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Key fire safety design issues for rail transit systems.

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

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From the TECHNICAL DIRECTOR



Book Review Epic Content Marketing

his is the first time that a book review has appeared in the Technical Director's column. And, the review is of a book that has nothing to do with fire protection engineering. So, why review this book? For one, the book describes a fundamental change in modern marketing techniques, and many fire protection engineers are involved in marketing in some way.

The book was written by a former managing editor of Fire Protection Engineering magazine (who made a cameo appearance on the cover of the Spring 2000 issue). And, Fire Protection Engineering magazine is highlighted in the book as a successful content marketing case study.

Epic Content Marketing by Joe Pulizzi defines "content marketing" as "the marketing and business process for creating and distributing valuable and compelling content to attract, acquire, and engage a clearly defined and understood target audience – with the objective of driving profitable customer action." What's "content"? Think technical information. Content marketing is a way of showing customers and potential customers that you know how to solve their problems.

The book is divided into five parts. Part I provides an overview of content marketing. It provides definitions (including the one quoted in the previous paragraph) and a history. Content marketing is not new; when a food ingredient manufacturer provides recipes on their packaging, that's an example of content marketing. This solves the buyer's problem (what to prepare) while selling more of the product (if the recipe is good, they'll buy more). Part I also presents a business case for content marketing, which is essentially to attract and retain customers. Lastly, a business case is provided, which is to earn customers' trust as a valued source of solutions to their problems.

Part II describes finding a content niche and strategy. The first chapter in this section notes that there is no content marketing silver bullet, and there is no right or wrong way to approach content marketing. There is only more right or less right. The next chapter defines the six principles of "epic" content marketing: filling a need, consistency, being human, having a point of view, avoiding sales speak, and being the best of the breed. Helping to discover and set content marketing goals (e.g., brand awareness, lead conversion and nurturing, customer conversion, customer service, customer retention, upsell) is also addressed in this section.

Part II goes on to describe audience personas, which are characterizations of the types of people to whom the content is targeted (e.g., architect, facility manager, developer, attorney, etc.). The next chapter defines the engagement cycle, recognizing that potential customers may want different types of information depending on where they are in their buying process. The penultimate chapter in Part II assists readers with defining their content niche, while the final chapter pertains to writing a content marketing mission statement.

Part III of the book provides information on managing the content process. It starts with building an editorial calendar, which is a planning document for what content will be published when. The next chapter provides guidance on managing the content creation process – whether the content is created internally or outsourced. Content types are described, such as blogs, videos, e-newsletters, and even magazine articles! Additional chapters provide suggestions on repurposing existing content and getting employees to contribute new content. Part III closes with chapters on selecting online content platforms and creating an action plan.

Part IV explains the need for and creation of a marketing story – or helping people find content that might be of interest to them. One could create great (or, as the book says, "epic") content, but if potential customers don't find it, it's of no use. The first chapter describes how social media can be leveraged to distribute content. Alternative promotion strategies are also addressed, including search engine optimization. The final chapter guides readers on how to leverage social influencers – people that already have a large online following within the targeted audience.

Lastly, Part V is about making content work. The first chapter addresses measuring the success of content marketing and the return on investment. The book closes with a chapter that summarizes content marketing success stories, and uses *Fire Protection Engineering* magazine as a strong example.

Content marketing serves to educate the reader, and a knowledgeable customer is a better customer. Since in most engagements, fire protection engineers have expertise that their clients do not have, fire protection engineers generally educate throughout the business engagement.

Busy people want to know who can solve their problems and give them the information they need. A lot of people just want to trust an expert to take care of them. So, content marketing is a tool to create action with that very busy prospect who just wants to trust the expert vs. figuring it out themselves.

Since the book provides a link for Fire Protection Engineering magazine – we will return the favor – http://bitly.com/epic-fpe.

Morgan J. Hurley, P.E., FSFPE
Technical Director

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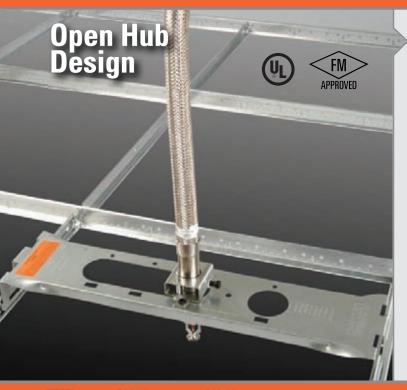
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By Marjorie M. Cooke

In April 1990, the Scandinavian Star, a large passenger ship operating in Europe, caught on fire with a loss of 158 lives. Not since the 1960s had there been such high loss of life - which begged the question, "How could a ship built to the latest standards have resulted in this catastrophe?"

The investigation into the fire determined that many had died trying to find their way out in smoke filled corridors that led them to 'dead ends'. Those who survived had relayed that the smoke alarms did not alert them to the emergency quickly enough to properly evacuate them to safety. The results of the investigation were submitted to a working group to determine what could be done to upgrade the requirements for existing ships. This would be a major change to the traditional way of only applying new requirements to new ships. There was a long history of opposing retroactive requirements. When retroactive fire safety requirements had been previously imposed by the international community, some passenger liners had been put out of business, most notably the Queen Mary. It was still a very sore memory.

Further, those who had the power to make changes to the requirements did not agree as to what changes should be made or what was wise, both technically as well as politically feasible. The strategy was to start the discussion with the 'easy' issues. Changing the design of new ships to eliminate 'dead end' corridors was readily accepted for all new ships. But, eliminating them on existing ships was not financially feasible. 'Low-location lighting' (LLL) was proposed as a possible solution. Those speaking on behalf of their governments did not all have experience with these systems. Visits were arranged to testing facilities with smoke filled corridors so representatives could experience the synthetic fear of finding a way out in a simulated smoke filled corridor. Agreement was reached that retrofitting LLL on existing ships could help prevent passengers from entering dead end corridors. That single initial agreement opened the door to considering other retroactive requirements.

Fire safety professionals were overwhelmingly in support of retrofitting both smoke detectors and sprinklers on all passenger ships in order to save lives. The regulations at that time required either sprinklers or smoke detectors, but not both. A requirement to retrofit sprinklers and smoke detectors on every large passenger ship was destined to be an uphill fight. Ships are designed to keep water on the outside of the hull, so sprinklers struck a particular uneasiness for some because they were not familiar with modern systems. They envisioned unnecessary water

damage to a large, luxurious cruise ship. However, there was some support from within the cruise ship industry. A few forward-thinking companies had recognized the risk of fires and had installed sprinklers. They acknowledged having had fires, but the fires remained very small due to the installed sprinkler system. The fires had not resulted in the need for a major response, but rather they could be dealt with by 'cleaning them up with a mop'. More were now willing to accept requiring both smoke detectors and sprinklers on new ships, but not retroactively imposing them on existing ones.

The greatest opposition, of course, was the added cost of retrofitting these systems. The cruise ship owners were opposed to this retroactive application, especially since it would substantially increase cost. As final negotiations were taking place, it became evident that a way had to be found to bring all, even those originally opposed, into agreement. Fire protection professionals were tapped to provide real-world costs for retrofitting sprinkler systems on board a large passenger ship. The costs were compared to those of shipyard costs for interior refurbishment. The costs for the sprinkler systems were comparable to those for installing new carpet. These figures were presented to representatives of the cruise ship industry and they confirmed them. It took this final confirmation and official submittals to the other administrations to gain the necessary support for passage of the retroactive amendments.

In December 1992, IMO adopted the amendments applicable to both new and existing ships.² These modern systems continue to provide fire safety aboard passenger ships for those who choose to see the world by sea as well as those who operate and serve them - professional mariners and crews. It took a combination of technical expertise and cooperation on the part of a large number of individuals and organizations to achieve a result that increased the level of safety while preserving the intact structure and reducing long-term costs.

Marjorie Murtagh Cooke is with Robson Forensic, Inc.

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- Schei, T. (ed.) "The Scandinavian Star Disaster of 7 April 1990: Report of the Committee Appointed by Royal Decrees of 20 April and 4 May 1990." Norwegian Official Reports, Oslo, Norway 1991.
- International Convention for the Safety of Life at Sea, 1974:1992 Amendments, International Maritime Organization, London, 1992.



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FLASHPOINTS > Fire Protection Industry News

WPI Researchers Receive Grant to Examine Green Building Fire Safety

A team of fire protection engineering researchers at Worcester Polytechnic Institute (WPI) is investigating the fire safety risks associated with green construction. The WPI team is working with a \$1 million grant from the U.S. Department of Homeland Security, which will fund a three-year project aimed at identifying and reducing the potential for firefighter and occupant injuries and deaths that could be associated with unanticipated hazards posed by green building elements.

This research will begin to quantify the fire hazards and risks, identify ways to mitigate those hazards and risks, and prepare the fire service to fight fires in buildings with green features and elements. These are all needs identified by the National Association of State Fire Marshals, the Fire Protection Research Foundation, and the National Fire Service Research Agenda, which are interested in understanding and addressing how the challenges of green or sustainable buildings impact firefighter safety.

In 2012, Brian Meacham, associate professor of fire protection engineering at WPI, co-authored "Fire Safety Challenges of Green Buildings," a report commissioned by the Fire Protection Research Foundation. The new project, funded by Homeland Security, will enable Meacham, who is principal investigator, to explore further some of the potential risks and hazards identified in the report.

For more information, go to www.wpi.edu.

New Paper Focuses on System Sprinkler Effectiveness

Fire Science Reviews announces the availability of a new online report titled, "A Review of Sprinkler System Effectiveness Studies."

Prior to writing the report, the authors compiled and tabulated sprinkler system component data and effectiveness estimates from system-based studies. In the report, they compare the merits of two approaches: component-based approaches using a fault tree of similar method, and system-based approaches using fire incident data where sprinklers were present.

The report includes recommendations for using the data for design purposes, including considerations for uncertainty and using a hybrid system/component approach for specific sprinkler system comparisons; the recommendations provide input on the reliability of systems in the development of performance-based fire safety design methods.

The report can be found at http://firesciencereviews.com/content/2/1/6.



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

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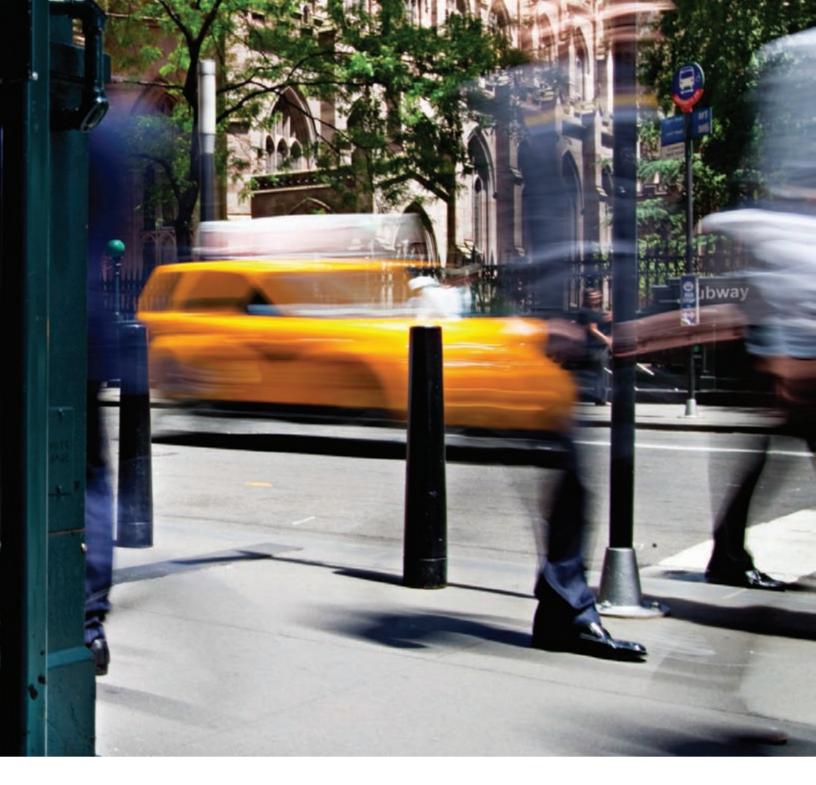
Fixed-Guideway Transit & Passenger Rail Systems Fire Safety: An Overview By John F. Devlin, P.E. Elevator to A G N B at 3 St

ixed guideway transit and passenger rail systems are efficient means of transporting a large population of passengers. New systems, including urban light rail and heavy rail commuter trains and inter-city passenger rail systems, are under design and construction in many cities and territories throughout the world. Subway systems in Boston,

New York, London, and Paris have been in continuous operation for more than 100 years. Codified fire safety standards specific to fixed guideway transit and passenger rail system are less than 40 years old.

NFPA 130, Standard for Fixed Guideway and Transit Systems, is an international fire safety standard widely used for design of transit systems. First published in 1983,

it applies a holistic approach to life safety from fire and fire protection requirements to include stations, trainway, emergency ventilation systems, vehicles, emergency procedures, communications, and control systems. NFPA 130 regulates, through design selection, type of materials, material fire safety properties (flammability, combustibility, and smoke production), and



potential fire hazards. These regulations are intended to control and/or limit the likelihood of a fire's occurrence, its growth rate, and severity. NFPA 130 applies to new systems, to extensions of existing systems, to new rolling stock, and to retrofitting existing rolling stock and equipment. The portion of the standard dealing with emergency procedures applies to new and existing systems.

VEHICLE FIRE SAFETY

Passenger vehicles (rolling stock) represent the greatest single combustible fuel load within a fixed guideway and passenger rail transit system. Several significant fires in the 1970s involving fixed guideway transit systems, including the BART trans-bay tunnel fire, revealed the magnitude of risk to passenger life

safety in a fire event.² Consequent fire hazard evaluation, full-scale fire testing, and the fire hardening program of the BART passenger vehicles and studies performed by U.S. federal government agencies on transit vehicle fire safety influenced the basis of the vehicle fire safety strategy in NFPA 130.³, 4, 5, 6

NFPA 130 attempts to achieve its fire safety goal by focusing on both

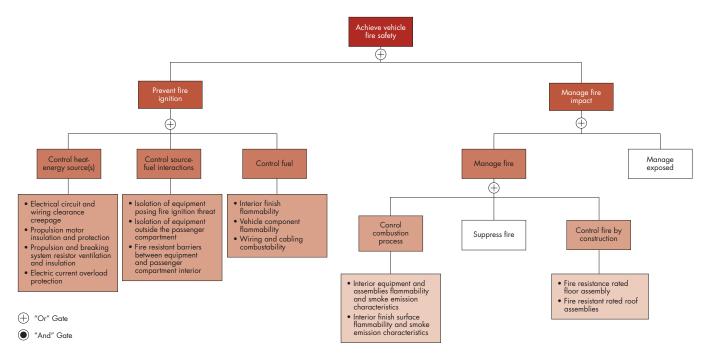
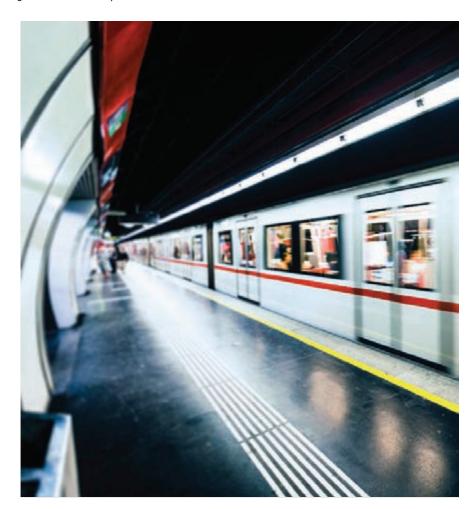


Figure 1: NFPA 130 strategy to achieving passenger vehicle fire safety

preventing fire ignition and managing the fire impact within passenger vehicles. For electric propulsion vehicles, performance requirements apply to controlling heat-energy sources from electrical components and wiring to minimize the potential of electrical component and wiring failure contributing to fire ignition. Figure 1 illustrates the relationship of the various NFPA 130 requirements associated with vehicle fire safety performance as viewed in the context of NFPA 550, Fire Safety Concepts Tree.⁷

Insulation, isolation, and electric power control are the primary methods prescribed by NFPA 130 as a means to prevent fire ignition by minimizing the potential of equipment or component failure as a contributor to fire. Segregating electrical equipment (including the propulsion system and propulsion and breaking system resistors and equipment with a high energy heat source potential) from the vehicle's exterior and separating the equipment from the passenger compartment via fire-resistance-rated floor and roof assemblies serves to





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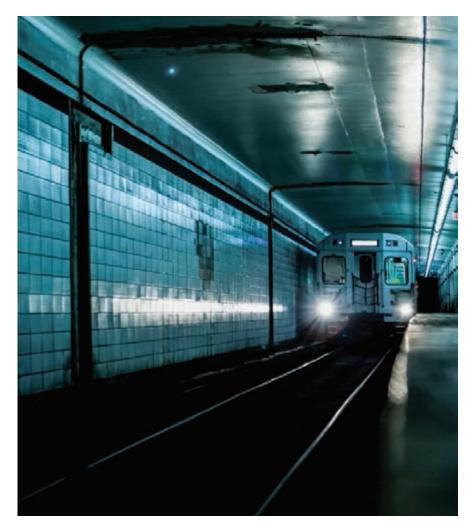
manage the fire impact by inhibiting fire spread beyond the failed component or piece of equipment.

The passenger vehicle interior has a significant influence on overall vehicle fire safety. It is possible to mitigate potential fire growth and spread from likely ignition sources by regulating the flammability, combustibility, and flame spread of the vehicle's interior, including seating, flooring, wall and ceiling lining materials, and vehicle insulation. Internal event ignition sources, including electrical failure, and external event ignition sources such as a burning bag of trash with paper and plastic, each pose differing levels of point-source ignition heat flux on the vehicle's interior. Full-scale fire tests evaluating the vehicle interior's fire safety performance when exposed to various probable internal and external fire scenario events provide the best understanding of the expected fire performance.

Full-scale testing is cost prohibitive and rarely performed during the design, specification, and procurement process of new passenger vehicles. Fire test standards adopted by NFPA 130 are individual material tests and apply point-ignition heat fluxes for both internal and external event scenarios. A reasonable degree of vehicle fire safety is achieved when all materials and assemblies comply with the performance criteria prescribed by NFPA 130.

NFPA 130 allows the use of an optional fire hazard analysis process to establish the fire performance of vehicle materials and assemblies in the context of actual use in lieu of compliance with the prescriptive requirements for equipment arrangement, flammability and smoke emission, fire performance, and electrical fire safety.

The fire hazard analysis is designed to understand the role of materials, geometry, and other factors in the development of fire within the vehicle that might not otherwise be ascertained through individual material



tests. The fire hazards analysis process is intended to achieve the fire safety goals and objectives established by NFPA 130. These goals and objectives are to provide an environment that is safe from fire and similar emergencies for the passengers not intimate with the initial fire development and maximize the survivability of passengers intimate with the initial fire development – and to protect occupants who are not intimate with the initial fire development for the time needed to evacuate, relocate, or defend-in-place during a fire or fire-related emergency.

TRAINWAY FIRE SAFETY

The trainway typically serves as the means of egress for passengers in the event it becomes necessary to evacuate a train. In an enclosed trainway/tunnel, the means of egress includes enclosed exits and cross passageways that serve as points of safety. The maximum distance between exits and cross passageways permitted by NFPA 130 is 2,500 ft. (762m) and 800 ft. (244m), respectively. In an urban transit system or intercity passenger rail system, the train population during peak period can be as many as 1,200 passengers. The expected required safe egress time to evacuate all passengers from the tunnel into an exit or cross passage can be one hour or longer. Accordingly, evacuation of passengers via trainway is considered the last option in a fire and emergency event.

Figure 2 illustrates the relationship of the NFPA 130 requirements

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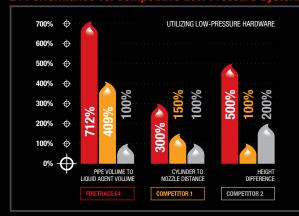




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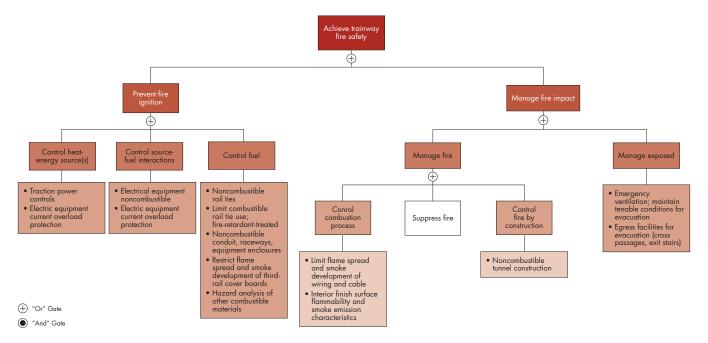


Figure 2: NFPA 130 strategy to achieving trainway fire safety

associated with trainway fire safety performance. Trainway fire safety is achieved by preventing fire ignition and managing fire impact. NFPA 130 restricts combustible components in the enclosed trainway to minimize its potential contribution to the fire load and creation of potential fire hazards.

Rail ties and walking surfaces are required to be noncombustible. Combustible contents are limited to essential equipment including cover boards serving to protect exposure to traction power contact (third) rail and wood rail ties at switches and crossovers. Cover boards are required to comply with maximum flame spread, smoke development, and peak heat release rates in accordance with specific fire test standards.

Wooden rail ties are required to be fire-retardant-treated. Power, communication, and signal wiring and cables installed within the trainway are required to be fire-resistant and have reduced smoke emissions. All conductors, except radio antennas, are required to be in armor sheaths, conduits, or enclosed raceways, boxes, or cabinets except in ancillary areas.

Ancillary areas are required to be separated from trainway areas by two-hour fire-resistance-rated construction and three-hour-rated construction when within underwater trainway sections.

NFPA 130 requires that an enclosed or tunnel trainway 200 ft. (61m) or more in length be provided with emergency ventilation to maintain a tenable environment along the path of egress from a fire incident. The emergency ventilation system is required to maintain tenable egress conditions for minimum duration of one hour, but not less than the required safe egress time.

STATION FIRE SAFETY

Modern transit station design is a single volume space formed by the passenger platform and contiguous trainway, possible intermediate mezzanine level(s), and continuous connection to the street level above. Modern stations often include extensive use of escalators and elevators for efficient passenger movement.

NFPA 130 station fire strategy is to manage fire impact. Controlling the fire in ancillary spaces by means of fire barriers and automatic sprinkler systems and installation of emergency ventilation in enclosed stations serves to manage the fire and manage the exposed.

The basis of station platform design is the NFPA 130 requirement to evacuate all passengers from the platform in four minutes and to reach a point of safety within six minutes. Escalators are permitted to serve more than half of the required means of egress from a platform and station when, for enclosed stations, at least one enclosed exit stair or exit passageway provides continuous access from the platforms to the public way.

The egress calculation procedure included in NFPA 130 is a simple hydraulic model. For stations with multiple passenger platforms, platforms on multiple levels, or converging egress routes, the use of a more robust model is often necessary to analyze variations that influence the required safe egress time.

In deep-tunnel stations, passenger elevators serve as the primary means of platform access and means of egress. The passenger elevator lobby holding area must be separated from the station platform by a fire barrier having a fire resistance rating of at least one hour but not less than the time required to evacuate the holding area occupant load. When elevators serve as the means of egress, at least one enclosed exit stair must be accessible from and enclosed in the holding area.

In enclosed stations, an emergency ventilation system is required to maintain tenable egress conditions for a minimum of one hour, but not less than the required safe egress time.

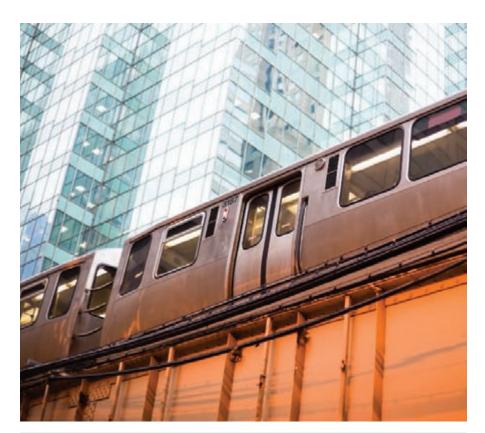
NFPA 130 requirements for station fire safety performance are similar to that of the trainway illustrated in Figure 2.

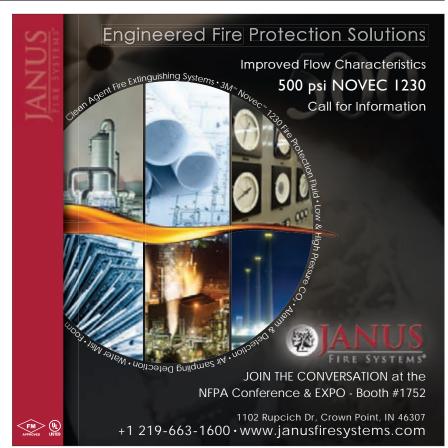
EMERGENCY VENTILATION

The basis for the emergency ventilation system's design is the expected fire severity, including heat release rate and fire smoke release rate produced by the combustible load of a vehicle and any combustible materials that could contribute to the fire load at the incident site. Fire heat release rate, heat release rate profile, peak heat release rate, and decay are significant contributors to the expected fire severity.

Tunnel trainway emergency ventilation systems typically exhaust smoke in one direction along the length of the tunnel while maintaining tenable conditions on the opposite/upstream side of the train. Required airflow rates are a function of the critical velocity to move smoke in one direction while preventing smoke back-layering from occurring. NFPA 130 acknowledges that, depending on the fire location within the train, a portion of the train will be exposed to smoke.

Enclosed station emergency ventilation is typically provided via the tunnel trainway ventilation system. In this design scheme, the station means of egress paths typically serve as a conduit for ventilation make-up





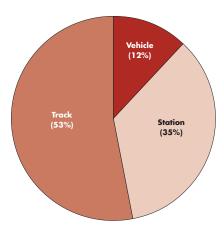


Figure 3: Overall Fire Incident Data Sorted by Fire Location⁸

air, thus maintaining tenable conditions for occupant evacuation. Other design schemes include point-extract ventilation within the station to maintain tenable conditions in the means of egress.

Emergency ventilation is a significant contributor to achieving fire safety in a tunnel trainway and enclosed station during a fire condition. NFPA 130 recognizes that ventilation system reliability and operability are essential and require a reliability analysis of the electrical, mechanical, and supervisory control subsystems. Emergency ventilation fans, their motors, and all related components exposed to the exhaust airflow must be designed to operate at the fan inlet airflow hot temperature condition of not less than 302°F (150°C) for a minimum of one hour, but not less than the required safe egress time.

NFPA 130 emergency ventilation system requirements apply to new fixed guideway transit and passenger rail systems and to extensions of existing systems.

FIRE RISK

Fire incident data obtained from eight of the world's top 12 transit agencies in North America and Europe over the period of 1998 to 2009 revealed that 88 percent of fires occur in the trainway or the station and 12 percent of the reported fires involved the passenger vehicle.8 (See Figure 3) No passenger deaths were reported. None of the vehicle fires reported were fully engulfed in fire. Fire events where the passenger vehicle was fully engulfed in fire, involving passenger vehicles complying with NFPA 130 are rare and extraordinary events.

The average life span of a passenger vehicle is approximately 40 years, and a vehicle will typically undergo complete overhaul near its mid-life. NFPA 130 requires new work and equipment on existing vehicles undergoing overhaul and retrofit to comply with the standard. Transit agencies, associated with the referenced fire incident data, adopt NFPA 130 or enforce fire safety requirements that are similar in scope and performance. These agencies operating vehicle fleets are compliant with at least the early editions of NFPA 130.

Improvements in passenger vehicle material fire safety mitigate the potential for extraordinary fire events. Diligence of transit agencies in maintaining tunnels and stations clear of potential fire hazards and combustible fuel loading lessens the likelihood of

death from fire in transit systems whose tunnels and enclosed stations were constructed without emergency ventilation. Overall passenger risk of death from fire is low in fixed guideway transit systems.

John F. Devlin is with Aon Fire Protection Engineering Corporation.

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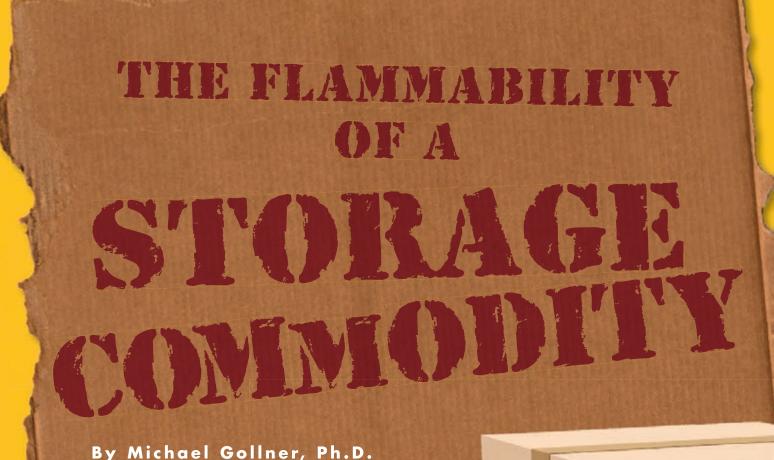
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arehouse fires have long posed a unique challenge to the fire protection engineering community. The rack-storage configuration, while being practical, economical, and efficient, also produces a challenging scenario with high densities of flammable goods stored at great heights over a vast floor space.

The general approach taken to protect warehouse storage configurations has been that of suppression, where commodity classification is used to design the parameters of suppression necessary to contain



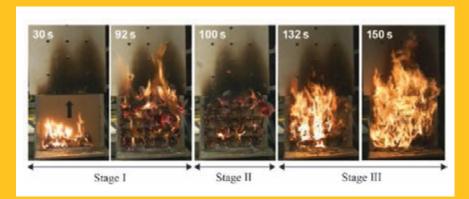


Figure 1: Fire Development Over a Group A Plastic Commodity⁵

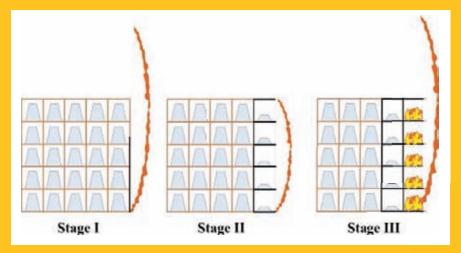


Figure 2: Three Stages of Burning of a Group A Plastic Commodity⁶

or extinguish fires. In commodity classification, full-scale tests on standardized commodities with appropriate fire suppression systems have established acceptable criteria for the protection of stored goods. 1, 2

While implementation and continued development of these standards have greatly reduced the number of warehouse fires, from more than 4,700 a year in 1980 to just 1,200 in 2011, the value of direct property damage has not shown a similar decrease.3 Between 2007 and 2011, storage fires still cost \$16 million per month on average.3

As storage facilities continue to grow larger and taller, the practicality of large-scale testing for all possible scenarios has become increasingly impractical. Some means of determining adequate protection from smaller-scale test results as well as relating known protection schemes to new, diverse commodities should be developed.

Unfortunately, the dimensional and material complexity of realworld storage commodities is a formidable obstacle. A rigorous approach includes computational fluid dynamics checked against fullscale experiments.

In the hopes of systematically reducing the prohibitive costs (actual and computational) associated with this approach, the industry has already established significant momentum in this direction, particularly at FM Global; however, a description of a mixed commodity to use within models has yet to be ascertained.

This study, funded by the SFPE Educational and Scientific Research Foundation, sought to develop a method to ascertain the flammability (including burning rate, flame spread rate, etc.) of a mixed warehouse commodity as a first step towards tackling this problem.

GROUP A PLASTIC TESTS

The classification scheme currently used in the U.S. places commodities into one of seven groups, Classes I-IV for general commodities or Groups A-C for plastic commodities. 1, 2 The Group A plastic commodity represents the greatest "benchmark commodity" fire hazard, consisting of crystallized polystyrene cups placed within a compartmentalized, corrugated cardboard box.

Although more challenging fire hazards exist, such as expanded



meat trays, polyurethane foams, etc., the basis of current commodity classification approaches for plastics is based around this Group A plastic; therefore, it was chosen for this study.4

In testing, the commodity was insulated on all sides except for the front face and ignited at the base, in many ways simulating ignition during an early-stage, rack-storage test. Thermocouples, load cells, cameras, and heat flux gauges provided data that was used to assess flame spread and burning rates of the commodity over time. The mixed commodity was found to progress through three distinct stages of burning, indicated in Figure 1, due to its unique geometry and material distribution. 5, 6

After ignition of the front face of the commodity, flames spread upward along the front face of the box with little involvement of interior material. Therefore, only the properties of corrugated cardboard are necessary to describe the upward flame spread process, described in detail later.

As the front face of the box chars and falls off, it reveals the first inner layer of segregating cardboard and unexpanded polystyrene cups, indicated as Stage I in Figure 2. This first layer of cardboard also pyrolyzes and burns as it is exposed to flames and outside air, contributing to the burning rate; however, the polystyrene cups inside do not heat sufficiently to janite, and

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only begin to soften and melt. The resulting heat-release rate in Stage I of burning increases from 0 to a peak of approximately 25 kW over approximately one minute, with flame heights reaching 1m (twice the height of the commodity), contributing to rapid involvement of additional fuel above the ignited commodity.

Once the first layer of cardboard burns out, not enough heat has been absorbed by the polystyrene cups to ignite them, nor have flames penetrated the second mixed layer of cardboard and cups; therefore, the heat-release rate and flame heights decay. With only smoldering combustion remaining, the commodity transitions to Stage II, where, on average, low heat-release rates of 10 kW and flame heights of 0.5 m provide a probable opportunity for

extinguishment before ignition of the plastic product.

As heat is continually absorbed by the polystyrene cups in Stage II, they eventually absorb sufficient heat to ignite, significantly increasing the heat-release rate of the overall commodity, with a peak of 40-50 kW and observed flame heights of 1-1.5 m, shown in Figure 1 and Figure 2 as

One parameter of significance for suppression applications in warehouses is the time to sprinkler activation, which largely depends on early-stage flame spread and heat-release rates.

Stage III. This stage continues as layer after layer of cups is exposed to air, illustrated in Figure 2. The segregated nature of the commodity allows burning to progress in a relatively steady manner, involving cardboard and plastic as earlier-ignited layers burn out.

The segregated nature of the commodity, illustrated in Figure 2, aides not only in a controlled transition between stages for the commodity, but also in access to fuel, providing a somewhat averaged behavior within each of the three stages, pointing to a potential means of simplifying the analysis of the mixed burning of the commodity. In Stage I, for instance, combustion is likely to be described by the geometry and properties of cardboard alone, while in Stage III, it is the burning rate and properties of the plastics, now melted and dripping while burning, that control the burning rate.

NONDIMENSIONAL APPROACH

One objective of this work was to develop an approach that was appropriate to measure small-scale fire behavior (at the scale of one or more commodity packages) up to behavior in large rack-storage tests. This significant challenge was not accomplished under this short-duration project; however, some advancement and probable concepts were presented.

The B-number, which appears as a boundary condition at the fuel surface in the classical Emmon's solution for forced-flow flames over a condensed fuel surface, was suggested as a possible means to present the burning behavior of a commodity package and serve as a relatively flammable comparison tool. This dimensionless parameter is a ratio that compares a summation of the various impetuses (e.g., heat of combustion) for burning to a summation of the various resistances (e.g., heat of vaporization) to



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the process. Originally a purely thermodynamic quantity, its definition can be extended to encompass effects of different heat-transfer processes, including radiative transport.^{8, 9}

The unexpected finding of three stages with distinctive burning behaviors added complexity to this approach by necessitating averages of the B-number for each stage of burning (1.8, 1.4, and 1.9 for Stages I, II, and III are reported⁵). This in some ways simplified matters, as Stages I and II only include flaming combustion and later smoldering of corrugated cardboard, while Stage III is a mixed product of cardboard and polystyrene combustion.

For Stage III, some possible methods for determining the B-number of mixed materials were presented, 5, 10 but more fundamental research needs to continue in order to establish a firm methodology for utilizing such averaged approximations.

UPWARD FLAME SPREAD OVER CORRUGATED CARDBOARD

One parameter of significance for suppression applications in warehouses is the time to sprinkler activation, which largely depends on early-stage flame spread and heat-release rates. Focusing on Stage I of the Group A plastic commodity tests, flame spread rates were shown to increase with time to the 3/2 power profile rather than traditional time-squared observations.¹¹

Based on experimental results, this behavior was hypothesized to be due to the unique properties of C-flute cardboard, which consists of a corrugated layer of paperboard glued between two flat sheets. As the outer layer burns, it delaminates from the corrugated surface and "curls" directly into the boundary layer, obstructing the flow of hot gasses and projecting the flame outwards and away from unburnt cardboard, shown in Figure 4.



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slowing the development of flame spread and possibly delaying sprinkler activation times. This reduction occurs even though progression of the burning process into the interior of the commodity (including involvement of plastics) will proceed as usual.

The results of these tests have yielded alternative scalings that may be better applicable to some situations encountered in practice in warehouse fires.¹¹ Understanding the time-dependent interaction of both the upward flame spread

warehouses.

IMPACTS ON PRACTICAL WAREHOUSE DESIGN

Ultimately, it will take years for the fruits of this labor to directly impact the design of fire protection systems, but some of the general insights should be useful in everyday designs. First, the ultimate flammability or fire hazard



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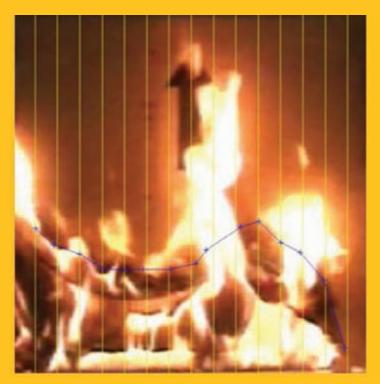




Figure 3: (left) Front video footage during a representative test. The blue contour across the width indicates the measured height of the pyrolysis region. (right) Image taken from the side of a sample during a representative test. Curling of the front layer of cardboard is visible in both images, but the extent of three-dimensional effects is more clearly seen in the side image.⁵

of stored commodities may not be as simple as a percentage classification of plastics and cellulosic materials. ^{1,2} The increasing number of exceptions to standard commodity classification listed in NFPA 13 and FM Data Sheet 8-1 is particularly revealing, in that the list of stored items that do not fall under traditional commodity classification schemes is growing; therefore, current methodologies cannot capture all relevant behavior without full-scale test methods. ^{1,2}

Smaller test methods here are shown to capture some of the complex behavior of stored commodities that, with future incorporation of suppression system performance, may be one piece of future system designs. Increasing progress in numerically simulating warehouse fires may help in this regard, but a method for simulating the in-depth combustion of mixed materials must be firmly developed. The ability to extract nondimensional burning behavior from a single warehouse

The focus should not be restricted to suppression systems alone because a closer look at individual commodities may be worth considering.

commodity also is one approach for developing a useful comparison between actual stored commodities and standard commodities used in full-scale tests, possibly limiting the number of large-scale tests in the future.





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[The Flammability of a Storage Commodity]

The focus should not be restricted to suppression systems alone because a closer look at individual commodities may be worth considering. For instance, if new packaging could be developed that significantly delays in-depth combustion while still allowing flames to quickly spread upward, triggering sprinkler activation, the large heat-release rates of Stage III may be prevented and the size of necessary extinguishment systems reduced. Similarly, different types of cardboard may be designed that speed or slow upward flame spread.

In essence, by looking at the constituent pieces of a warehouse fire, it may be possible to not only design a suppression system for a fire hazard, but also to modify the fire hazard to match a suppression system in the future. These approaches would require strict control of stored commodities; there are many occupancies where this is possible. Full-scale

testing also would be necessary to finally validate these concepts; however, with further modeling and understanding, there is room for revolution in the ways storage occupancies are protected.

Acknowledgements:

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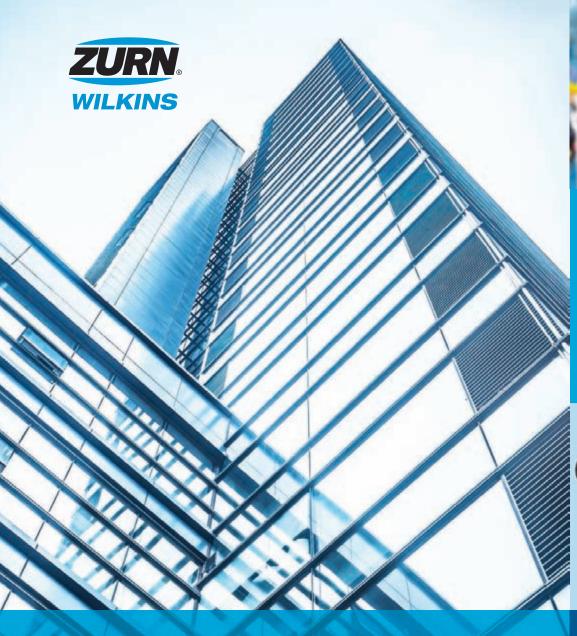
Michael Gollner is with the University of Maryland, College Park.

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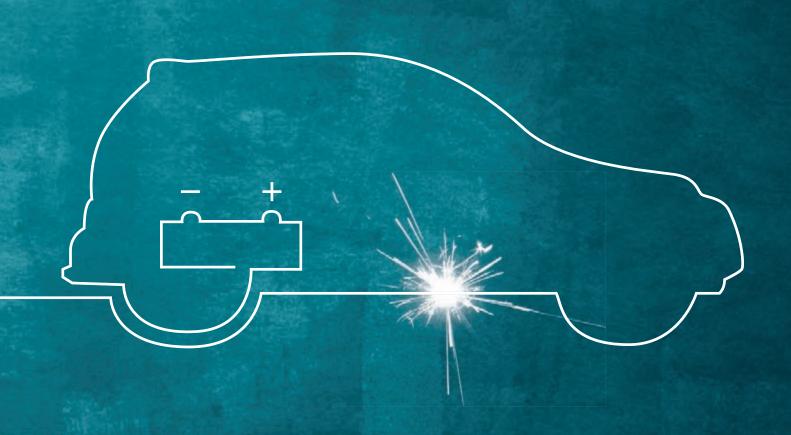


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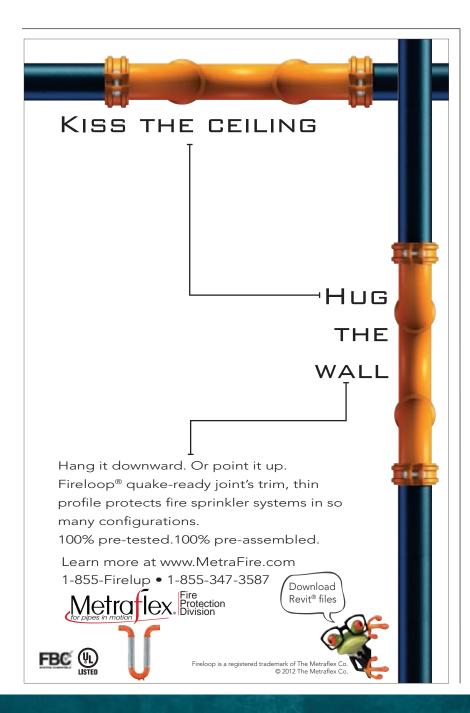
By R. Thomas Long, Jr., P.E., and Andrew F. Blum, P.E.



ires involving cars, trucks, and other highway vehicles are a common concern for emergency responders. Between 2009 and 2011, there was an average of 187,500 highway vehicle fires per year. 1,2 Fire service personnel are accustomed to responding to conventional vehicle (i.e., internal combustion

engine [ICE]) fires, and generally receive training on the hazards associated with those vehicles and their subsystems. However, in light of the recent proliferation of electric-drive vehicles (EDVs), a key question for emergency responders is, "What is different with EDVs and what tactical adjustments are required when responding to EDV fires?"

A research program was conducted to develop the technical basis for best practices for emergency response procedures for EDV battery incidents, with consideration for suppression methods and agents, personal protective equipment (PPE), and clean-up/overhaul operations. A key component of this project



goal was to conduct full-scale fire testing of large format Lithium-ion (Li-ion) batteries as used in EDVs.

This article summarizes the fullscale fire tests performed, reviews the current emergency response tactics, and discusses what, if any, tactical changes relating to emergency response procedures for EDV battery incidents are required.

PROJECT HISTORY

In 2009, the National Fire Protection Association (NFPA) began a partnership with the U.S. Department of Energy (DOE) and the automotive industry to develop and implement a comprehensive training program to provide safety training to emergency responders to prepare them for their role in safely handling incidents involving electric drive vehicles (EDVs). This program had a lack of data to draw on to address the potential hazards associated with damaged EDV batteries.

Full-scale fire suppression tests were conducted to collect data and evaluate differences in EDV fires as compared to traditional internal combustion engine (ICE) vehicle fires. In particular, members of the emergency response community had questions regarding: (1) personal protective equipment (PPE); (2) firefighting suppression tactics; and (3) best practices for overhaul and post-fire clean-up.

To answer these questions, the research program they developed included six primary tasks:

- A review of industry best practices for ICE and EDV firefighting tactics;
- Identification of additional EDV PPE required for emergency responders;
- Identification of battery technologies and representative battery types for full-scale fire testing;
- Development of a full-scale EDV fire testing program;
- 5. Full-scale EDV battery fire tests;
- A report on final results and summary of best practices for emergency response to incidents involving EDV battery hazards.

For the full text describing each of these tasks and the fire test results, see the NFPA Fire Protection Research Foundation (FPRF) report titled, "Emergency response to incidents involving electric vehicle battery hazards."³

INDUSTRY BEST PRACTICES FOR FIREFIGHTING TACTICS FOR ICES AND EDVS

Existing guidance^{4,5,6} describes the potential consequences associated with hazards posed by EDVs and suggests common procedures to protect emergency responders, tow and/or recovery, storage, repair, and salvage personnel after an



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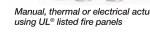
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incident has occurred involving an EDV. Nickel metal hydride (NiMH) and Lithium-ion (Li-ion) batteries used for vehicle propulsion power are the assumed battery systems addressed in these recommended practices and guides.

The recommended practices and guides^{4,5,6} outline the same basic steps for fire service personnel responding to an EDV fire: identify the vehicle; immobilize the vehicle; disable the vehicle; extrication; extinguishment; and overhaul operations. EDV tactics are generally consistent with current recommendations for ICE tactics: however. first responders must now identify the vehicle prior to immobilizing the vehicle. Other key differences

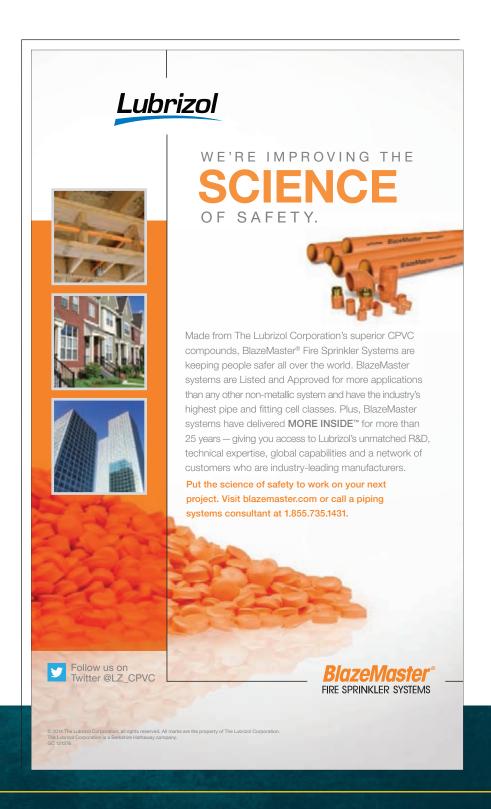
> Li-ion battery cells arranged in large format Li-ion battery packs are being used to power many EDVs currently in the marketplace.

between the two include: the need for copious amounts of water to extinguish an EDV battery fire, the high voltage electrical hazards associated with EDVs, and the recommendation to store all damaged EDVs at least 50 ft (15 m) from other structures or vehicles post-fire.

IDENTIFY BATTERY TYPES FOR FULL-SCALE TESTING

Li-ion battery cells arranged in large format Li-ion battery packs are being used to power many EDVs currently in the marketplace. This chemistry is different from previously popular rechargeable battery chemistries (e.g., NiMH,⁷ nickel cadmium, and lead acid).8 Most notably, Li-ion batteries contain a high energy density coupled with a flammable organic electrolyte rather than an aqueous solution typically employed in previous battery chemistries. This has created a number of new challenges with regard to fire suppression for first responders.

Given the current direction of the automotive industry, Li-ion batteries were chosen for full-scale testing. Batteries were procured from two automobile manufacturers, designated Battery A and Battery B. Both batteries procured were based on a Li-ion technology currently being used in production vehicles. Battery A is a 4.4 kWh battery utilized in a



plug-in hybrid electric vehicle (PHEV) that is installed under the rear cargo compartment of the vehicle. The 4.4 kWh battery pack is enclosed in a metal case and is rigidly mounted in the lower portion of the rear cargo area behind the rear seat.

Battery B is a 16 kWh battery that is utilized in an extended range electric vehicle (EREV). The T-shaped battery spans nearly the length of the vehicle from the rear axle to the front axle and is rigidly mounted underneath the vehicle floor pan. A vehicle

passenger compartment floor pan separates the battery assembly from the passenger compartment.

DEVELOPMENT OF A FULL-SCALE FIRE TESTING PROGRAM FOR EDV BATTERIES

The testing program developed included one full-scale heat release rate (HRR) test of a EDV battery (HRR test) and six tests involving suppression of EDV batteries installed within a generic vehicle fire trainer (VFT)

prop (fire suppression tests). The fire suppression tests were conducted with and without vehicle interior finishes to demonstrate the impact of the burning battery on the overall vehicle fire, if any.

All tests subjected the batteries to simulated exposure fires originating underneath the battery/vehicle chassis, and all fire suppression activities were conducted by qualified, active duty firefighters. The simulated exposure fires were produced using an external propane





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Figure 1: Battery B configuration and burner locations for HRR testing

gas burner system that provided a steady and repeatable exposure of approximately 400 kW to the batteries, which is equivalent to a moderate-size gasoline pool fire.

Gas samples and fire suppression water samples were collected for analysis of potential contaminants (chemical hazards). Voltage and current measurements were recorded at the battery, VFT chassis, and suppression nozzle for analysis of electrical hazards. Instrumentation also monitored fire growth and development, including, but not limited to, HRR, temperature, and heat flux (thermal hazards).

FULL-SCALE FIRE TESTS

Full-scale HRR testing was performed at Southwest Research

Institute (SwRI) in San Antonio, Texas. The primary objective of the HRR testing was to determine the amount of energy released from the battery alone when ignited by an external ignition source. The full-scale suppression testing was performed at Maryland Fire Research Institute (MFRI) in College Park, Md. The primary objectives of the suppression testing were to evaluate tactics and procedures for first responders, PPE of first responders, adequacy and amount of water as a sole suppression agent, and procedures for overhaul and post-fire clean-up.

HRR TESTING

Due to the limited number of EDV batteries provided, only one battery

was subjected to HRR testing. Battery B was centered under a 20 ft by 20 ft (6 m by 6 m) hood supported by five stainless steel legs. The leg supports held the battery in place 20 in (500 mm) above the ground to provide a viewing angle to the bottom of the battery during testing. Four propane-fueled burners were placed six inches (150 mm) underneath the battery to provide a steady and repeatable approximate exposure fire to the battery that could be easily controlled (Figure 1).

Temperature and heat flux measurements were recorded on the exterior battery casing, interior battery, and at standoff distances of 5 ft and 10 ft (1.5 m and 3 m) from the battery. Gas samples were collected for analysis for toxic or corrosive compounds. The battery was allowed to burn until completion (i.e., no suppression).

The maximum HRR measured during testing was approximately 700 kW at 17 minutes and 30 seconds into the test. Removing the 400 kW propane burners, the peak heat release the battery attributed to the fire was approximately 300 kW. Once the burners were turned off, around the 20-minute mark, the HRR plateaued as the battery underwent self-sustaining combustion and then slowly decayed (Figure 2).

A total of 14 air samples were collected and analyzed after the test. The results showed only carbon



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monoxide (CO) and carbon dioxide (CO₂) present in significant quantities.

After approximately one hour and 34 minutes of elapsed time, all visible flaming ceased. Thermal images were recorded as the battery cooled and were captured for an additional three hours and 15 minutes. When visible flaming ceased, the observed exterior maximum temperatures were approximately 400 °C. Three hours after all visible flaming ceased, maximum observed temperatures were approximately 150 °C.

SUPPRESSION TESTING

In lieu of procuring fully intact production vehicles for the full-scale suppression tests, a VFT prop was outfitted with the two different battery assemblies. This allowed for multiple tests of different batteries and battery sizes, dimensions, and installation locations, all while using the same VFT prop. The VFT prop was constructed to resemble a modern EDV both in size and design and opened in the back, similar to a hatchback, to allow for the installation of the batteries (Figure 3).

The batteries were placed on top of a ¼-in (6 mm) steel plate simulating the floor pan of the vehicle. The plate had two portals to allow the burners, positioned six inches (150 mm) below the batteries in the VFT prop, direct access to the bottom

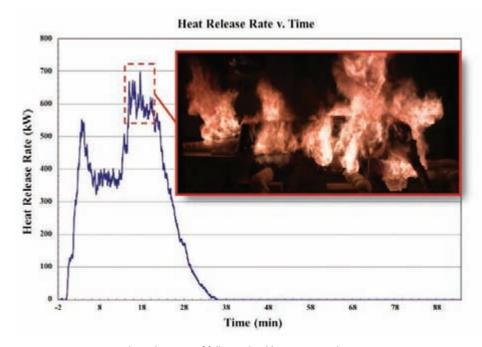


Figure 2: HRR test results with image of fully involved battery at peak HRR

of the battery assemblies in their respective locations.

The VFT prop was placed on a concrete burn pad at MFRI in the open air, as would be expected during a normal vehicle fire.

Electrical measurements were recorded to investigate the possibility of electric shock by a firefighter while suppressing an EDV fire, either through direct contact with the VFT prop or by applying a steady water stream to a high-voltage battery. Following a methodology similar to previous studies, the electrical measurements were conducted by measuring both the voltage and current at the fire

suppression nozzle and at the body of the chassis in which the battery sat while inside the VFT prop.

Water samples were collected after each test to analyze any potentially harmful byproducts present in the water after being used to suppress an EDV battery fire. In addition, temperature and heat flux measurements were collected during testing until external battery temperatures dropped to near ambient levels. These measurements were collected at similar locations as the previous HRR testing: temperatures were recorded on the external battery casing and at internal battery locations, and heat fluxes were



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Figure 3: VFT: Side profile (top); rear profile with hatchback open (bottom left); and front profile with hood open (bottom right)

recorded at standoff distances of 5, 15, 20, and 25 ft (1.5, 4.6, 6, and 7.6 m) distances.

Suppression activities were handled by MFRI. No guidance was given to the firefighters regarding what they could and could not do tactically to suppress the fires. They were instructed to fight the fire as they would normally approach a vehicle fire with an offensive attack. Any tactics or modifications to those tactics during the fire tests were at the sole discretion of the MFRI staff and

based on their many years of firefighting and training experience. The suppression teams were, however, restricted from using forcible tools to access the VFT prop and the battery for safety reasons and were restricted from fighting the fire from underneath the VFT prop (i.e., shooting water up to the undercarriage of the batteries) due to the presence of the four propane burners.

Water without additives was chosen as the suppression agent for all tests conducted. Water was supplied from a nearby hydrant connected to a municipal water system. A 1.75-in (44.5 mm) diameter hose line fed the nozzle, which discharged approximately 125 gallons of water per minute (7.9 lps) at 75 psi (520 kPa). The water usage was tracked during the tests so that an estimate of the total water used for suppression could be determined. In addition, interviews with firefighters after the tests were conducted to record firsthand observations.

In total, six tests were conducted – three using Battery A (designated A1, A2, and A3) and three using Battery B (designated B1, B2, and B3). For each battery type, two of the tests were performed with the battery pack alone positioned inside the VFT and one test was performed with typical interior finishes/upholstery installed within the VFT in addition to the battery pack.

The following is a summary of test observations/results, firefighter feedback regarding firefighting tactics, the adequacy of water as the lone suppression agent, and observations regarding overhaul and cleanup. Images from Test A3 are provided in Figure 4.

OVERALL TEST OBSERVATIONS AND RESULTS

• At a standoff distance of 5 ft (1.5 m) from the VFT, maximum





Figure 4: Test A3: Ignition of propane burners (top left); rear involved (top right); initial suppression activities (bottom left); suppression complete (bottom right)

heat flux measurements for tests without interior finishes were between 2.1 and 3.7 kW/m². In comparison, maximum heat flux measurements for tests with interior finishes were between 8.1 and 11.9 kW/m².

- No projectiles were observed from the battery pack in any of the tests.
 None of the batteries tested "burst" or "exploded" when ignited externally by an exposure fire.
- In all tests, "popping" and "arcing" sounds and off-gassing of white smoke consistent with internal battery cells from the battery pack during thermal runaway were

- observed. In addition, significant plumes of smoke were generated during all tests.
- Water was used to successfully extinguish all fires during the suppression tests; however, the amount of time required applying water and the total volume of water necessary for extinguishment was significantly larger than what is typically required for extinguishing a traditional ICE vehicle fire.
- The water samples collected during testing indicated the presence of chloride and fluoride (likely in the form of HF and hydrogen chloride [HCl]).

- However, the concentration of chloride in the solution was only two to three times greater than normally detected levels, while the concentration of fluoride was more than 100 times greater than normally detected levels. No other corrosive or toxic compounds were identified in the water samples.
- In all tests, the chassis current was negligible, and the voltage levels at the chassis made it up to the approximately 0.3 or 0.4 V range, which was consistent with pre- and post-measurement tests.
- In addition, voltage and current levels at the nozzle were negligible while the firefighters applied water to the batteries.
- Following extinguishment of the batteries, temperatures were monitored after the tests until they returned to near ambient conditions. In one test, the battery reignited 22 hours after the battery was extinguished (i.e., no signs of visible flaming, no signs of significant off-gassing or smoking, and surface temperature readings on the battery were approximately ambient) after it had been removed from the VFT and set aside for storage.

FIREFIGHTER TACTICS

 After initial size up and knock-down of the visible flames, suppression



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activities were halted. In all tests, re-ignition occurred after the initial size up and knock-down of the visible flames. These events likely coincided with thermal runaway at the individual cell level internal to the battery packs. While visible flames from the batteries were clearly extinguished, it was evident that temperatures within the batteries were still high enough that thermal runaway of internal cells was occurring. These re-ignitions repeated until enough water had flowed to sufficiently reduce internal battery temperatures to the point where thermal runaway did not proceed.

 Once the main battery fire had been controlled, continuous application of water to the battery with the nozzle set on fog, as was performed during several of the tests, further cooled the exterior of the battery, thereby helping to reduce the temperatures of the internal cells. This reduced the likelihood of additional off-gassing of electrolyte and re-ignition of internal battery cells, reducing the overall water quantity needed for suppression.

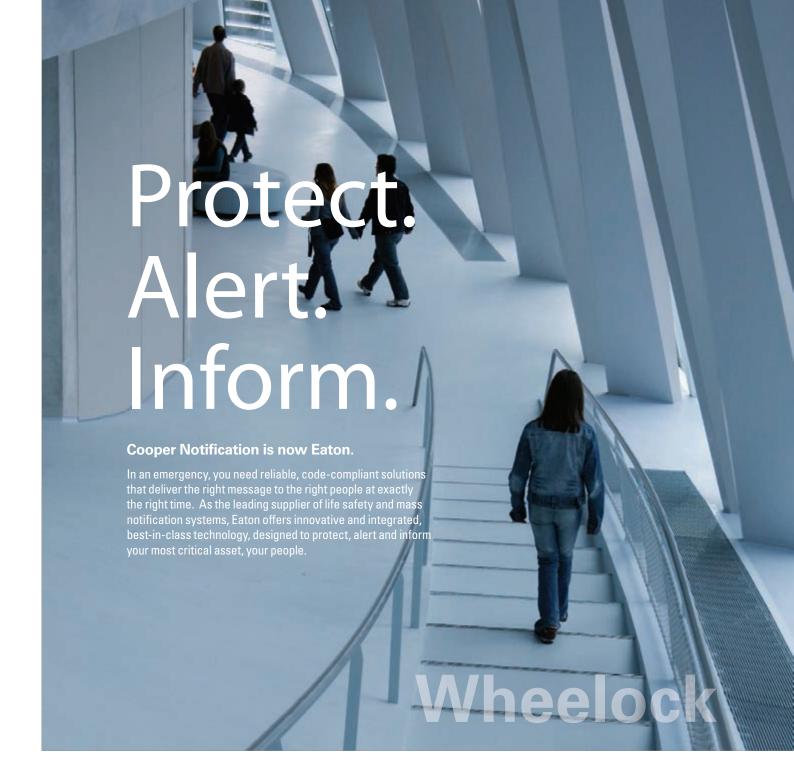
- In two tests, the total time for extinguishment exceeded the available air supply for one of the firefighters.
- Firefighters unanimously reported that access to the "hot spots" or "heat" was a significant barrier to extinguishing efforts. Firefighters were unable to get water where the heat and flames

were originating to quickly extinguish the fire. In these tests, access to the batteries was much easier than what firefighters experience in real world vehicle fire scenarios, as the batteries were placed inside a VFT prop and not installed within an actual vehicle. It can be assumed that access issues experienced by firefighters during this test program will be magnified during real-world vehicle fire scenarios

WATER AS EXTINGUISHING AGENT

 Water was used to successfully extinguish all fires during the suppression tests.





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• Overall, EDV battery fires require significantly longer active suppression operations (up to 50 minutes in this test program) o battle re-ignitions and significantly larger total volumes of water — up to 2,600 gallons (approximately 10,000 liters) of water — than traditional ICE vehicle fires. This increase is attributed to the need for water to not only extinguish the visible flames, but to cool the battery component to the point where thermal runaway will not continue.

The authors would like to thank the SwRI and MFRI crews for their

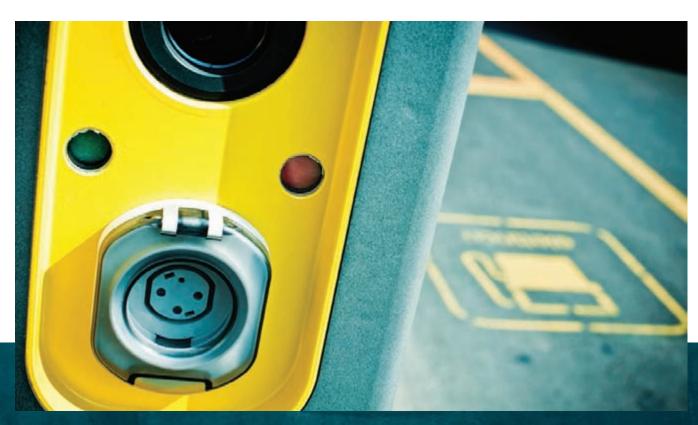
efforts in setting up, instrumenting, and conducting the HRR and full-scale fire suppression tests and providing access to the data and analysis gathered during testing.

The authors further thank Casey Grant and Kathleen Almand of Fire Protection Research Foundation; DOE/INL; DOT/NHTSA; Alliance of Automobile Manufacturers; Battery Technology Advisory Panel; Emergency Responder Advisory Panel; Project Technical Panel for Project on EV Battery Hazards; and Keith Wilson of Society of Automotive Engineers.

R. Thomas Long, Jr., and Andrew F. Blum are with Exponent, Inc.

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USCG USES EXPERIMENTATION AND FDS MODELING TO AID

By LCDR John H. Miller, P.E.

he U.S. Coast Guard (USCG), with the assistance and cooperation of the Passenger Vessel Association (PVA), recently completed a fire protection engineering study involving fire testing and computer modeling to validate a USCG policy that allows reductions in structural fire protection between certain areas aboard small passenger vessels.

Fire is a major concern with any type of structure, but especially on a seagoing passenger vessel. When a passenger vessel experiences a fire while at sea, there is no fire department to assist, no public way to exit. The crew is tasked with extinguishing the fire or relying on the structural fire protection and active fire suppression systems to protect the vessel and the passengers on board.

This fire threat, along with many other potential risks associated with seagoing passenger vessels, is the basis for one of many missions of the U.S. Coast Guard, which is to regulate the safety of the small passenger vessel (SPV) industry. The stringent regulations of Title 46 of the Code of Federal Regulations¹ (CFR) include numerous requirements applicable to SPVs that include, but



are not limited to, hull construction, fire protection, lifesaving, manning, and operations. These requirements can vary depending on the size of the vessel and the number of passengers it carries.

The fire protection aspect of the CFR includes requirements for firefighting equipment, as well as structural fire protection to provide fire boundaries between spaces. This article discusses very low fire load spaces, or so-called "5A" spaces, in particular. The USCG-developed policy regarding these types of spaces is intended to provide relief to the SPV industry from certain structural fire protection requirements, permitting weight savings that directly impact vessel fuel efficiency, capacity, stability, and speed, for spaces with very low, controlled fire loads. Type 5A spaces are commonly found on high-speed ferries or tourist excursion vessels.

BACKGROUND

The USCG policy ("5A policy" hereinafter) was first established in 1994, and is a relaxation of structural fire protection requirements specified in 46 CFR Subchapter K for A-60 structural fire protection boundaries between certain passenger spaces and areas of refuge, embarkation areas, external escape routes, and other adjacent spaces. Subchapter K applies to a SPV of less than 100 gross tons carrying more than 150 passengers, or with overnight accommodations for more than 49 passengers. "A" class bulkheads or decks are composed of steel or equivalent material capable of preventing the passage of smoke or flame for one hour when subjected to the standard fire test. In addition, they must be insulated with approved structural insulation, bulkhead panels, or deck coverings so that, if subjected to the standard fire test for the applicable time listed below, the average temperature on the unexposed side does not rise



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Figure 1: 5A Space - Old Style (i.e., non-cushioned seats, small seating area)



Figure 2: 5A Space – New Style (i.e., cushioned seats, large seating area)



Figure 3: 5A Space Example – New Style (i.e., cushioned seats, large seating area)

more than 139°C above the original temperature, nor does the temperature at any one point rise more than 181°C above the original temperature:

A-60 Class – 60 minutes; A-30 Class – 30 minutes; A-15 Class – 15 minutes; A-0 Class – 0 minutes.

The 5A policy, which allows the use of C-Class (smoke tight and noncombustible) boundaries in lieu of A-Class boundaries, is conditional upon the use of a very-low-design fire load in the 5A space as well as other design and operational requirements. By controlling the fire load, vessel designers and operators are able to use aluminum construction with minimal insulation, thereby reducing vessel weight and increasing operational efficiency. (See Figures 1-3)

Since 1994, substantial increases in size, complexity, and furnishings of Subchapter K passenger vessels have raised concerns about the assumptions and safety margins inherent in the 5A policy. At the same time, advances in computational fire modeling capabilities have enabled the Coast Guard and designers to take a more thorough look at the issue. In 2010, Change-1 to the USCG's Navigation and Vessel Inspection Circular (NVIC) 9-97 "Guide to Structural Fire Protection"² revised the 5A policy to require designers to submit a performance-based engineering analysis to support the relaxation of fire protection requirements for 5A spaces. Given the potential costs and complexity involved with performing such an analysis, the Coast Guard and the Passenger Vessel Association agreed to form a working group to study this issue with the intent to identify performance guidelines for 5A spaces, which may be accepted in lieu of a full engineering analysis.

REPORT OF STUDY OVERVIEW

The USCG/PVA 5A Working Group developed a method of validating the

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5A policy using current fire protection engineering analysis techniques. The validation method completed by the group included the following:

- a. Select a representative 5A vessel for the analysis;
- b. Develop a Fire Dynamics Simulator (FDS) computer model of the test vessel and define the assumptions of the simulations:
- c. Employ a Coast Guard graduate student at the University of Maryland College Park (UMCP) to develop and complete a fire test experiment on select finishing materials and collect heat release rate data for the fire modeling;
- d. Conduct FDS simulations for the test vessel with fire data obtained from the UMCP experiment program and interpret the results; and
- e. Develop performance-based guidelines taking into account the results of the FDS simulations.

TEST VESSEL AND FDS MODEL

The group selected the M/V IYANOUGH (O. N. 1185366) as the 5A test vessel. This vessel, operated by the Massachusetts Steamship Authority (one of the key operational partners in this working group), was deemed to be representative of the state-of-the-art of current 5A vessels in passenger service. The M/V IYANOUGH is a 144.5-ft. (34.90 m) long aluminum vessel certificated to carry 393 passengers. A two-deck model with an interior staircase and an un-insulated aluminum deck between the two spaces was constructed in FDS to represent the M/V IYANOUGH passenger spaces. Working group representatives from USCG Headquarters, the USCG Marine Safety Center, and Gladding-Hearn Shipbuilding visited the vessel in order to observe arrangements and record the as-built dimensions. The FDS model of the vessel was constructed from the general arrangement plans and the as-built observations and measurements.

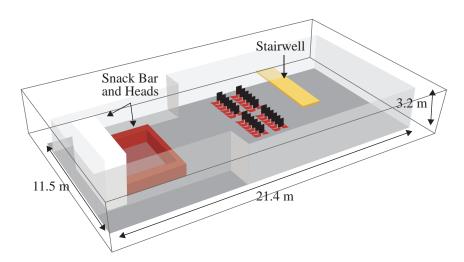
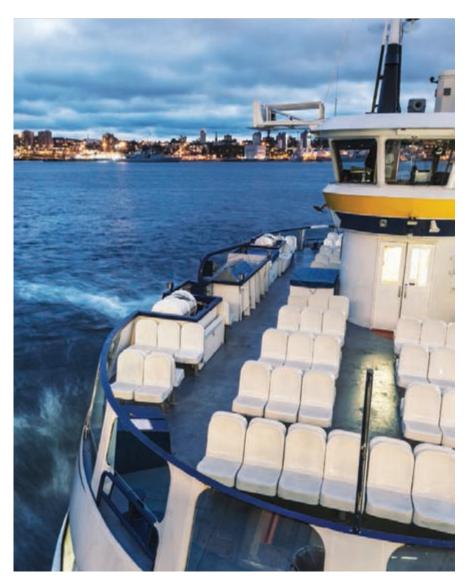


Figure 4: Model of 5A space used for simulation. Some seat rows were taken out to reduce clutter for illustration.





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UMCP EXPERIMENT PROGRAM AND FDS COMPUTER SIMULATIONS

A thesis³ completed by a UMCP graduate student determined the burning characteristics and heat-flux-dependent ignition time of certain furnishing materials representing the primary fire loads aboard the M/V IYANOUGH. This data was obtained by completing cone calorimeter testing on the seat cushion foam and fabric provided by the vessel seat manufacturer. (See Figures 5-7)

A majority of the foam used in the seats had a density of 38 kg/m³, a combustible mass of approximately 1.7 kg, and a tear strength factor of 200 N. This type of foam was used for testing and assumed to be the main fire load contributor. A select few other types of foam with slightly different properties were used in the seats in small quantities to prevent excessive compression and provide additional comfort. These foams were not tested because they were assumed not to be a main fire load contributor. The fabric on the seats was available in an assortment of designs and colors, but the type of

fabric was a consistent blend of 60% worsted wool and 40% polyester.

The material properties, measured through experimentation, were entered into the FDS model to determine what effects a burning seat cushion would have on other combustibles within the 5A space. FDS simulations of the two-deck M/V IYANOUGH model were conducted via a multi-processor computer using these seat material ignition time data sets.

In conjunction with running the FDS simulations at the exact dimensions and fire load of the M/V IYANOUGH, additional simulations were completed with two and three times the fire load as well as variations in compartment volume and placement of the fire loads. The criteria for acceptable fire performance during the 60 minutes after detection of the fire for the FDS model 5A space were as follows:

- a. The aluminum deck underneath the area of refuge must not reach 200°C over any square meter;
- b. No single point of the deck will reach 400°C; and
- c. The refuge area (second deck of the model) will remain free of smoke.



Figure 5: Foam and Fabric Sample Sustaining Flame After Ignition

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Figure 6: Seat Assembly For Full-Scale Testing





Figure 7: Sample Chair Fully Engulfed (left) and a Chair After Extinguishment (right)

REPORT OF STUDY RESULTS

The experimental program and fire modeling conducted in cooperation with UMCP determined that, without suppression, a fire starting in a single seat will spread to a maximum of 10 seats (two rows of five) for the base case (as built) arrangement. This conclusion is based on:

- a. A fire involving an individual seat (that meets the requirements below) will likely ignite adjacent seats that are less than 12 in (0.3 m) away;
- A fire involving a single row of seats (with a maximum of five seats) will likely ignite seats in an adjacent row in a back-to-back arrangement regardless of the angle of the seat;
- Rows facing the same direction will not ignite an adjacent row provided the distance between rows is greater than 30 in (0.76 m – measured front to front);
- d. Rows facing each other will not allow fire spread provided the knee gap is greater than 18 in (0.46 m – measured front to front) apart AND tables or other intervening furnishings are "fire resistant" per 46 CFR 116.423;
- e. Carpet or other floor coverings meeting the low flame spread requirements of IMO FTP Code⁴ Annex 1, Parts 2 and 5 (for floor coverings) will not become involved in a fire originating on seating that meets the requirements of this policy.

These results form the basis for a set of performance guidelines that can be used by industry, as an alternative to a full performance-based analysis to obtain a relaxation of the structural fire protection required for areas of refuge, embarkation areas, and external escape routes.

These guidelines are listed in the below.

This report of the study did not address every possible scenario involving the use of 5A spaces aboard passenger vessels. Arrangements not addressed in the guidelines may require additional performance-based analysis.

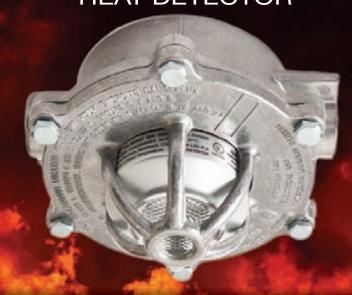
SPACE PERFORMANCE GUIDELINES

These performance guidelines are intended to guide designers and operators in the design and maintenance of Type "5A" spaces as equivalent to the structural fire protection requirements in 46 CFR Subchapter K. Where NVIC 9-97, Change 1 calls for a performance-based analysis, these guidelines may be used instead.

A. 5A Space Requirements and Conditions

- 1. Transient fire load must be controlled:
 - a. To prevent a fire from extending past the row of origin.
 - b. To prevent the obstruction of aisles or escape paths.
 - c. Not to exceed a combustible weight of 0.5 lb/ft² (2.5 kg/m²).
- 2. Seating density and restrictions:
 - a. No more than five contiguous seats in a row.
 - b. No more than 300 seats in any space.
 - c. Seats must be fixed and arranged to comply with 46 CFR 116.820.
 - d. A 5A space with an interior or exterior refuge area directly above is limited to a maximum enclosed volume of 24,750 ft³ (700 m³) and a minimum volume of 8,830 ft³ (250 m³).
 - e. The minimum acceptable distance between rows facing the same direction is 30 in (0.76 m).

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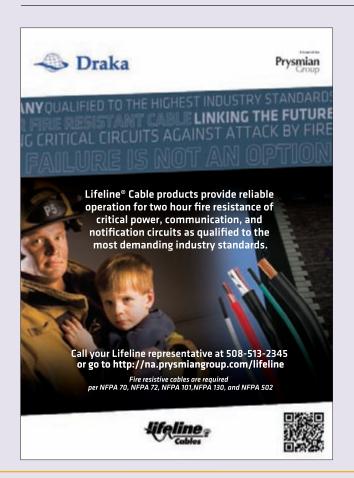


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- f. The minimum acceptable distance between rows facing each other is 18 in (0.46 m).
- g. Tables and other intervening furnishings must be "fire-resistant."
- h. Back-to-back seating arrangements of a maximum of 10 total seats are permitted.
- The combustible fire load in the space from construction and outfitting materials must not exceed 5 kg/m² (1 lb/ft²).
- 3. All carpet or other floor coverings must meet the low flame spread requirements of IMO FTP Code Annex 1, Parts 2 and 5.
- 4. Primary engine room access must not open to a 5A space or any corridor directly accessing a 5A space.
- 5. The following conditions must be met per NVIC 9-97, Change 1, Section 4.2:
 - a. Fire load calculations, in accordance with section 4.3 of NVIC 9-97, Change 1, must be used to demonstrate compliance with the limits set in this guideline.
 - b. Any installed interior finishes or trim must be approved.
 - c. Furniture and furnishings, draperies, curtains, rugs, and carpets must be fire-resistant in accordance with 46 CFR 116.423.
 - d. Any aluminum frame windows fitted in the

- bulkheads used to separate refuge areas, lifeboat embarkation stations, or escape routes from type 5A spaces must be either Coast Guard-approved A-0 windows, or provided with steel retaining clips. Ordinary glass (tempered or laminated) with steel clips is acceptable for the exterior bulkheads of 5A spaces located below or adjacent to areas of refuge.
- e. The aluminum deck of a 5A space does not require top-side A-class insulation.
- f. A USCG-type-approved fire detection and manual fire alarm system must be installed in accordance with 46 CFR 118.400. Smoke detectors must be fitted in all accommodations, control stations, and service spaces.
- g. A fire pump and fire main system complying with 46 CFR 181.300-320 must be installed for vessels greater than 65 ft (19.8 m).
- h. The shell plating and framing below the main deck must be A-O construction for a distance that extends at least 12 in (0.3 m) below the lightest load waterline. Insulation is not required for voids and fuel tanks that meet conditions (i) and (j) below.
- Fuel tank boundaries may be un-insulated aluminum or steel construction, provided they meet USCG conditions.
- Voids and other spaces where the fire load does not exceed 0.5 lb/ft² (2.5 kg/m²) and constructed of steel or aluminum do not require insulation.
- k. Stairs and ladders located entirely within a type 5A space or stairs located entirely within a stair tower enclosure may be constructed of un-insulated aluminum or steel.





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- 5A vessels may be allowed excursion permits if the proposed function is within the approved arrangement and fire load assumptions.
- m. In public areas, one A-II portable fire extinguisher must be provided for every 500 ft² (45 m²) of deck area or fraction thereof.
- 6. Seat construction restrictions:
 - a. Must have noncombustible frames.
 - b. Total combustible weight of each seat must not exceed 3.85 lb (1.75 kg).
 - c. Cushions and upholstery must be tested and determined to be fire-resistant in accordance with USCG NVIC 9-97, Change 1, Section 4.2.

B. Equivalence Allowed (Provided the requirements and conditions listed above are satisfied, the following arrangements may be accepted.)

- Boundaries between 5A spaces and refuge areas may be non-combustible and smoke tight (C-Class) in lieu of A-O bulkheads required by 46 CFR 114.400.
- 2. Up to 0.5 lb/ft² (2.5 kg/m²) of the weight of floor coverings that meet the IMO FTP Code Annex 1, Parts 2 and 5 may be excluded from the 1 lb/ft² (5 kg/m²) fire-load limit.

- 3. Stanchions within a 5A space that support a deck between two 5A spaces may be of un-insulated aluminum construction.
- 4. Bathrooms with a single toilet and sink with vanity, which do not have storage provisions for other materials, may be considered part of the space in which they are located, and not necessarily a separate Type 8 space.
- 5. Consistent with the treatment of areas of refuge on other U.S. passenger vessels, the space above need not be considered an area of refuge for the purposes of a fire in a space, if there is sufficient refuge located elsewhere on the vessel.

LCDR John H. Miller is with the U.S. Coast Guard.

References:

- Title 46, Code of Federal Regulations, Government Printing Office, Washington, DC, 2014.
- 2 Navigation and Vessel Inspection Circular (NVIC) 9-97 "Guide to Structural Fire Protection," Change 1, U.S. Coast Guard, Washington, DC, 2010.
- 3 Shriner, N. "Fire Growth Evaluation for Regulations of Fire Load for Type 5A Spaces on Seafaring Vessels." MS Thesis, Department of Fire Protection Engineering, University of Maryland, College Park, 2012.
- 4 Fire Test Procedures Code, International Maritime Organization, London, 2010.







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POTTER ELECTRIC SIGNAL

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

Internal corrosion of dry and preaction 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



Potter Electric Signal Company 5757 Phantom Drive, Suite 125 St. Louis, MO 63042 www.potternitrogen.com 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 moistur e 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

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

Corrosion Solutions team performed a

inhibiting effects of 98% nitrogen gas

galvanized steel, in an environment

when applied to both carbon steel and

yearlong study analyzing the corrosion-

- 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. For complete results, explanation of

For complete results, explanation of experimental procedures, and appendices, please visit www.potternitrogen.com.

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W.S. Darley & Co. 325 Spring Lake Dr. Itasca, IL 60143 www.firesprinklerpumps.com it is important to ensure that your fire sprinkler system will operate correctly; especially in a real live fire. Darley's patented Self Testing System (STS) technology will change the standard for residential fire protection. The Self Testing System (STS) is designed to provide homeowners with the most convenient, safe and affordable option to ensure complete fire safety of their home. The STS will perform an automatic bi monthly self test on the pump system, ensuring that pump and panel react to a demand for water without any human intervention. The system can send the home owners an email after every completed test or be remotely checked through an online web address. Contractors benefit from the installation process because the auto calibration allows the sprinkler system to learn the appropriate pressure readings for any

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Please visit www.firesprinklerpumps.com or email pumps@darley.com for more information.





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Engineering Technology Conference

This year's keynotes are

- > James Quiter, P.E., FSFPE, ArupFire, USA "The TransBay Center Incorporating a Performance Approach in a Unique Building."
- > Dr. Akiko Umezo, KCROM, Japan "Status of a Code/Standard for Fire Safety of Built Heritage and Associated Challenges in Japan"
- > Anthony Hamins, NIST, USA "NIST Research to Reduce the Impact of Fire in Communities and Buildings"
- > Jaime Moncada, P.E., FSFPE, IFSC, USA "Chronicle of Death Foretold The Kiss Nightclub Fire in Brazil"
- > John Frank, P.E., CFPS, XL Group, USA "How Property Insurance Companies Prepare for Major Losses"
- > Mike L. Hennegan, P.Eng., EML Fire Protection, Canada "Tradegy at L'isle Verte Fire Protection Engineering Perspectives"

Professional Development Seminar

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

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- New 3-Day Format! Sprinkler Design for the Engineer
- New! Hydraulic Calculations
- Protecting Flammable and Combustible Liquids
- Advanced Fire Dynamics Simulator and Smokeview
- Principles of Fire Protection Engineering
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- Smoke Control: Session II Design Fires, Atrium Control and Tenability System
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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.



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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/

SharpenYourExpertise/Education/ 2014SFPEAnnualMeeting.aspx

October 22-23, 2014

14th International Water Mist Conference Istanbul, Turkey

Info: www.iwma.net

The Society of Fire Protection Engineers (SFPE) is offering our members our new **Innovations Series** with CEU credits: an exclusive series of online technical sessions focused on helping SFPE members strengthen your professional skills and stay on top of industry trends. Professional expert instructors will lead the webinars, highlighting top technical content that is essential for keeping your skills up to par.

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Mark your calendar for our innovations sessions:

January 23, 2014 (archived at youtube.com/user/SFPEorg)

FIRE SAFETY FOR VERY TALL BUILDINGS with Morgan Hurley, P.E., FSFPE, Technical Director, SFPE

May 20, 2014, 5pm-6pm EST

TUNNEL FIRE SAFETY -PERFORMANCE BASED DESIGN

with David Barber, Principal, Arup

June 17, 2014, 11am-12pm EST

THE ROLE OF FIRE PROTECTION **ENGINEERING IN SUSTAINABLE DESIGN**

with Raymond A. Grill, P.E., FSFPE, Principal, Arup

Registration opens two weeks prior to each session, so look for more information on the SFPE Blog to sign up. We look forward to your participation!

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BRAINTEASER | Problem/Solution

Problem

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?

Solution to Last Issue's Brainteaser

cost \$10.00 more than the ball cost, how much did the ball cost.

Determining the costs of both requires solving the following simultaneous equations:

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Ball + \$10.00 + Ball = \$11.00. Therefore, the ball cost \$0.50, and the bat cost \$10.50.

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PRODUCTS [LITERATURE]

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www.armstrongfluidtechnology.com

-Armstrong Fluid Technology

Residential Upright Sprinkler

Viking has added a new cULus Listed residential upright sprinkler to its Freedom® Residential product line. The new Model VK467 has a K factor of 4.9 (71) and is approved for up to a 16 x 16 ft. area of coverage. Although UL-Listed for installation in any type of residential occupancy, the Model VK467 is particularly well-suited for loft-style residential applications where the sprinkler system's piping network is exposed.

www.vikinggroupinc.com

—Viking Corp.

Tunnel Fire Protection

Morgan Advanced Materials announces the availability of FireMaster® FireBarrier™ 135 sprayed refractory cement, ideal for concrete tunnel lining fire protection and the fire protection of ventilation shafts, escape tunnels and refuges, as well as critical systems such as water mains and communication cables. FireMaster® FireBarrier™ 135 can withstand repeated and prolonged exposure to high temperatures and can be installed onto concrete or metal substrates using standard spray equipment.

www.morganadvancedmaterials.com

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The Pro-Alert 480 Area of Rescue System and the Pro-Alert 610 Nurse Call System, both from Jeron Electronic Systems, have been integrated into the Farenhyt line of fire alarm and emergency communication systems, enabling Farenhyt distributors to offer healthcare and senior-living facilities more comprehensive life safety solutions. Both are available through all Silent Knight Farenhyt distributors throughout the U.S.

www.farenhyt.com

-Silent Knight

Assembly for Cold Storage Applications

Victaulic introduces the VicFlex Style AB6 Assembly for cold storage applications, said to reduce hands-on installation time by as much as 75% because it eliminates the use of rubber boots, foam sprays, and glue. There also is no need to cut and measure hard pipe. Designed to eliminate condensation, the VicFlex bracket can also combat differential movement between ceilings.

www.victaulic.com

–Victaulic

DC Video Supplies

Honeywell Power has announced a new series of power supplies that deliver more DC power to CCTV cameras and other peripheral devices. The HP1205UL and HP1210UL deliver 12VDC at 5.5 amps or 12VDC at 11 amps through 4, 8, or 16 outputs (depending on the model). The new line's electronic circuit protection detects short conditions and immediately removes power from the affected circuit to safeguard remaining outputs and ensure that there are no interruptions to the other cameras on the system.

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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.

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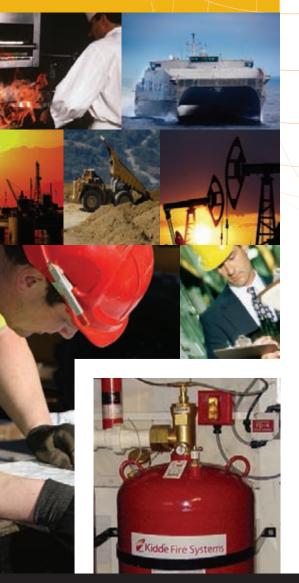
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Proven, Effective and Reliable...





Fire Protection that's Engineered Clean and Safe

Equipment and processes are vital to the success of all commercial endeavors. Consider the ramifications of a fire in these critical areas. Smoke or soot contamination, water damage, destroyed equipment and idle process lines could force your business offline and out of competition. Kidde's ECSTM Clean Agent Suppression Systems extinguish a fire in seconds, safeguarding your people and property.

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





FIRE PROTECTION FOR PEOPLE AND PROPERTY