitable for a wide range of industries and applications. The perimeter PRO-E Passive Infrared detectors are capable of detecting human targets by sensing temperature differences between them and the background at distances over 700 feet. When combined with the FastTrace 2/2E Remotely Managed Multi-service Gateway and i-LIDS approved IntrusionTrace, these solutions deliver detection, reliability, and flexible integration while introducing the new concept of field-programmability to the security market.

**www.xtralis.com**
– Xtralis

## Wire to Fiber Converter

Silent Knight has released the SK-F485C Wire to Fiber Converter, designed to allow new and existing Silent Knight systems to significantly increase wire runs between fire alarm control panels and power supplies, while providing a major boost in surge protection. The new fiber converter allows one Intelliknight™ addressable fire alarm control panel from Silent Knight to be extended over fiber-optic cable to protect multiple buildings while severely limiting the risk of damages from electrical surges. UL-listed and sold over-the-counter at Security Equipment Wholesalers nationwide.

**www.silentknight.com**
– Silent Knight

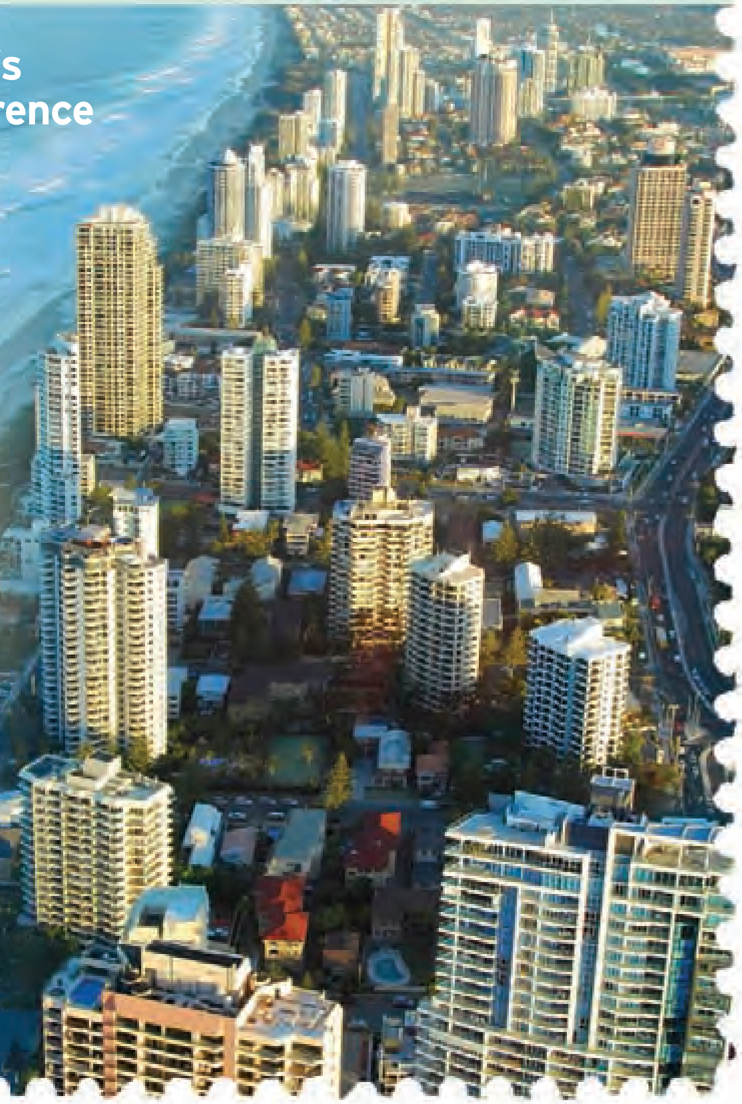
## AC Video Power Supplies

Honeywell Power has released a new line of UL listed AC Video system supplies that provide 24VAC of constant power to support systems of any size. Equipped with up to 16 output circuits and made to overcome common voltage drop issues, the new AC Video Power Supplies are ideal for systems with longer wire runs and more cameras. The output circuits include LEDs that illuminate when power is present and extinguish when a short condition is detected.

**www.honeywellpower.com**
– Honeywell Power

# PUSHING THE BOUNDARIES

## 10TH INTERNATIONAL CONFERENCE ON PERFORMANCE-BASED CODES AND FIRE SAFETY DESIGN METHODS



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**AUSTRALIA**

**NOV 10-12 | 2014**

**Register online at www.sfpe.org before Friday, October 10, 2014 to receive discounted fee.**

If you are interested in becoming an exhibitor or sponsor for this year's international conference, contact Julie Gordon at jgordon@sfpe.org.

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# Fire Protection Engineering

*Fire Protection Engineering* (ISSN 1524-900X) is published quarterly by the Society of Fire Protection Engineers (SFPE). The mission of *Fire Protection Engineering* is to advance the practice of fire protection engineering and to raise its visibility by providing information to fire protection engineers and allied professionals. The opinions and positions stated are the authors' and do not necessarily reflect those of SFPE.

# Kidde Fire Systems

## ECS Clean Agent Suppression Systems

## Proven, Effective and Reliable...


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With more than 90 years in the industry, Kidde Fire Systems is the leader in the Clean Agent special hazards market. Kidde's quality products and services can be found globally with distributors located in major cities around the world and a network, of more than 300, throughout the United States and Canada.

### Kidde ECS Systems Feature:

***Rapid-Response.*** In seconds — not minutes, the ECS System discharges Clean Agent suppressant into the hazard area providing the fastest fire protection available. This results in less damage, fewer repair costs and reduced downtime.

***Damage-Free.*** Clean Agent suppressants allow virtually immediate return to "business as usual" without the interruption of a costly clean-up and the expense of damage to assets from suppressant residue.

***People-Safe.*** Our ECS System is safe for use in occupied areas. Clean Agents do not impair breathing or obscure vision in an emergency situation — providing an added measure of safety for personnel.

***The Right Fire Protection Company.*** The Kidde integrated approach offers a complete fire protection system that is designed, manufactured, installed and serviced by one company. From refineries to commercial kitchens... it's likely that Kidde Fire Systems is on the job.

*www.kiddefiresystems.com*

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**FIRE PROTECTION FOR PEOPLE AND PROPERTY**