

FIRE PROTECTION Engineering

3RD QUARTER 2013 Issue No. 59

APPROACHES AND RESOURCES FOR BUILDING **FIRE RISK** ASSESSMENT

**Application of Fire Risk Assessment in Building Design
and Management**

Addressing the National Wildland Urban Interface Fire Problem

**Fire Protection Inspection, Testing, and Maintenance
and Building Fire Risk**



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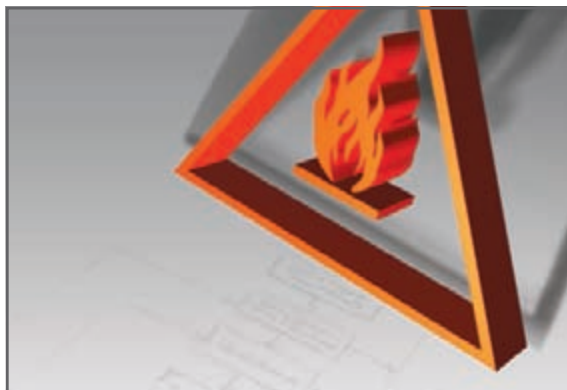
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From the **TECHNICAL DIRECTOR**

Fire Risk Assessment

The theme of this issue is “fire risk assessment.” Fire risk assessment differs from other forms of fire safety analysis or design in how the probability of an event is considered. With most forms of fire safety analysis, the only consideration of the probability of an event occurring is in the context of whether or not the event is likely enough that it should be addressed. All events that are considered likely enough to merit protection are then considered equally.

This occurs in both performance-based designs (at least those that are not conducted on a risk basis) and within prescriptive codes. For example, many prescriptive codes contain requirements that are predicated on a single fire occurring at any time. That is not to say that more than one fire is not possible, only that the developers of these codes considered more than one fire happening at once to be sufficiently unlikely that it is not necessary to protect against this occurring.

Conversely, in fire risk assessment, the consequences of a fire event are weighted by the probability of the event occurring. The traditional way to do this is to multiply the consequences of an event (lives lost, cost of damage, hours of downtime, etc.) by the event’s frequency (e.g., once every 100 years) and then sum these products for all scenarios. The result is a measure of the risk associated with an activity, in units like dollars of fire loss per year.

Simpler methods of fire risk assessment are available as well. The viewpoint by Dr. John Hall on page 4 summarizes these approaches nicely.

Unlike other forms of fire protection analysis or design, rare events can’t be excluded from fire risk analysis solely on the basis that they are highly unlikely. Even extremely rare events must be considered, but their (usually extremely high) consequences are weighted by the low frequency at which these events would occur.

There are two major challenges associated with fire risk assessments: the time that they take to perform and the availability of data. For analyses with a large number of scenarios, the time necessary to conduct a fire risk assessment can be substantial. It can also be difficult to find data associated

with the frequency of events occurring or the reliability of fire protection systems.

In some cases, it might be necessary to apply engineering judgment. When this is done, the uncertainty associated with the values used should be considered – such as by selecting conservative values or conducting an uncertainty analysis. Similarly, system reliability data can be hard to find. An article summarized sprinkler system reliability studies,¹ which identified system reliabilities ranging from 81.3% to 99.5%; this shows that even published data can vary. For other types of fire protection systems, finding good reliability data can be a real challenge.

However, fire risk assessment can be a very powerful, cost-effective tool. If a few scenarios dominate the fire risk, then the fire risk can be reduced by focusing on ways to reduce either the frequency of the scenarios occurring or their consequences. This allows for resources to be applied in a very efficient manner.

With the exception of a few industries – like the nuclear industry and the petrochemical industry – fire risk assessment is rarely used in fire protection engineering design. The articles in this issue provide an excellent overview of the approaches that can be used to conduct a fire risk assessment and the references that are available to assist.

Reference:

- 1 Budnick, E. “Automatic Sprinkler System Reliability,” *Fire Protection Engineering*, Winter, 2001, pp. 7-12.

Morgan J. Hurley, P.E., FSFPE
Technical Director
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By John R. Hall, Jr., Ph.D.

How many legs does a horse have if you call a tail a leg? Four. Calling a tail a leg does not make it a leg. Calling something fire risk assessment does not make it so either. Still, not every fire risk question requires all the information you can muster. If the cost of more information exceeds its value, a prudent engineer will use less.

My work has tended to emphasize more sophisticated methods and the dangers involved if you settle for less. My frequent partner, Jack Watts, has emphasized less sophisticated methods and the value they can provide. We're both right and both wrong, on occasion. I'm going to try to channel both of us and provide an overview of the spectrum of fire risk analysis methods.

A fire risk question starts with three questions: What could happen? How bad could it be? How likely is it? A fire risk decision adds a fourth: What should I do about that?

Checklists (including narratives)

Checklists comprehensively address what could happen (hazards) and what should be done about it, jumping over the other questions. This approach is required by law in the United Kingdom and used in "community fire risk assessment."

Checklists are the least expensive option. It is not surprising they are most used when fire risk assessment is routine. Checklists can be useful prods to make plans complete. Add a bit of information on how bad it can be, and you can set inspection priorities. Think how useful this simple tool would have been in West, Texas.

You can convert checklists into logic trees, showing the interaction of different hazards and safeguards. A fault tree may show there are alternative paths to safety.

Indexes

Indexes are the first step into quantification. An index identifies elements that contribute to fire risk (hazards, safeguards) and rates the element (e.g., hazard severity or likelihood, safeguard effectiveness) and its importance (weights), often in a framework that shows system interactions. Quantification is subjective but systematic. An index rarely uses data but should be consistent with data. Some indexes have been withdrawn because they failed that test.

Indexes are used in the insurance industry, dating back to the Dean schedule in 1902, in part because there is no need to persuade multiple interests of the index's accuracy and fairness.

The index philosophy of simple displays of mostly subjective estimates, systematically developed, also lives in FRA methods like risk matrixes and risk curves.

Quantitative FRA

Sophisticated fire risk assessment is embodied in the SFPE¹, ISO² and ASTM³ guides to fire risk assessment. This kind of complexity sends local authorities diving for copies of NFPA 551⁴, the guide to evaluating FRAs.

There are many reasons to favor quantitative FRA. Likelihood and severity are examined explicitly. Different kinds of fires are examined. The paper trail allows different interests to critique and modify the analysis. There is enough information for a conversation about tolerable risk. And the measures of risk can be compared to costs.

There are many reasons to be uncomfortable with quantitative FRA. Data requirements are enormous. Subjective judgments are still needed in abundance. The physics must be simplified to lower the calculation burden, and the physics is not self-sufficient, because people and chance (ignition probabilities, reliabilities, uncertainties, and human behavior) make too big a difference to ignore.

If you are going to comply with the code anyway, the risks at stake aren't big enough to justify the cost. If you want to prove code equivalency, however, large risks are at stake and you need a technical case strong enough to support a proposal – and survive an NFPA 551 review.

NFPA's performance-based initiative stresses that use of sophisticated equivalency methods would be rare and exceptional. Quantitative FRA should be even more rare and exceptional, but when you need it, you really need it. No one should be expected to abandon insistence on strict code compliance based on a few thin arguments labeled as fire risk assessment.

John R. Hall, Jr. is with the National Fire Protection Association.

References:

- 1 SFPE *Engineering Guide – Fire Risk Assessment*, Society of Fire Protection Engineers, Bethesda, MD, November 2006.
- 2 ISO 16732-1, *Fire Safety Engineering—Guidance on Fire Risk Assessment*, International Organization for Standardization, Geneva, Switzerland, 2012.
- 3 ASTM E1776, *Standard Guide for Development of Fire-Risk-Assessment Standards*, ASTM International, West Conshohocken, PA, 2013.
- 4 NFPA 551, *Guide for the Evaluation of Fire Risk Assessments*, National Fire Protection Association, Quincy, MA, 2013.

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

UMD Launches Fire Protection Engineering Legacy Campaign for a Professor of the Practice

Fire Protection Engineering graduates from the University of Maryland are rallying around their department to support the Legacy Campaign for a Professor of the Practice, a new initiative to help ensure students stay current on the latest technologies used in the field. According to Fire Protection Engineering Department Chair James Milke, the professor of the practice will bring hands-on field experience to the undergraduate curriculum and will strengthen the school's ties with industry.

"This department has been recognized for many years for producing outstanding young engineers and more recently for the high quality of research we conduct," Milke says. "The main purpose of the professorship is to preserve the connection of the department to the profession and to the applied side of the field."

Already, the Department has raised close to \$500,000 of its \$2.5 million goal. Support has come from alumni and industry. Andrews Group, LLC, Poole Fire Protection, and Tyco have each made \$100,000 gifts to the campaign.

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

Report Shows How Earthquake Damage Can Impact Building Fire Safety Performance

A study of post-earthquake building fire performance conducted in 2012 shows that damage to building structural elements, elevators, stairs, and fire protection systems caused by the shaking from a major earthquake can play a critical role in the spread of fire and hamper the ability of occupants to evacuate, as well as impede fire departments in their emergency response operations.

"When the ground stops shaking after a major earthquake, the damage may have just begun," says Brian Meacham, associate professor of fire protection engineering at Worcester Polytechnic Institute (WPI) and principal investigator for the post-earthquake fire study. The study looked at the effects of earthquakes and post-earthquake fires on a full-scale building. Here are some of the impacts on fire and life safety systems that Meacham and his team documented:

- Structural damage on the second and third levels was significant; while the building didn't collapse, it had to be shored-up to support gravity loading prior to the fire testing.
- Damage to the building's interior and exterior wall and ceiling systems created openings through which smoke and flames could spread; debris from the walls and ceilings became obstacles that would have hampered the evacuation of occupants or the movements of firefighters.
- A number of doors were unable to be opened or closed (open doors allow fire to spread; stuck doors can cut off escape routes or hinder the movements of first responders).
- Access to the upper floors was cut off when the staircase became detached from the landing and distortion of the elevator doors and frame on some levels made the elevator unusable. During the fire tests, smoke and hot gasses entered the elevator shaft through the open doors, spreading smoke to other floors and raising temperatures to dangerous levels.
- Most of the active and passive fire protection systems, including the sprinkler system, the heat-activated fire door, fire dampers, and fire stop materials, performed well.

"Through this research, we have begun to build a base of knowledge that will allow us to design more resilient buildings and building systems, and provide better protection to people, property, and mission. But there is much more to do and a lot more we can learn in subsequent studies," Meacham says.

To read the complete report, go to <http://www.wpi.edu/academics/fpe/policy-risk-engineering-framework.html>

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AN OVERVIEW OF APPROACHES AND RESOURCES

FOR BUILDING FIRE RISK ASSESSMENT

By **Brian J. Meacham, Ph.D., P.E., FSFPE**

Everyone knows that fires happen. In 2011, there were 1,389,500 fires reported in the United States alone.¹ These fires caused 3,005 civilian deaths, 17,500 civilian injuries and \$11.7 billion in property damage. Structure fires accounted for only 35% of these fires (484,500), but they resulted in 84% of the civilian deaths (2,640), 79% of the civilian injuries (15,635) and 83% of the property damage (\$9.7 billion). While a majority of the losses were in domestic settings, 17 of the 22 large life-loss fires reported in 2011 occurred in non-residential structures, resulting in a total property loss of \$293.9 million.² Large life-loss

fires occur, such as The Station nightclub fire in 2003. It seems that a day does not go by where such a large life-loss or financial-loss structure fire does not occur.

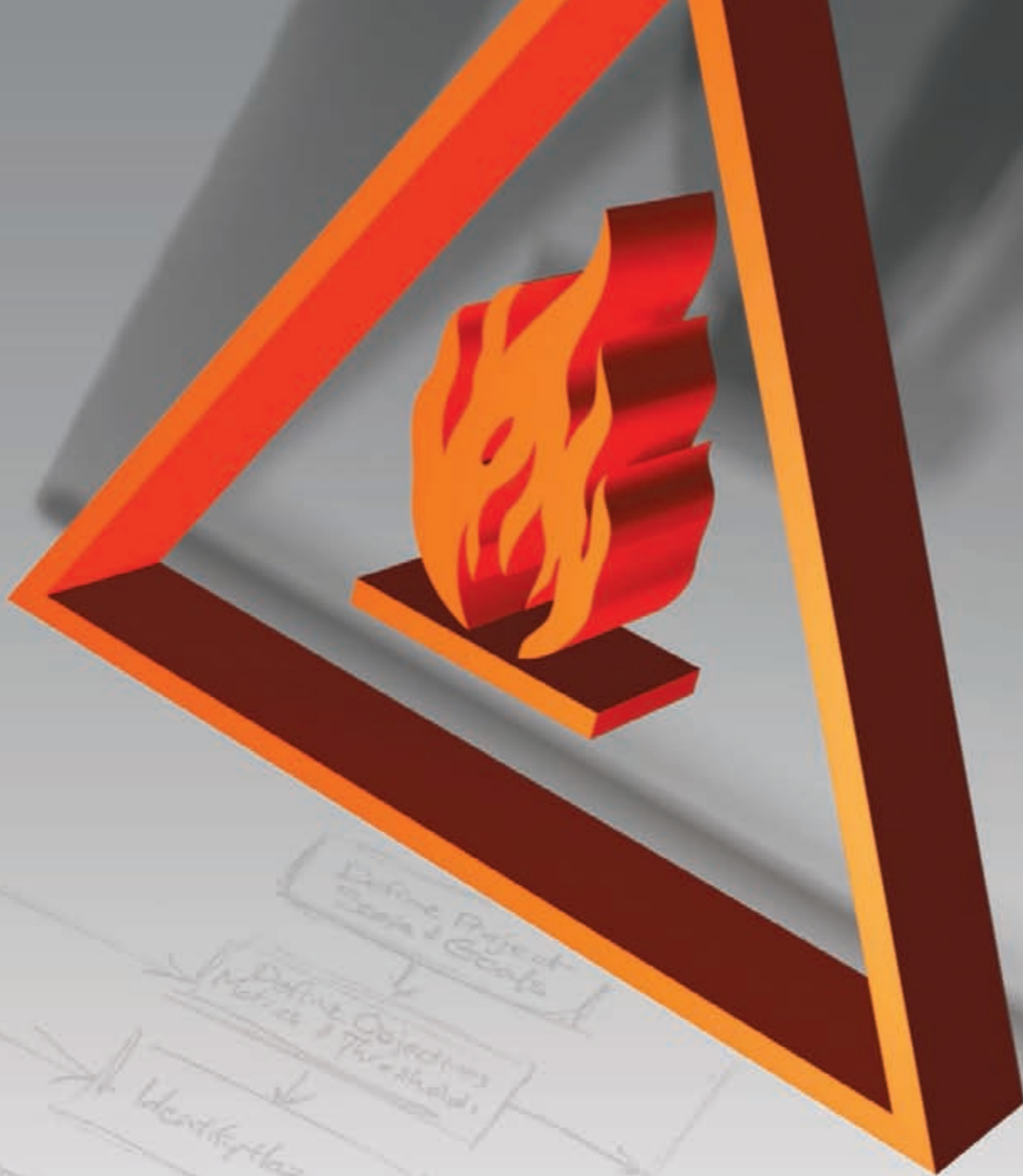
The challenge that all fire protection engineers face is that nobody knows exactly when or where a fire will occur, under what conditions, and who will be at risk. In part, this is because one cannot predict the future. However, it is also because building and fire regulations are used to manage the risk. The building and fire regulatory system is complex and comprehensive, which for most buildings results in a generally tolerable level of fire performance. It also means that unknown or unacceptable life safety or financial loss concerns might

exist in any given building, particularly if there are attributes of the building, its occupants, processes or mission, which are not specifically addressed by applicable codes and standards. One way to determine whether such a potential exists is by undertaking a fire risk assessment of the building or facility.

FIRE RISK ASSESSMENT

The general aim of fire risk assessment (FRA) is to identify and characterize the fire risks of concern and provide information for fire risk management decisions. The intent is to answer three basic questions: what can happen (what can go wrong), how likely is it that it will

S



There are four basic strategies to managing risk: **avoidance** (do not engage in the risky activity), **mitigation** (take steps to reduce the risk), **transfer** (shift the responsibility for loss control elsewhere, such as through insurance), or **accept the risk**. Building and fire regulations provide aspects of all four, in that they preclude certain operations for specific occupancies (avoidance), include requirements for fire protection systems (mitigation), relieve some burden of actually assessing the risk (transfer), and provide a mechanism for assuming all is okay if one complies with the code (acceptance).

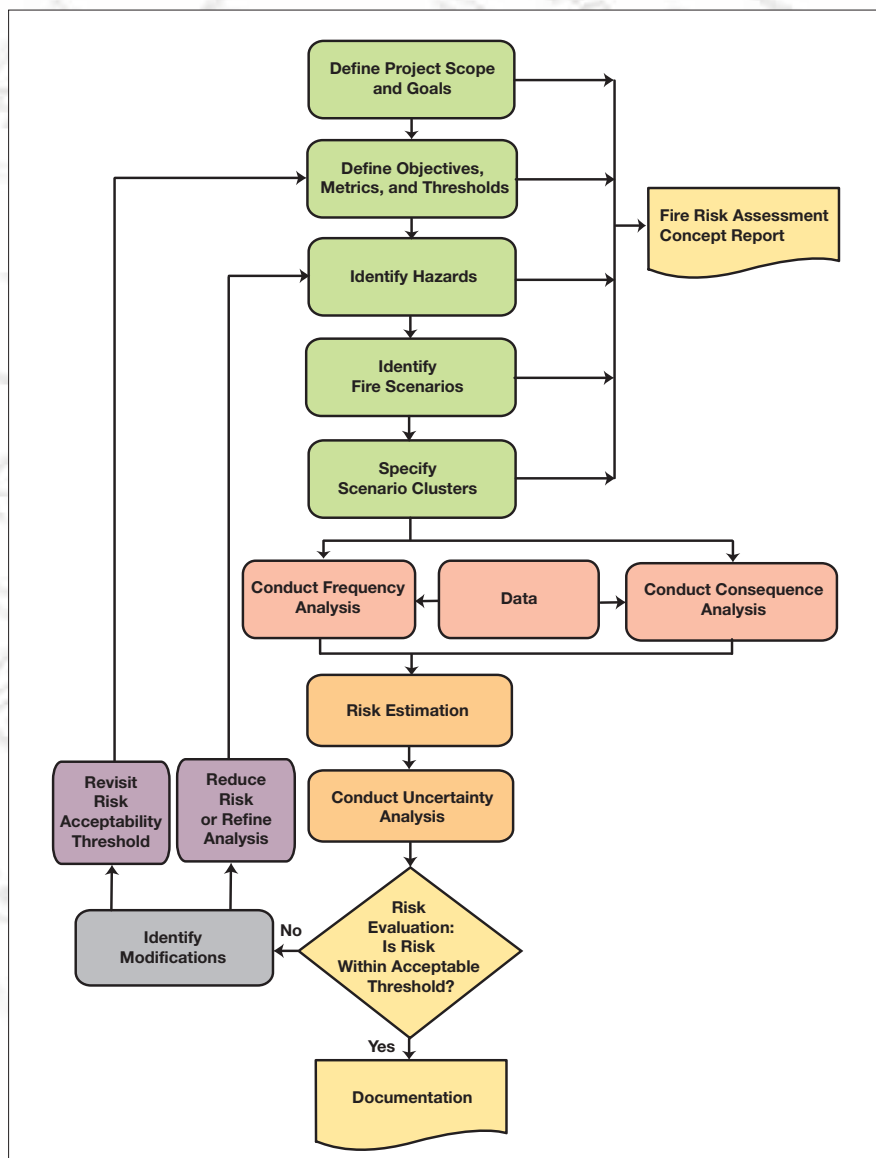


Figure 1. Fire Risk Assessment Process⁴

happen, and if it does happen, what are the consequences?³ FRA is distinguished from fire hazard analysis (FHA) and consequence analysis by the inclusion of an estimate of likelihood of occurrence, in addition to assessment of those factors that could lead to a fire and the impact should a fire occur.

FRA involves several steps, including identifying the objectives of the assessment, the metrics for assessment, the hazards of concern and the potential fire scenarios, conducting frequency and consequence analyses on the scenarios of concern, and estimating the risk associated with the scenarios. In some cases, FRA may be extended to assessment of options to mitigate the risk (either through reducing the likelihood of occurrence or magnitude of consequences), although this is also part of the risk management process. One framework for the FRA process is shown in Figure 1.⁴

Risk Assessment Objectives, Metrics and Thresholds

Some of the most important steps in the FRA process are identifying the objectives of the risk assessment, the measure(s) that will be used to express risk, and how the risk measures will be presented or communicated for decision-making purposes.

For example, a high-level goal might be to “provide an environment for occupants that is reasonably safe

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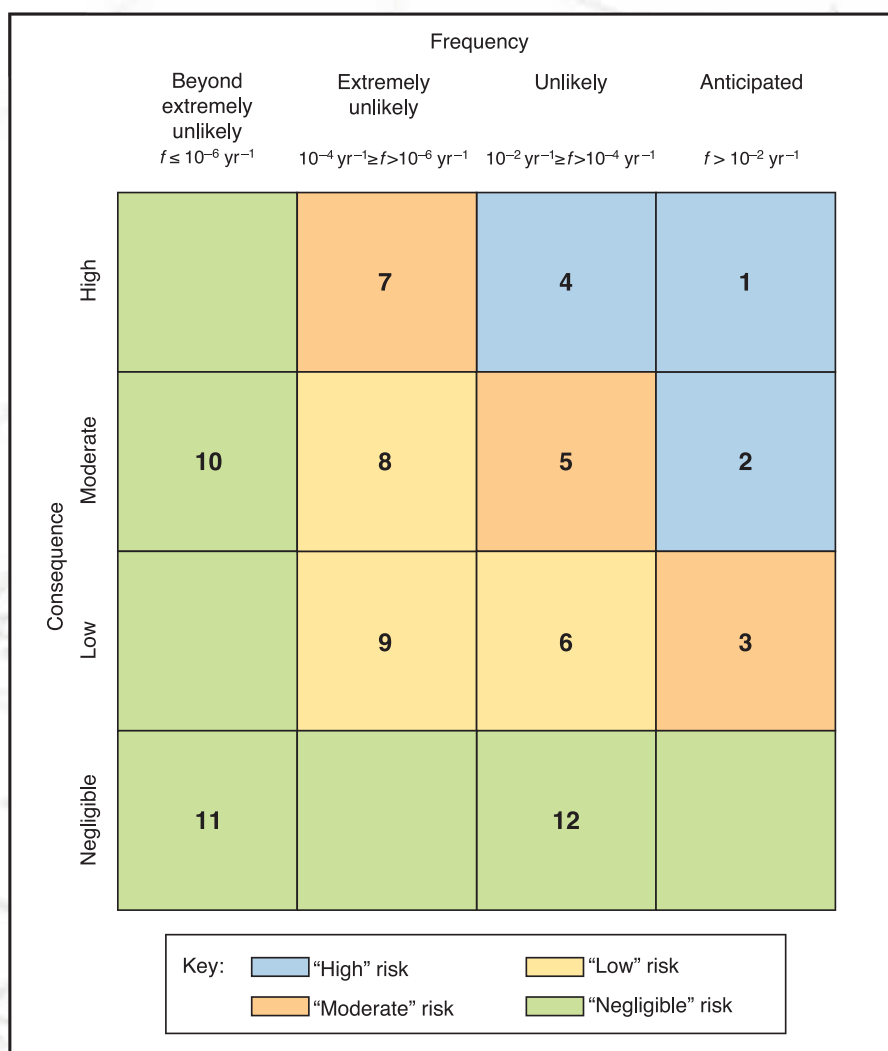


Figure 2. Consequence Ranking, Frequency Ranking and Risk Matrix¹¹

from fire by protection of occupants not intimate with initial fire development and improvement of the survivability of occupants intimate with the initial fire development."⁵

A first question might be: which occupants – all of them, only the most sensitive population, another subgroup? One then needs to ask under what conditions – smoke inhalation, radiant energy exposure, high temperatures, all, others, at any time of day, or under any circumstances? Characterizing the population and their risk thresholds is important as it will help drive scenarios of consideration and risk estimation and evaluation later in the process.

The same holds true for financial loss objectives, as might be associated with property loss (direct) or operational continuity (indirect). Is the focus structure only, contents, all contents or only some, contents and the structure? Is the impact related only to local operations, or is there an exposure somewhere in the supply chain or market delivery? What one chooses to address can influence the assessment, and whether or not all scenarios of concern are selected will depend on the focus.

How one chooses to measure and present the risk is equally important and can make a significant difference in terms of how the risk is perceived. For example, the life safety risk discussed

| Consequence Level | Impact on Populace | Impact on Property/ Operations |
|-------------------|--|---|
| High (H) | Immediate fatalities, acute injuries—immediately life threatening or permanently disabling | Damage > \$XX million – building destroyed and surrounding property damaged |
| Moderate (M) | Serious injuries, permanent disabilities, hospitalization required | \$YY < damage < \$XX million – major equipment destroyed, minor impact on surroundings |
| Low (L) | Minor injuries, no permanent disabilities, no hospitalization | Damage < \$YY – reparable damage to building, significant operational downtime, no impact on surroundings |
| Negligible (N) | Negligible injuries | Minor repairs to building required, minimal operational downtime |

Table 1. Possible Consequence Ranking Criteria¹¹



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above could be expressed in terms of the ratio of fire deaths to population, which could be expressed as 9.6×10^{-6} for the general population, or 2.99×10^{-7} for nonresidential buildings. The audience may or may not have a feel for what this means, so a comparative number might be given, such as risk of death in an automobile accident, which is much higher at 1.03×10^{-4} . They might still not appreciate the numbers, so one might use reciprocals, i.e., 1 in 104,161, 1 in 3,344,481 and 1 in 9,708 respectively. One might also choose fire-per-building type, risk of untenable conditions, or some other metric.

Hazard, Event and Scenario Identification

As used here, a hazard is a condition or physical situation with a potential to result in harm to the focus of the risk assessment (e.g., people, property, operational continuity). The threat posed by the hazard is a basis for identifying scenarios. If the potential for undesirable consequences of the hazard manifests in an occurrence, that constitutes an event. A fire scenario is a fire incident characterized by a sequence of events. Fire hazards include heat sources (for ignition) and fuels (type, arrangement, products of combustion). An initiation hazard might be heating equipment. A contributing hazard might be an earthquake, which could cause the heating equipment to come in contact with an unintended fuel source. If the fuel ignites because the heating equipment was knocked over in an earthquake, that is an event. If the fire spreads to adjacent fuels and continues to grow, that is a scenario.

A fire scenario is a qualitative, time-sequence-based description of a fire that identifies key events that characterize the fire. It should describe the fire from initiation until burnout or extinguishment, including performance of passive or active fire protection systems that may be present. It should also identify outcomes in terms of whom or what is exposed to the fire and what the magnitude or severity of the harm is. Scenario clusters

are groups of scenarios that have some, but not necessarily all characteristics in common, and are expressed at a level of detail appropriate for engineering analysis. Scenario clustering is needed because any individual scenario (sequence of events) will have negligible frequency data. For example, a fire

Consequence analyses are often undertaken using analytical or computational tools, assessing such factors as performance of a building's fire protection systems for the defined fire scenario.

scenario may start as: "A lit candle tips over onto an upholstered chair in a living room. The chair ignites and the fire grows." Frequency data for this exact scenario may not exist. However, a scenario cluster might be: "An open flame ignites combustible fuel package within a living area." Data to support frequency assessment of this scenario cluster could be found in resources such as NFPA fire statistics reports.

Frequency Analysis, Consequence Analysis and Data

A key factor that distinguishes FRA from fire hazard analysis (FHA) is the inclusion of an estimate of the likelihood that an event or scenario will occur. For the frequency analysis,

data are needed from reliable sources. This may include entities such as NFPA, which report fire statistics; insurance companies, which collect fire data; and manufacturers or others, such as the Center for Chemical Process Safety, which have component and system reliability data.⁶ Databases such as NFIRS⁷ capture data on extent of fire spread (e.g., contained to item of origin, room of origin, etc.), which can be helpful in looking at reliability of containment.

Consequence analyses are often undertaken using analytical or computational tools, assessing such factors as performance of a building's fire protection systems for the defined fire scenario. However, they can also make use of historical data, from similar operations or occupancies, at least to benchmark the process. Expert judgment can also be applied for screening purposes.

Risk Estimation

To develop a risk estimate, one combines information generated during the frequency and consequence analyses of the scenarios of concern. This can be accomplished in a variety of ways, including qualitatively, semi-quantitatively and quantitatively. Qualitative approaches treat both frequencies and consequences qualitatively, and include methods such as risk matrices and risk indices. The NFPA Fire Safety Evaluation System,⁸ the risk matrix approach in MIL-STD-882D,⁹ and the risk binning approach outlined in DOE-STD-3009¹⁰ are examples of this. An example of the risk binning and risk matrix approach is illustrated in Tables 1 and 2 and Figure 2.¹¹

Semi-quantitative approaches combine quantitative and qualitative aspects. Semi-quantitative frequency approaches use sources such as actuarial data, which provides data for quantitative frequency analysis, but qualitative consequence analysis. Semi-quantitative consequence approaches use fire effects modeling for quantitative consequence analysis and treat frequencies qualitatively. These

approaches can be used with event trees or other analysis frameworks.

Event tree analysis (ETA) is often used to analyze complex situations with several possible scenarios, where several fire or life safety systems are in place or are being considered. Event trees are developed for a scenario, with frequencies and consequences described, and the risk then estimated. One method for quantifying fire risk from multiple fire scenarios is given as:^{11,12}

$$\sum Risk_i = \sum Loss_i \times F_i$$

where

$Risk_i$ = Risk associated with scenario i

$Loss_i$ = Loss associated with scenario i

F_i = Frequency of scenario i occurring

A final type of risk estimation technique is the benefit-cost approach, which either determines costs required to achieve various levels of risk reduction, or determines optimum levels of fire protection based against expected losses. These approaches are often employed within the insurance industry and by facility management to balance acceptance, mitigation, transfer, or avoidance decisions. Output is often expressed in terms of expected losses or costs, which include capital expenditures, maintenance costs, and expected losses.

GUIDANCE FOR FIRE RISK ASSESSMENT

Given the growing interest in the use of risk assessment techniques for building fire safety evaluation, a number of organizations have prepared guidance documents that are useful to designers and approval authorities (i.e., AHJs) in relation to buildings.* These guides are not risk assessment methodologies or

risk analysis techniques. Rather, they are directed at assisting practitioners in selecting the appropriate methodology for any given building and ensuring that the process of risk assessment and approval is undertaken in a proper engineering manner.

SFPE Engineering Guide: Fire Risk Assessment

The *SFPE Engineering Guide: Fire Risk Assessment*⁴ is aimed at qualified practitioners who are undertaking design and evaluation of buildings and/or process fire safety. The document provides guidance on the selection and use of risk assessment techniques and provides a recommended process to follow. The *SFPE Fire Risk Assessment Guide* does not specify particular risk assessment methods or techniques. However, it highlights

- A recommended process for fire risk assessment (Figure 1)

- Tools that may be used for hazard identification
- Sources of data for risk assessment
- Approaches to consequence modeling
- Methods for calculating fire risk
- Documentation of fire risk assessment

The *SFPE Guide* is structured to follow the flowchart represented in Figure 1, providing guidance and information association with each step in the process. This information is supported with many references and a comprehensive list of information sources for further reading for each step of the risk assessment process.

NFPA 551, Guide for the Evaluation of Fire Risk Assessments

NFPA 551, *Guide for the Evaluation of Fire Risk Assessments*,¹³ was developed in the United States in recognition of the fact that fire risk assessment

*The discussion is excerpted from the chapter, *Building Fire Risk Analysis*, to be published in the 5th Edition of the *SFPE Handbook of Fire Protection Engineering*.

| Acronym | Description | Frequency Level (median time to event) | Description |
|---------|---------------------------|--|---|
| A | Anticipated, expected | $>10^{-2}/\text{yr}$ (<100 years) | Common incidents that may occur several times during the lifetime of the building |
| U | Unlikely | $10^{-4} < f < 10^{-2}/\text{yr}$ (100 to 10,000 years) | Events that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this probability class include UBC-level earthquake, 100-year flood, maximum wind gust, etc. |
| EU | Extremely unlikely | $10^{-6} < f < 10^{-4}/\text{yr}$ (10,000 to 1 million years) | Events that will probably not occur during the life cycle of the building |
| BEU | Beyond extremely unlikely | $<10^{-6}/\text{yr}$ (>1 million years) | All other accidents |

Table 2. Example Frequency Criteria Used for Probability Ranking¹¹

methods are increasingly being used in developing fire and life safety solutions for buildings and other facilities. This guidance document is directed at those responsible for approving or evaluating fire and life safety solutions based on a fire risk assessment. It provides a framework that describes the properties of a fire risk assessment, particularly where it is being used in a performance-based regulatory framework. As a result, this guide is suited to a building or fire official or other authority having jurisdiction required to evaluate or approve a building design where the design is being supported by a fire risk assessment. Like the *SFPE Engineering Guide: Fire Risk Assessment*, NFPA 551 neither specifies particular fire risk assessment methods nor attempts to set acceptance criteria. Rather, it sets out the technical review process and documentation that should be used by those evaluating or approving. The review process is illustrated in Figure 3.

NFPA 551 defines five categories of fire risk assessment methods in order of increasing complexity, namely

- Qualitative methods
- Semi-qualitative criteria-based methods
- Semi-qualitative consequence methods

- Quantitative methods
- Cost-benefit risk methods

It highlights the importance of identifying the objectives of any fire risk assessment and other factors that should be considered by those undertaking fire risk assessments. For each of the five categories of methods, the characteristics of each approach are identified, and issues of inputs and outputs, assumptions and limitations, selection of fire scenarios, and uncertainty are discussed.

BS 7974-7, Probabilistic Risk Assessment

The British Standards Institute (BSI) provides a number of fire-related design standards. A framework for the application of fire safety engineering principles for the design of buildings is provided within BS 7974. This document is supported by the Published Document series PD 7974 Parts 0 to 7. The final document, Part 7, provides guidance for the probabilistic risk assessment of buildings.¹⁴ The document provides a framework for risk assessment commensurate with a number of approaches. Specifically, the document provides guidance with regard to acceptance criteria for life safety and financial assessments,

which may use either comparative or absolute methodologies.

The absolute criteria for individual risks and societal risk are provided. The logic tree is illustrated using both event trees and fault trees. An assessment methodology using complex analysis techniques is also provided. The annex to this document provides guidance about the probability of fire starting, depending on the type and use of the building. Further, the average area damaged and the distribution of damage are provided.

There are also valuable statistics on the frequency distribution of the numbers of deaths attributed to fire, the probability of flashover, and reliability data concerning active and passive fire safety systems. These data are principally based on U.K. fire statistics recorded over a representative sample period and as such are considered a valuable source of information, although generally applicable to U.K. projects.

ISO 16732-1 Fire Safety Engineering – Fire Risk Assessment

ISO 16732-1¹⁵ provides the conceptual basis for fire risk assessment by stating the principles underlying the quantification and interpretation of fire-related risk. The principles and concepts



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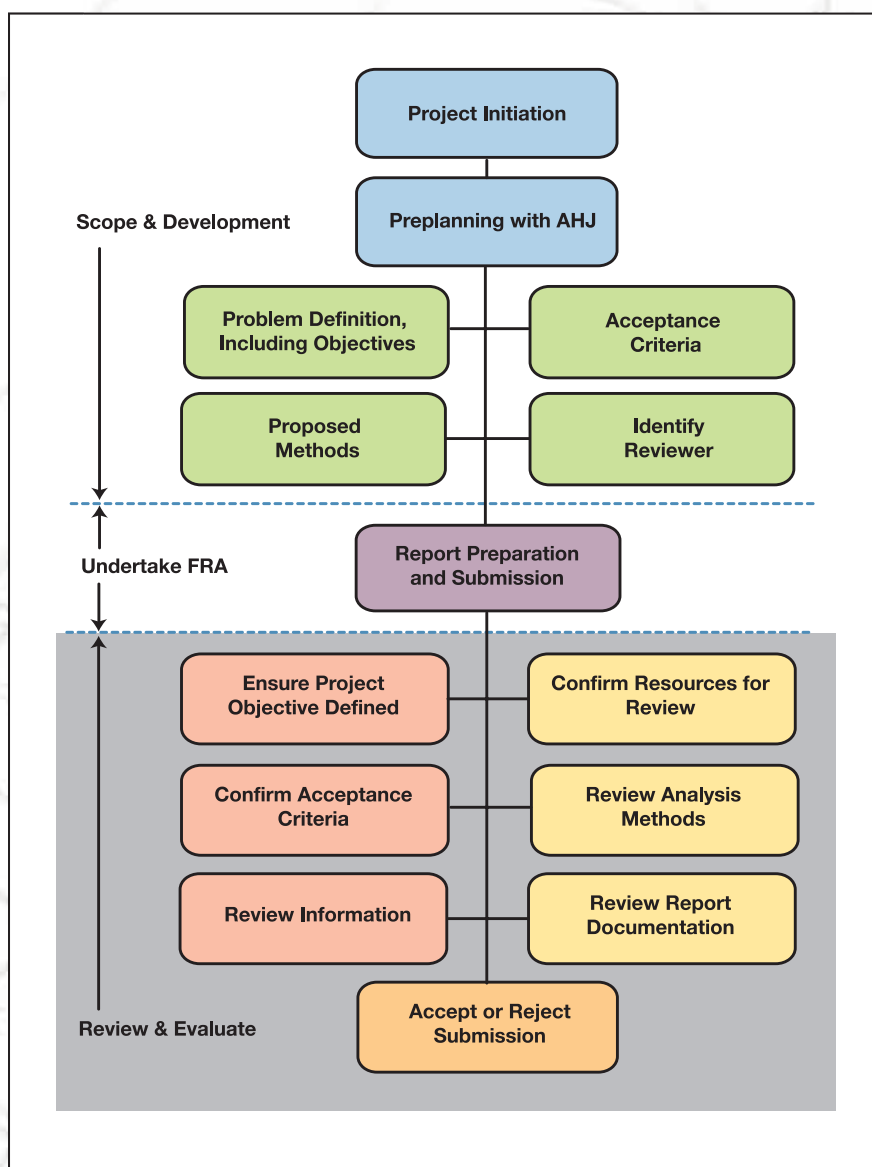


Figure 3. NFPA 551 Review Process

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outlined in the standard can be applied to any fire safety objectives, including life safety, conservation of property, business continuity, preservation of heritage, and protection of the environment.

The fire risk principles discussed in the standard apply to all fire-related phenomena and user applications, which means that the principles can be applied to all types of fire scenarios. In ISO 16732-1, principles underlying

the quantification of risk are presented in terms of the steps to be taken in conducting a fire risk assessment. These quantification steps are initially placed in the context of the overall management of fire risk and then explained within the context of fire safety engineering.

The use of scenarios and the characterization of probability (or the closely related measure of frequency) and consequence are then described as steps in fire risk estimation, leading to

the quantification of combined fire risk. Guidance is also provided on the use of the information generated, i.e., on the interpretation of fire risk.

Finally, there is guidance on methods of uncertainty analysis, in which the uncertainty associated with the fire risk estimates is determined and the implications of that uncertainty are interpreted and assessed. As described by ISO 16732-1, risk management includes risk assessment, but also typically includes risk treatment, risk acceptance, and risk communication (see Figure 4).

TEXTBOOKS

There have been new chapters added to the *SPFE Handbook of Fire Protection Engineering* on various aspects of fire risk assessment, e.g., by industry, occupancy type, and sector (built environment, transportation), with each new edition. As another indicator of the growing interest in fire risk assessment, and the desire for information relative to tools and techniques for fire risk assessment, a number of textbooks have been published in the last decade.

Evaluation of Fire Safety,¹⁶ while not strictly a text on fire risk assessment, includes many aspects of fire risk assessment throughout. Written by a collection of five leading authorities in fire safety engineering, the text includes chapters on sources of statistical fire loss data, measurements of fire risk, various fire risk evaluation methods (e.g., point systems, logic trees, stochastic fire risk modeling, and the fire safety concepts tree and derivative approaches). It provides a comprehensive suite of information for anyone embarking on fire safety evaluation of the built environment.

Following the tragic events of Sept. 11, 2001, the text *Extreme Event Mitigation in Buildings: Analysis and Design*¹⁷ was published to provide a resource for understanding and assessing building performance under extreme events. While not focused solely on fire, the text provides information on



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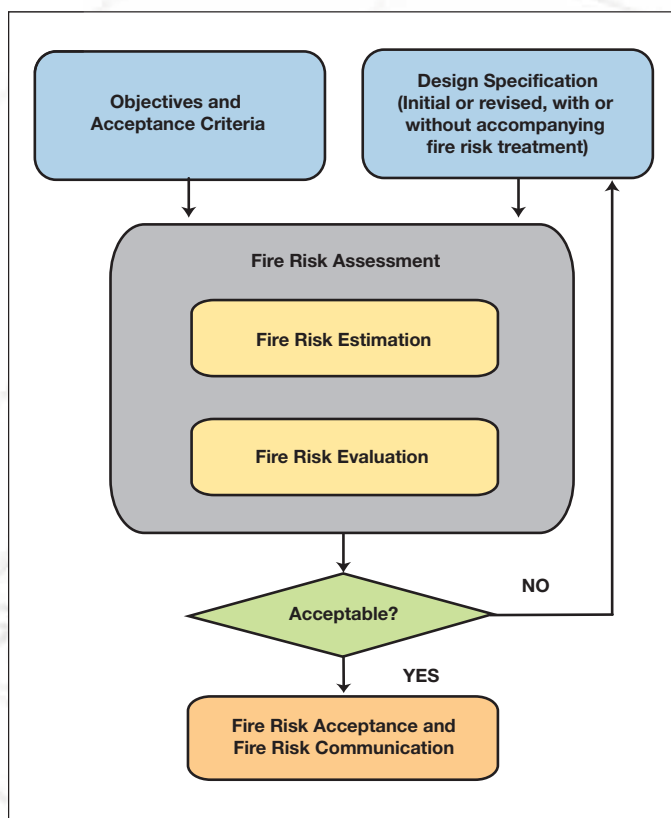


Figure 4. ISO Fire Risk Management Concept¹⁵

assessing likelihood of occurrence, potential impacts, and strategies for mitigation for a wide range of extreme events – natural, technological, and deliberate, while aiming to achieve a balance of acceptable levels of risk, performance, and cost. The text outlines how risk-informed performance-based analyses can be used to help make important risk mitigation decisions.

In 2007, a trio of risk experts from Australia published the book, *Risk Analysis in Building Fire Safety Engineering*.¹⁸ As the title implies, this text is focused on tools and techniques that are fundamental to applying risk concepts in fire safety engineering. It starts with elements of probability theory required for the understanding of risk analysis, then transitions into various tools for risk analysis, including the beta reliability index, Monte Carlo analysis, event tree and fault tree analysis, and cost-benefit analysis. Several chapters are then provided relative to modeling the probabilistic and stochastic aspects of fire safety systems. Case studies are provided to illustrate the application of these concepts in performance-based fire safety design.

*Principles of Fire Risk Assessment in Buildings*¹⁹ is presented in two parts: Part I overviews simple approaches to fire risk assessment, and Part II outlines a fundamental approach to fire risk assessment—considering fire growth, smoke spread, occupant response, and other factors using fire risk assessment concepts. This book was authored by an expert in the field who has developed models for fire risk assessment.

Most recently, two renowned fire risk experts from the UK

collaborated on the 2011 text, *Quantitative Risk Assessment in Fire Safety*.²⁰ This text presents a broad ranging discussion of qualitative, semi-quantitative and quantitative risk assessment techniques—discussing sources of data, structuring of the assessment technique, assessment, and evaluation. Probabilistic and stochastic analysis of fire development and spread and response of fire safety systems is also provided. Reliability of fire safety systems, performance of people, and effectiveness of the fire services are also presented.

These texts, as well as others written for specific industries, hazards, and risks, provide fire protection engineers with additional resources for tackling the challenges of building fire risk analysis.

Brian J. Meacham is with Worcester Polytechnic Institute.

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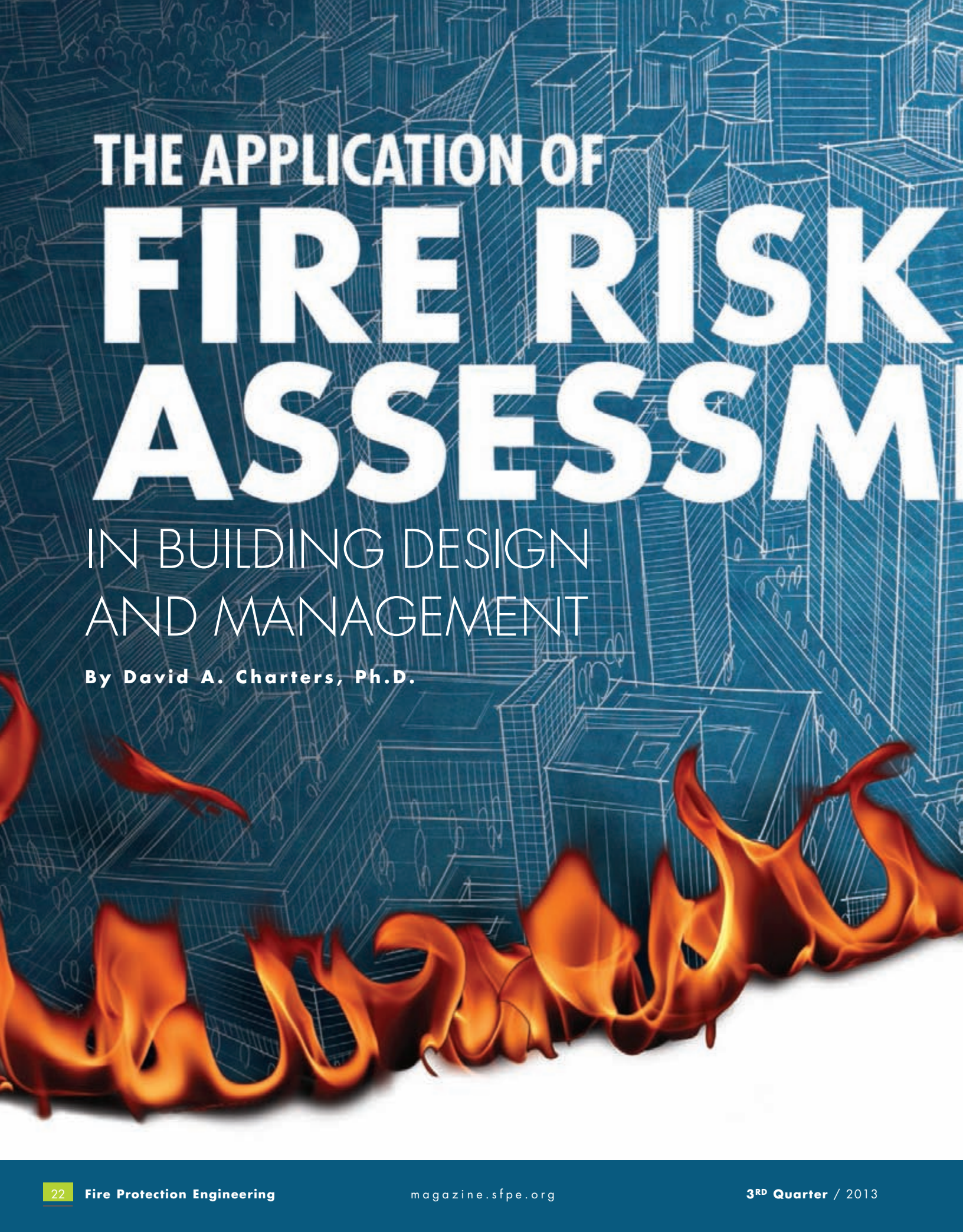
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THE APPLICATION OF FIRE RISK ASSESSMENT

IN BUILDING DESIGN
AND MANAGEMENT

By David A. Charters, Ph.D.



WHY ASSESS FIRE RISKS?

For the vast majority of history, fire risks have not been assessed for the design of buildings, so why start now? There are a number of answers to this question, but the primary motivation is to avoid the many and varied multiple fatality fire disasters that have occurred in the past. These disasters are well known to fire professionals; to avoid the risk of omission, they are not listed here.

Paradoxically, one of the things that past disasters have in common is that they are all different. They are in different buildings types, with different causes and contributory factors. So it seems whatever is done to prevent the last disaster from happening again, the next disaster is likely to be almost completely different. Fire risk assessment provides the opportunity to address the potential risks from all foreseeable potential future disasters, not just the last one.

Another reason for undertaking fire risk assessment

| Occurrence Frequency, F | Range | Rating |
|-------------------------|--------------------------------|--------|
| Never | < 1 in 10,000 years | 0 |
| Remote | 1 in 1,000 to 1 in 9,999 years | 1 |
| Rare | 1 in 100 to 1 in 999 years | 2 |
| Infrequent | 1 in 10 to 1 in 99 years | 3 |
| Occasional | 1 in 1 to 1 in 9 years | 4 |
| Frequent | Once to 10 times per year | 5 |
| Common | > 10 times per year | 6 |

Table 1. Example of Frequency Ratings for the Matrix Method

in building design is that risk (and its management) is at the heart of the engineering process, standards, testing, certification, etc. For example, a slightly tongue in cheek definition of engineering is that:

“Engineering is the art of modelling materials we do not wholly understand, into shapes we cannot precisely analyse, so as to withstand forces we can properly assess, in such a way that the public has no reason to suspect the extent of our ignorance.”

That quote, by the way, was by the president of the Institution of Civil Engineers in 1946, so perhaps one of its other messages is that even mature engineering disciplines never stop questioning the basis on which they practice.

Closer to performance-based fire safety design practice, the principle of ‘equivalency’ is often used to determine whether an alternative design solution is adequate. Equivalency can be defined as:

“...demonstrate that a building, as designed, presents no greater risk to occupants than a similar

type of building designed in accordance with well-established codes.”

Although the equivalency of most alternative solutions can be assessed at face value or by using deterministic performance-based analysis (such as smoke movement and evacuation analyses), the true metric of equivalency by this definition is risk.

Most fire risk assessments, however, are undertaken because it is a legal requirement. In some countries, it is a legal requirement to have a fire risk assessment that is suitable and sufficient. High hazard industries globally tend to have regime where a safety case is required to operate; often these safety cases are risk-based and include fire as a hazard. In many countries, legislation relating to corporate governance also requires boards of directors to manage the risks (including fire) that the organization faces.

QUALITATIVE FIRE RISK ASSESSMENT

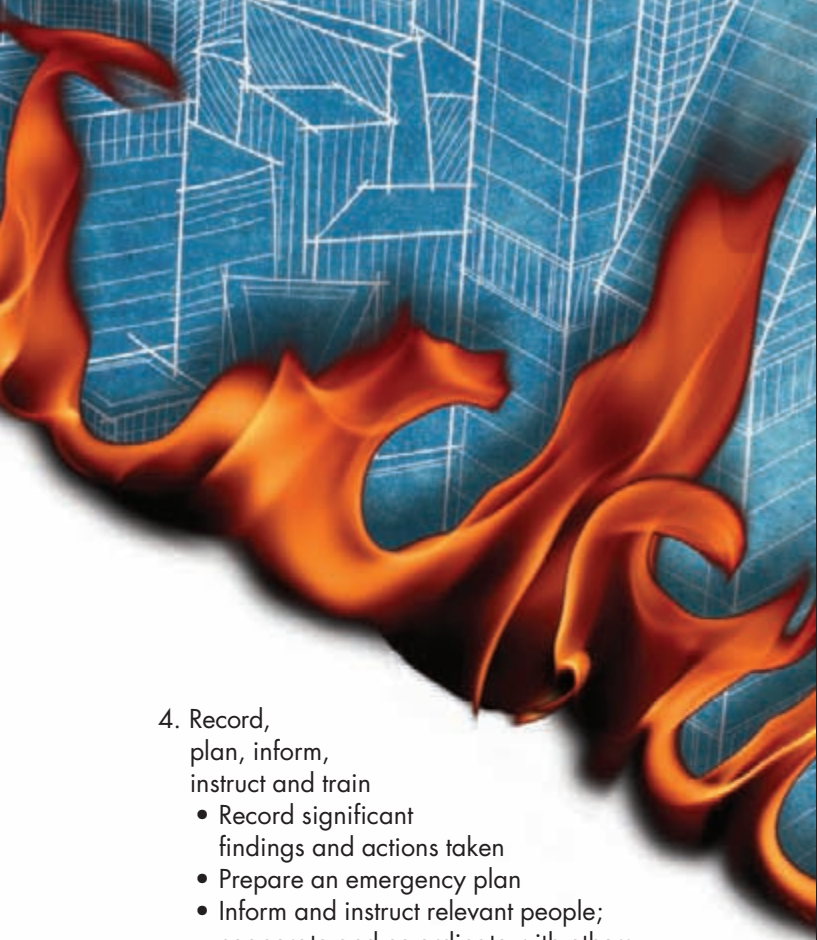
Most people in society undertake risk assessments without realizing it – for example, when crossing the road.

Sometimes fire protection engineers do likewise. For example, the review process at the start of any performance-based fire safety design process [known as Fire Protection Engineering Design Brief (FPEDB) or Qualitative Design Review (QDR)²] usually contains a list of tasks including:

- Review the structural design of the building
- Set fire safety design objectives
- Identify fire hazards and potential consequences
- Identify trial fire safety designs
- Agree upon acceptance criteria and method(s) of analysis
- Identify the fire/occupant scenarios for analysis
- Report

The process involved in qualitative fire risk assessment of existing buildings (in the UK³) identifies the following tasks:

1. Identify fire hazards
 - Sources of ignition
 - Sources of fuel
 - Sources of oxygen
2. Identify people at risk
 - People in and around the premises
 - People especially at risk
3. Evaluate, remove, reduce, and protect from risk
 - Evaluate the risk of a fire occurring
 - Evaluate the risk to people from fire
 - Remove or reduce fire hazards
 - Remove or reduce the risks to people
 - Detection and warning
 - Fire-fighting
 - Escape routes
 - Lighting
 - Signs and notices
 - Maintenance



4. Record, plan, inform, instruct and train
 - Record significant findings and actions taken
 - Prepare an emergency plan
 - Inform and instruct relevant people; cooperate and co-ordinate with others
 - Provide training
5. Review
 - Keep assessment under review
 - Revise where necessary

There is similarity between these and other qualitative risk assessment processes.^{4,5,6,7,8} Qualitative assessments of risk alone may be sufficient for small and simple premises where fire risks are naturally low. However, qualitative methods may not be sufficient on their own for larger, more complex premises, where the risks from fire might naturally be higher.

SEMI-QUANTITATIVE FIRE RISK ASSESSMENT

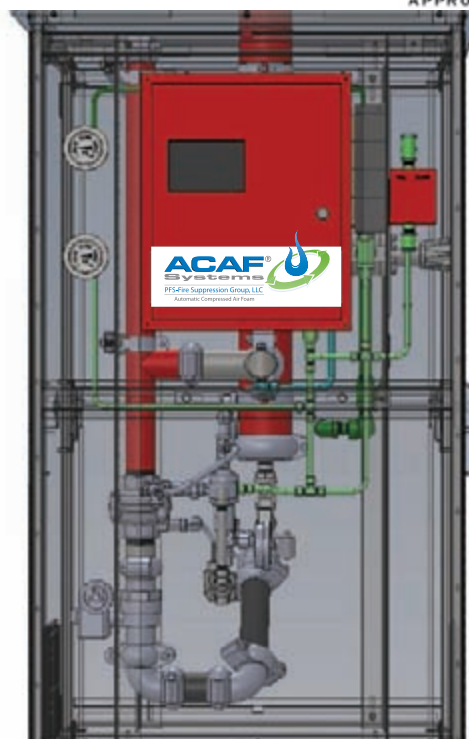
Often, there is a need to identify a wide range of fire risks and then prioritize the way these risks are addressed. Semi-quantitative fire risk assessment provides a way of assessing and prioritizing a whole range of fire risks that may be present in a complex building.

The matrix method is one of the most popular and robust examples of these types of approaches to risk assessment. The matrix method defines a series of categories for how often things might go wrong (Table 1) and another series of categories for how bad unwanted fire events might be (Tables 2 and 3).

Each rating in each series usually represents an order of magnitude range, and so no great precision is

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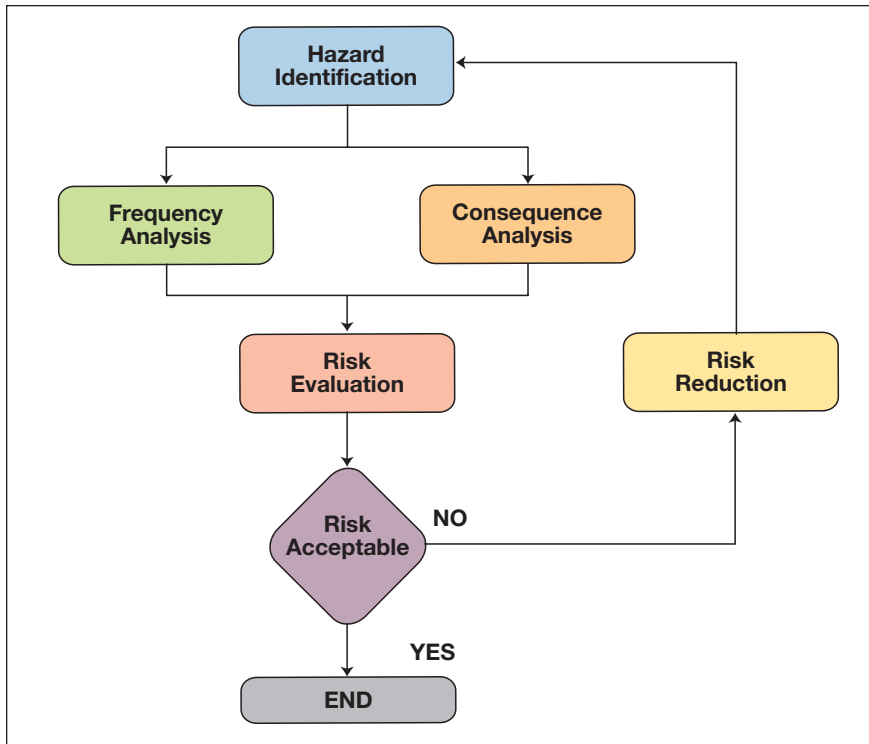


Figure 1. Quantitative Fire Risk Assessment Process⁶

| Severity (Life Safety), S | Rating |
|---------------------------|--------|
| None | 0 |
| Minor Injuries | 1 |
| Major Injuries | 2 |
| One Fatality | 3 |
| Multiple Fatalities | 4 |

Table 2. Example of Severity Ratings for the Matrix Method

| Location | Risk Rating |
|---------------------------|-------------|
| Extension Site Works | 7.0 |
| Retail Outlets | 6.0 |
| Concourse and Forecourt | 5.0 |
| Platforms and Access Road | 5.0 |
| Clothes Store | 4.0 |
| Underground Station | 3.0 |
| Public Highway | 3.0 |
| Hotel Way | 2.0 |

Table 3. Example of Combined Risk Ratings for the Matrix Method

implied in the matrix method. With the assistance of a group of people familiar with the building under consideration and relevant historical information, one can assign each area an occurrence frequency and a severity rating. These ratings can then be combined to give a risk rating for each area (Table 3). This can be a powerful way of prioritizing risk reduction or more detailed analysis on risks that are highest.

Although these comparative risk ratings can be helpful in prioritizing risk reduction and identifying areas worthy of further analysis, they offer insufficient refinement for comparison between alternative life safety solutions or criteria or for investment appraisal of further fire safety investment. Better information is needed to perform these more detailed tasks.

THE LARGEST FIRE EXPERIMENT IN THE WORLD

In the quest for better information to predict levels of fire risk, and given that:

“What can go wrong, will go wrong.” – Disreali

“If you can’t measure it, you can’t control it.” – Lord Kelvin

“If one would divine the future, then one must study the past.” – Confucius

It might be worth considering the largest fire experiment in the world and its participants. Every time a building is used, in a philosophical sense it could be considered an experiment in fire safety. Almost always, the “experiment” ends safely and there is no fire. Every time a building has a fire presents an opportunity to measure fire risk by collecting data, with the intention of improving control over it. This data can be analyzed for information on areas of concern or types of buildings whose fire safety might need improving.

This can be a very powerful way of looking back at fire safety across segments of buildings or specific building types, but may not be very helpful when considering the future potential fire risks of a specific building under design.



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

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

What are the real cost differences between CPVC and steel?

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

What are some of the lifetime risks to CPVC and steel?

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

What do the histories of CPVC and steel in fire sprinkler systems say about their futures?

CPVC has been used in fire sprinkler systems for less than 40 years. More than 50 materials and/or products have been identified as incompatible and cannot come into contact with CPVC.

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

How specific should specifications be?

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

Why has this liability transferred to contractors, AHJs and engineers, when it previously fell on the manufacturer?

The contractor chooses the materials for the fire sprinkler system and submits them to the engineer for approval prior to installation. The AHJ then gives final approval. Thus, if the system fails due to improper CPVC use, the contractor and all involved in the process are held liable for selecting improper materials.

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- Solder flux
- Oil- or solvent-based paint
- Polyurethane (spray-on) foams
- Residual oils with HVAC applications
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- Sleeving material
- Spray-on coatings
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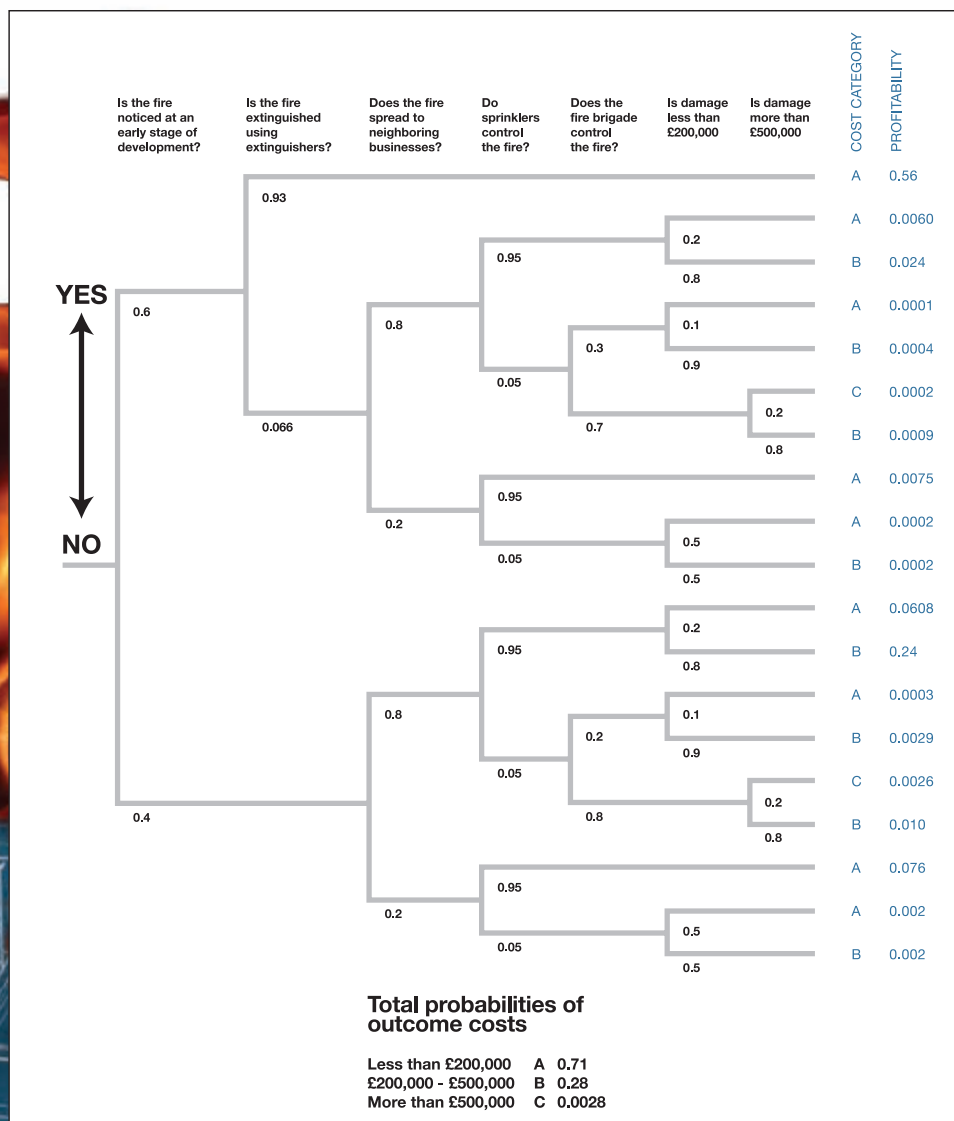


Figure 2. Example of an Event Tree⁹

QUANTITATIVE FIRE RISK ASSESSMENT

To consider the future potential fire risks of a specific building under design, full quantitative fire risk assessment might be necessary. This approach combines the probabilistic information from fire report data with predictions of the physical consequences of fire events.

Figure 1 shows the main tasks in a fully quantitative fire risk assessment where:

- Hazard identification – *what can go wrong?*
- Frequency analysis – *how often is it likely to happen?*
- Consequence analysis – *how bad might it be?*
- Risk acceptance – *what should be done about it?*

How Often Might It Go Wrong?

One of the major challenges to quantifying future fire risk for a specific building design is that the events of greatest concern are very rare, and in many cases may not have happened yet and are not recorded in fire report data. Therefore, there is a need to break the fire event process down into many sub-events (for which there is data) so that they can be reconstructed to predict the probable frequency of fire events that have not happened yet.

Typically, the way this is done is through event trees and fault trees (Figures 2 and 3).

Event trees are helpful in considering all the possible outcomes (on the right-hand side) from an initiating event (on the left-hand side), which is usually ignition for fire risks. The frequency of the initiating event can be estimated from fire report data, and the conditional probabilities of the sub-events can be quantified from fire report data or fault trees.

Fault trees are helpful in quantifying the probability of a top event of concern (such as the failure of a fire protection system) from all the potential root causes (at the bottom), again quantified from fire report data.

It is not uncommon for concerns to be raised over the quality of data used in this analysis. However, the reasons why quantitative risk assessments are undertaken, in spite of the limitations of the available data, include:

- A lot can be learned about the failure modes of (and so improve) a design by simply constructing fault and event trees.



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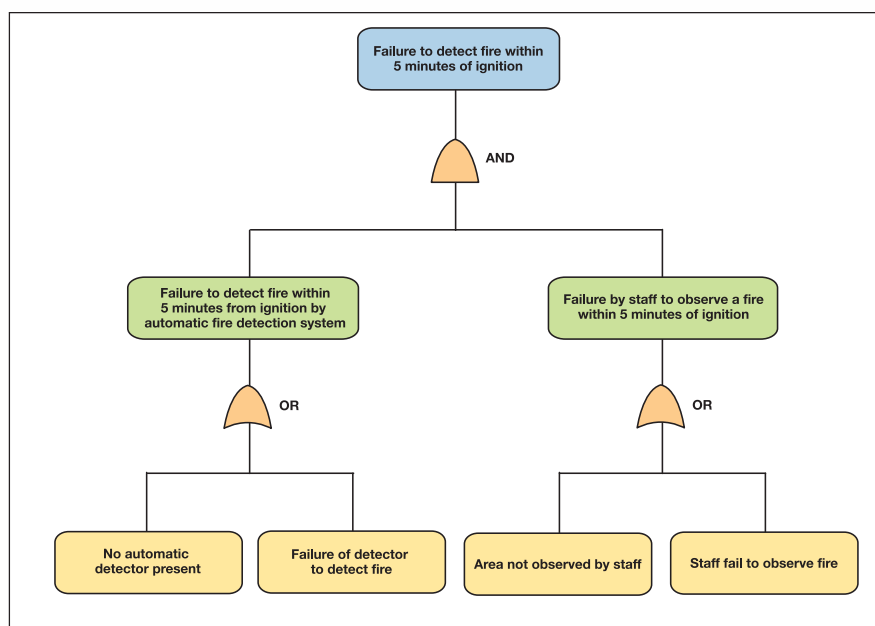


Figure 3. Example of a Fault Tree¹⁰

- The numerical outcome should never be treated as a precise prediction; it is just another way of better informing a design decision, in the same way that prescriptive standards and deterministic performance-based analysis are used to improve design decisions.

So quantitative assessment of fire risk should not be treated as an accurate prediction – any more than a fire test on a new item can guarantee the performance of all subsequent items in all applications throughout a product's life. However, they can both improve the risk outcome of a design.

How Bad Could It Be?

Having estimated how often it might go wrong, to predict levels of fire risk, it is also necessary to consider how bad the outcome of a range of fire events might be. The most potentially accurate way of estimating how bad a fire might be is through full-scale fire experiments.

While this might be the most interesting way to predict consequences, for the wider range of fire events under consideration in quantitative risk assessment, it

would quickly become prohibitively expensive and time consuming. Therefore, most quantitative fire risk assessments use computer models to predict consequences.

What Should Be Done About It?

Having quantified the fire risks from a building design based on the frequency and consequence analysis, the crucial question then becomes what should be done about it. To inform this decision, it is worth considering why people accept or tolerate risk.¹¹

The most common reason that people accept or tolerate risk is simply that they are not aware of it. The risks associated with asbestos and smoking used to fit into this category. Simply undertaking a fire risk assessment should help reduce the number of fire risks.

The next most common reason that people tend to accept risks is that the risk is so small to be of little or no (negligible) concern. People also tolerate risks where there is a significant benefit as a result of the activity associated with the risk. An example of this is travelling by road,

which continues to be popular even when many people are injured and killed in road accidents each year.

Risk acceptance also identifies some interesting paradoxes. For example, why are most people who have a fear of flying happy to drive? Flying is much safer than driving, yet people tend to have more of a fear of flying. The difference can usually be explained by the insight that people are happy to accept a higher level of risk in an activity if they feel they have some control over the level of risk. So people feel they have a large degree of risk control when driving (voluntary risk) and little risk control (involuntary risk) when flying. This might also explain why societies are generally more tolerant of fire risks in single dwellings than they are in public buildings.¹²

For fire risk assessment in design, acceptance criteria can vary:

- For life safety (in the absence of absolute risk criteria), fire risks are usually compared to the fire risks for a similar type of building designed in accordance with well-established codes;
- For financial fire safety objectives, there is usually some financial cost/benefit or rate of return on investment criteria.

EXAMPLES OF THE APPLICATION OF FIRE RISK ASSESSMENT TO BUILDING DESIGN

In the following cases, quantitative fire risk assessment was used in conjunction with, not instead of, prescriptive guidance and



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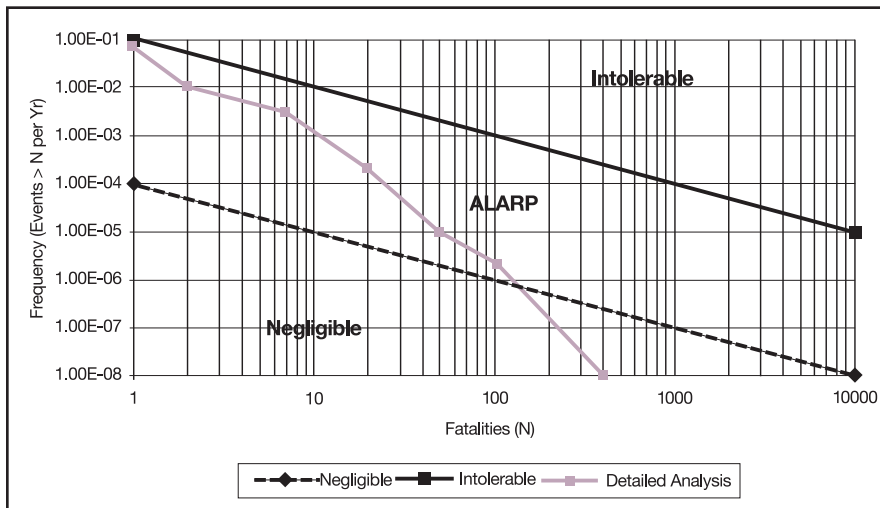


Figure 4. Example of F-n Curve Showing Different Levels of Risk⁷

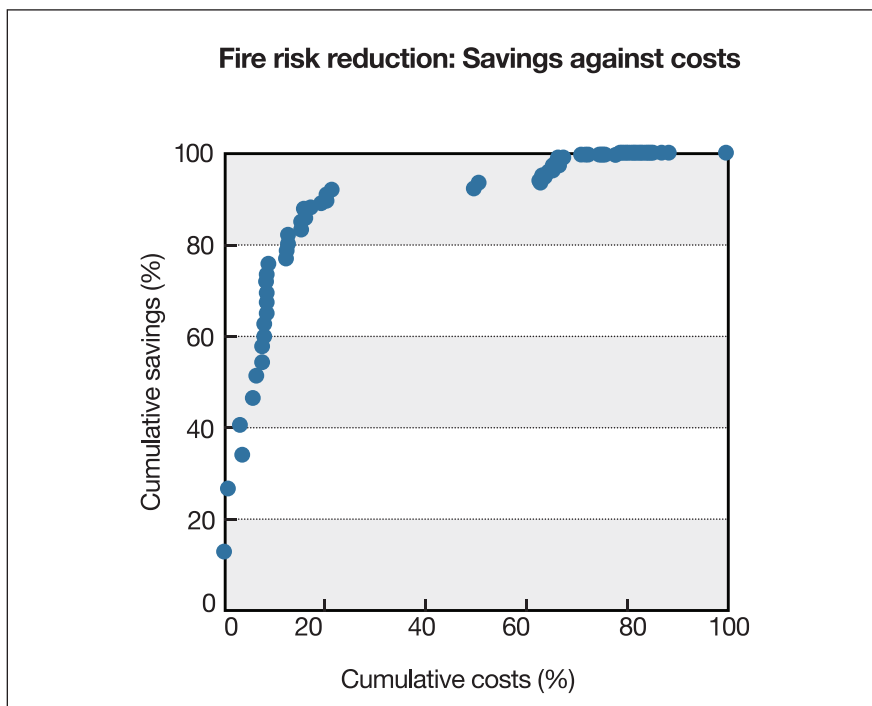


Figure 5. Example of Risk/Cost Benefit Ratios for A Range of Fire Safety Investment Options¹²

deterministic performance-based fire safety design to give additional insights and more complete perspective on the fire safety design of the buildings.

Fields Shopping Center, Denmark

Fields was the first shopping center to be built in Denmark. While

its design might be considered standard in some countries, the development was in the context of a general concern surrounding fire safety in retail premises. The Authority Having Jurisdiction (AHJ) asked for a quantitative fire risk assessment to supplement the code-compliant and performance-based design aspects of the project.

Due to its general concerns surrounding retail fire safety, the AHJ developed some absolute fire risk criteria. The fire risk assessment indicated that the fire risks in all retail areas of the development were below the risk criteria. The predicted level of risks (similar to Figure 4) also showed a difference between small units and large units (with risks in the latter being higher). At this early stage in the design, the system designers were able to reduce the level of fire risk in the large units at minimal additional cost by increasing the redundancy and reliability of some of the key fire protection systems.

Rail Infrastructure

Although life risks from fire were historically and consistently low, a major rail infrastructure operator was concerned about the number of fires, unwanted fire signals and their financial consequences for the business.¹³ Therefore, a series of risk workshops using the matrix method was undertaken to prioritize the areas of highest fire risk and identify potential risk reduction measures for consideration.

The risk cost/benefit of these risk reduction measures was then quantified, and they were all presented on a graph in order of cost/benefit ratio (similar to Figure 5).

What the graph showed was that 80% of the risk reduction benefit could be realized from just 15% of the potential investment. This meant that for a £3million investment, there would be a return of £14million year on year (no payback or discounted cash flow analysis); in addition, a poor investment of £22million could be avoided. There was also a benefit for the users of the rail infrastructure, in that many of the risk reduction measures improved punctuality, while maintaining fire safety.

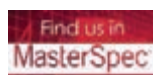


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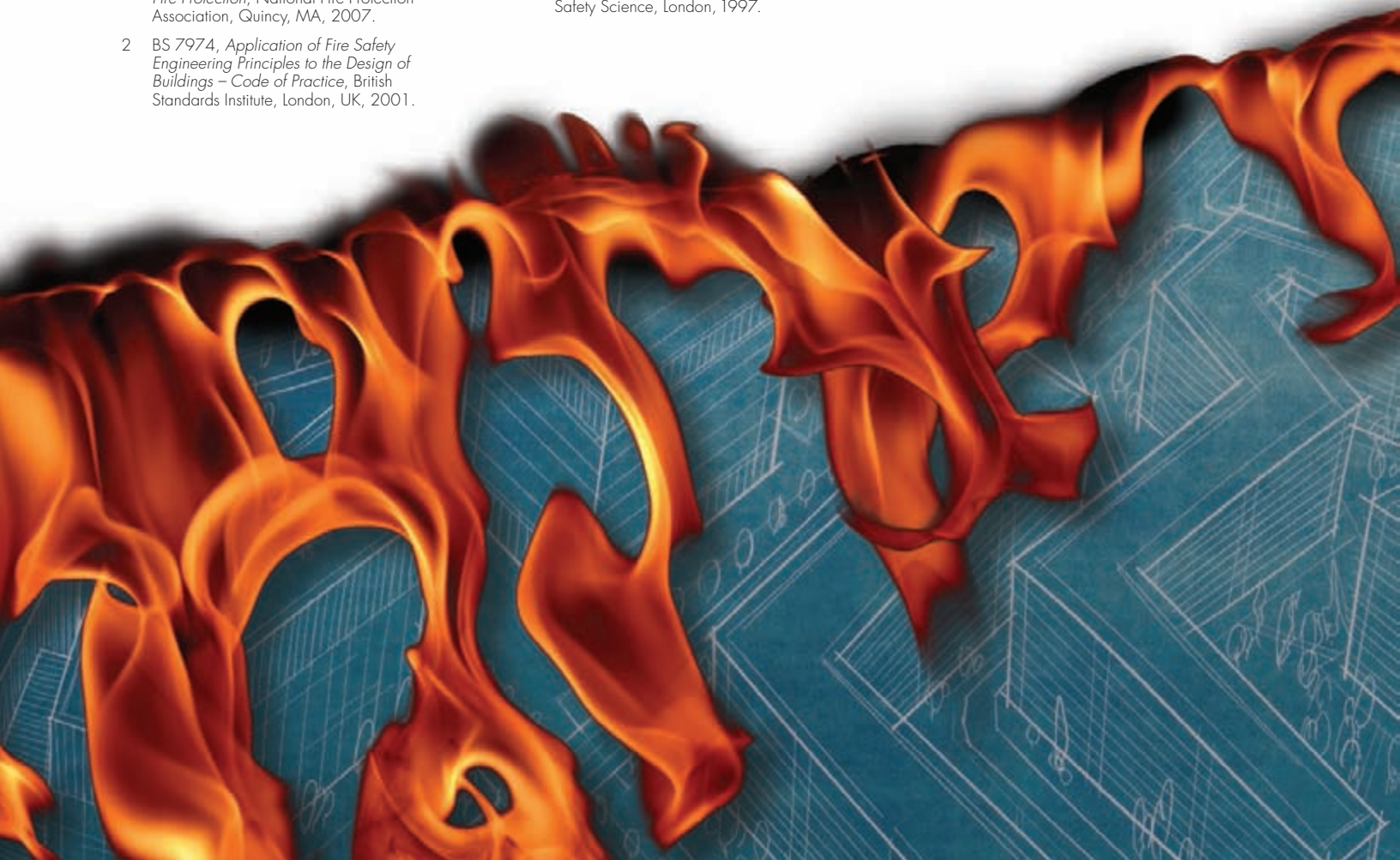
FIRE SAFETY GUIDANCE

Much of the current prescriptive guidance is now informed by statistical analysis of fire report data, and in some cases, no changes are made unless it is risk/cost beneficial. For example, in the UK, the proposal to discount an additional staircase in high-rise buildings following 9/11 was found not to be risk/cost beneficial. That is, the increased cost in prescribing the provision far outweighed any likely reduction in risk. Therefore, the prescription also includes the alternative of upgrading the lift provision for use during evacuations.

David A. Charters is with
BRE Global.

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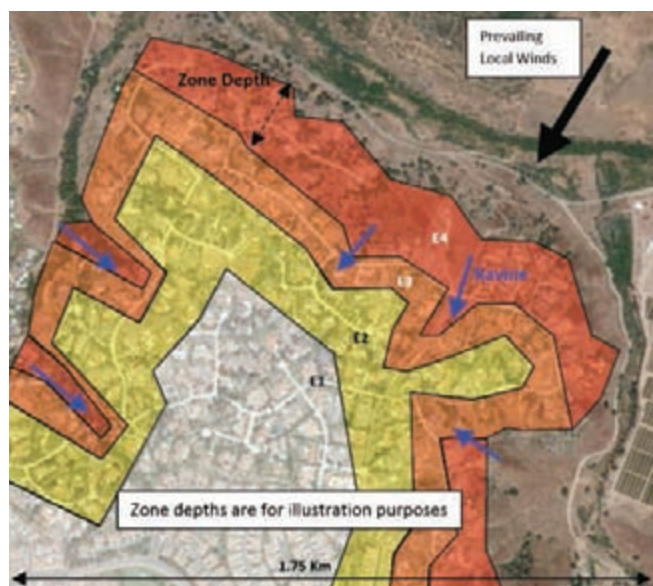
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Framework for Addressing the National Wildland Urban



This article is an excerpt from NIST Technical Note 1748.¹

Destruction of homes and businesses from Wildland Urban Interface (WUI) fires has been steadily escalating, as has the fire suppression costs associated with them. Since 2000, more than 3,000 homes per year have been lost to WUI fires in the United States. The WUI fire problem affects both existing communities and new construction.

One of the fundamental issues driving the destruction of homes at the interface is the very limited consideration of potential wildland fire and ember exposures in building codes and standards. The limited information currently available does not address the full range of realistic WUI exposures and offers little context for the design of ignition-resistant landscapes and buildings. While the principles of ignition and fire spread at the WUI have been known,

By Alexander Maranghides
and William Mell, Ph.D.

Interface Fire Problem



actual exposure quantification has been very limited. The resulting gap between exposure and structure ignition has therefore resulted in a lack of tested and implementable hazard mitigation solutions.

As an example, there is currently little quantifiable information that links the ember generation from wildland fuels (treated or untreated) to building assemblies testing. Additionally, there has been

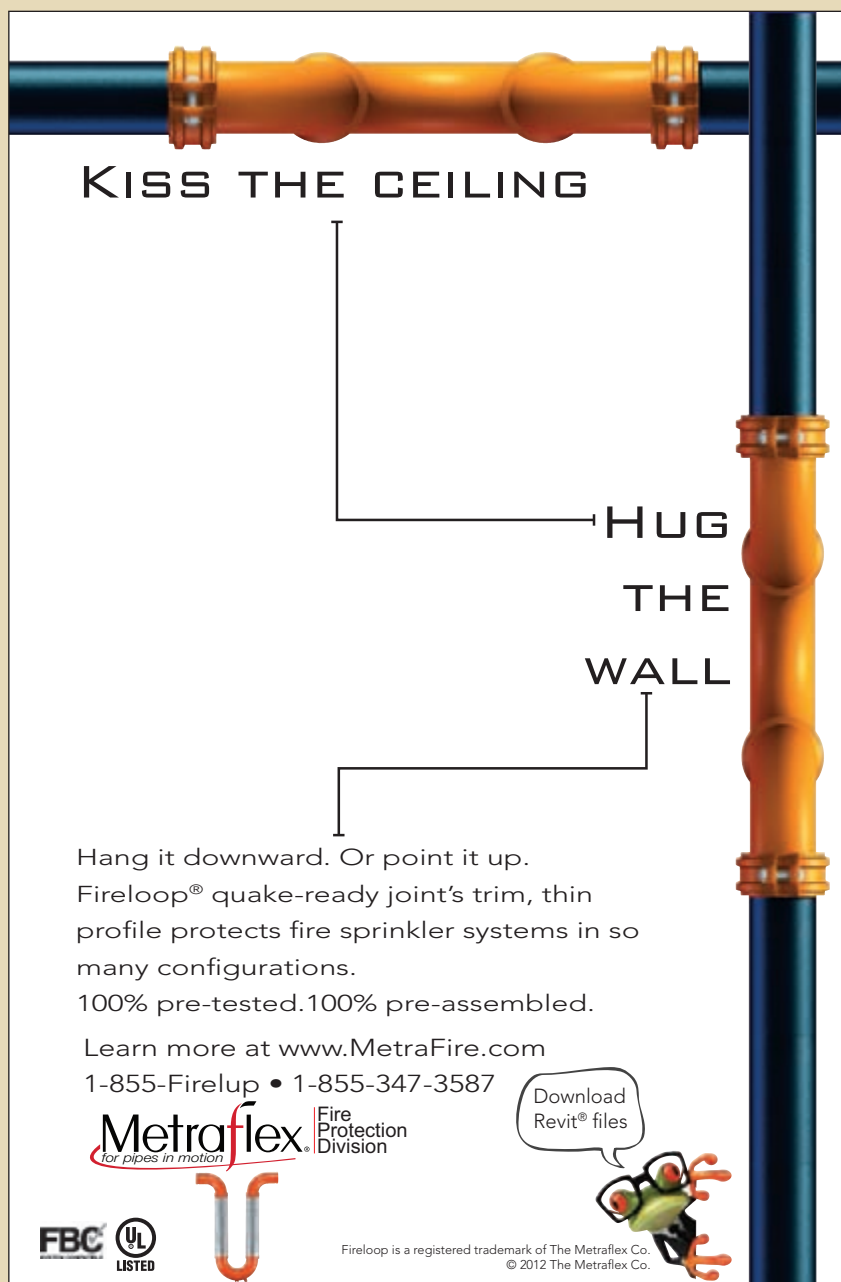
no consideration of first responder and homeowner safety to ember/fire exposure.

WUI fires present a unique challenge to the firefighting and fire protection engineering communities. The scale of the events can be vast, spanning in many cases more than 40,000 ha (100,000 acres), and the moving fire perimeter can be tens of kilometers long with potentially thousands of structures at risk.

To date, post-fire WUI field data collections have failed to address three critical components: impact of defensive actions on structure survivability, systematic documentation of structure response to WUI fires, and quantification of fire and ember exposures.

The severity of the fire depends on vegetative (wildland and ornamental) and structural fuels, topography, and weather. Compared to hurricanes and earthquakes, fire intensity can vary significantly over relatively short distances (fractions of a kilometer) requiring complex fire suppression and evacuation operations.

The WUI exposure scale concept is based on quantifying expected fire and ember exposure throughout an existing or proposed new WUI community. The proposed WUI scale can be used to explicitly identify WUI areas that have a fire and ember exposure problem, as opposed to areas that meet housing density or wildland vegetation requirements. The scale therefore can be used to provide the boundaries where specific land use and/or building construction regulations would apply.



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CURRENT WUI BUILDING CODES AND STANDARDS PRACTICES

WUI building construction is influenced by codes and standards developed from the cumulative expertise and experience of the participating committee members. This includes the evaluation of structural performance during past WUI fires, limited laboratory work, and very limited WUI fire modeling.

WUI post-fire assessments consider structural performance, and if conducted systematically, should be used as part of a comprehensive approach that includes laboratory and full-scale experiments as well as computer modeling to guide and confirm the effectiveness of changes to buildings codes, standards, and best practices.

To date, post-fire WUI field data collections have failed to address three critical components: impact of defensive actions on structure survivability, systematic documentation of structure response to WUI fires, and quantification of fire and ember exposures.

EXISTING HAZARD SEVERITY ASSESSMENT SYSTEMS

An example of an existing community-scale hazard severity assessment program is the one developed by California Department of Forestry and Fire Protection (CAL FIRE). The CAL FIRE and Resource Assessment Program (FRAP) Fire Hazard Severity Zone is used to determine fire hazard on a 9 m (30 ft) grid. This information is applied in areas under state jurisdiction. FRAP is one of the few programs in the United States that links fire severity (exposure) and building codes (construction attributes). The FRAP system, with respect to building construction, is two-tiered: a structure is either in the WUI or it is not.

While FRAP links expected exposure to specific building code

requirements, its classification system focuses primarily on proximity to wildland fuels and does not address the likelihood that buildings could be destroyed due to other sources of fire and ember exposures, such as from an adjacent burning structure. Other similar programs with less complex

WUI hazard rating systems exist and are implemented across the United States.

The Home Ignition Zone (HIZ) concept represents another WUI hazard severity assessment framework designed to be implemented at a parcel or structure level.



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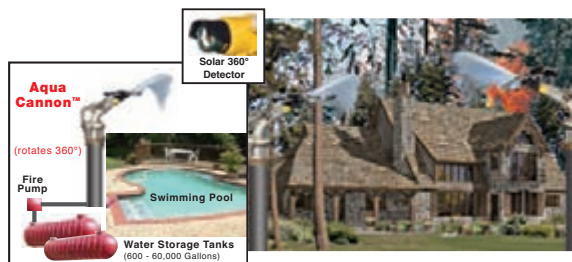
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HIZ includes the home and surrounding area within 30 to 60 m (100 to 200 feet). The method has been successfully used to educate homeowners on the different parameters that affect structure survivability.

The primary limitation of the HIZ methodology in the context of this article is that it does not offer a framework to link the fire and ember exposure threat to building codes and standards. An additional limitation of the HIZ system is that it does not account for WUI scenarios with higher housing densities. A framework similar to the HIZ is also used by the *International Wildland-Urban Interface Code*² as well as many other national and state hazard mitigation programs.

THE PROPOSED WUI SCALE

Fire behavior in the wildlands and the WUI is a function of fuel (vegetative and structural), topography and local weather during the event. A fire and ember exposure-driven WUI scale, therefore, needs to account for these local environmental conditions. Using such a rating, an overall WUI area may receive a range of ratings. The ratings will reflect the potential severity of a WUI fire event at specific locations. Additionally, the framework links fire and ember exposure and resident and firefighter safety.

The WUI scale is designed to the range of fire and ember exposure conditions experienced by structures at the WUI. Fire and ember exposure can be traced to

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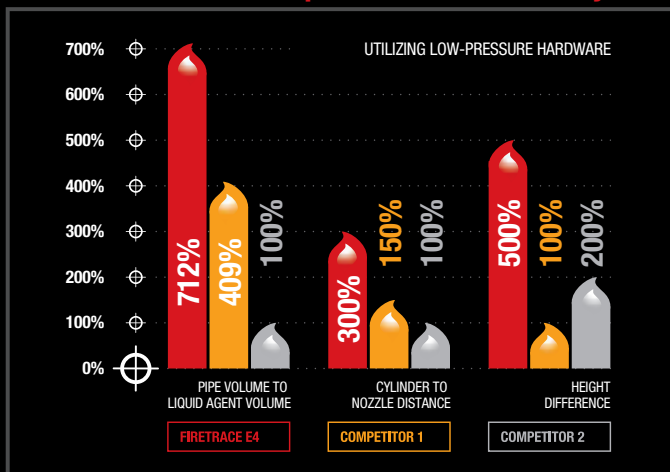
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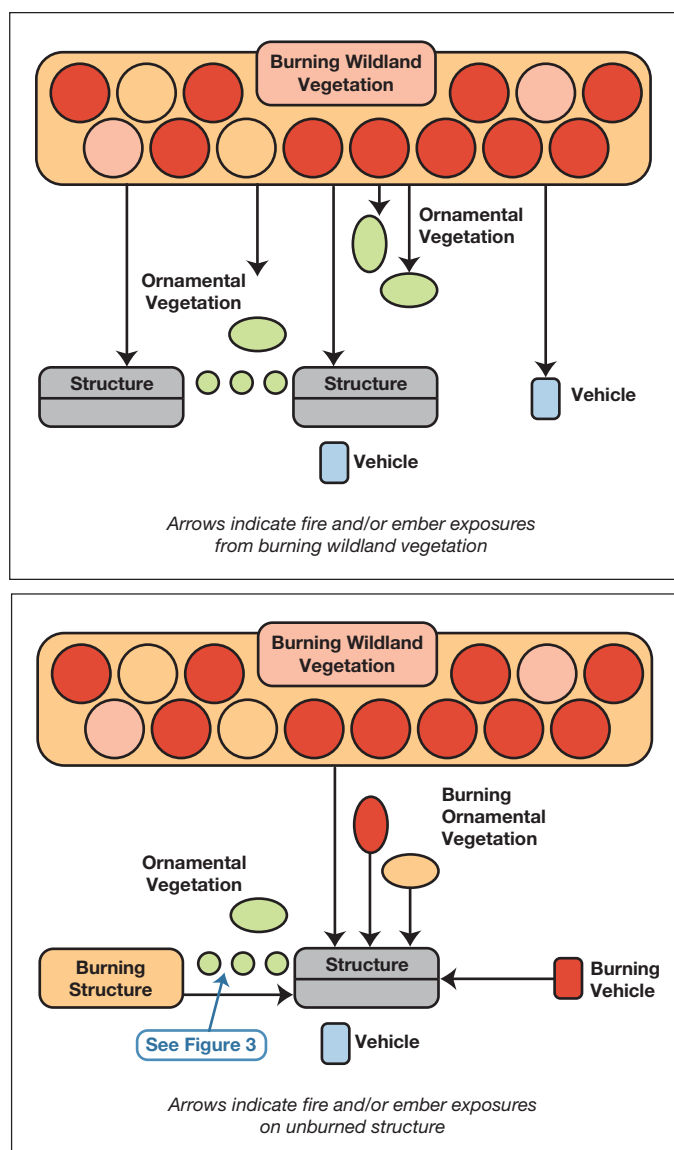


Figure 1. Primary Fuels Responsible for Fire and Ember Exposure at the WUI – Wildfire approaching a WUI community (top), with parts of the community ignited (bottom)

| Building Elements | Potential Ignition Vulnerability | |
|---------------------------|----------------------------------|-------------|
| | Embers | Direct Fire |
| Metal Frame Closed Window | No | Yes* |
| Untreated Wooden Deck | Yes | Yes |
| Attic Insulation | Yes† | No |

Table 1. Building Element Vulnerability to Ember and Fire Exposure

* Window may break under direct flame exposure.

† Combustible insulation may ignite from embers inside attic, away from exterior attic vents.

four primary sources of WUI fuel: wildland fuels, ornamental vegetation, structures (including homes, auxiliary buildings such as sheds and garages), and vehicles (Figure 1). The WUI-scale is designed by considering these sources as well as the local weather. These combined parameters are referred to as FTLW, which is short for fuels, topography, and local weather.

In the proposed framework, an exposure rating is uncoupled from ignition, so that the exposure rating is independent of the response to a particular structural element or landscaping attribute. The figure at the beginning of this article illustrates community ember exposure zones from a wildland fire. Figure 2 illustrates the proposed matrix for capturing fire and ember exposures from wildland fuels.

The proposed WUI scale is developed with the primary objective of reducing the ignition risk of buildings in the WUI. This will be accomplished by linking the ignition resistance required of structures to anticipated exposures by using the exposure scale. Also, an understanding of exposure can help improve the effectiveness of wildland fuel treatments.

During a WUI fire, a given structure can be exposed to fire and/or embers. Both threats need to be independently quantified and addressed. A structure can be hardened for embers, fire, or both. Table 1 is used to illustrate how three distinct building elements may be vulnerable to exposure from embers and/or fire.

Two issues must be addressed to make the scale quantitative: the critical lack of quantitative information on the exposure of structures to embers and fire; and the lack of a well-characterized, systematic effort that combines pre- and post-fire observations, laboratory, and field experiments, and fire modeling needed to characterize the ignition regimes of different WUI fuels.

TECHNICAL ASSUMPTIONS

The following assumptions are used in the development of the WUI scale:

1. The fire and ember exposure conditions at a given location can originate from fire in wildland fuels and fuels within the WUI community. The fire and ember exposure each zone experiences is the linearly combined exposures of the external (wildlands) and internally generated exposures. As an example, structures within a zone may experience a significant ember assault from its proximity to wildland fuels, and from any burning fuels within the zone itself.
2. During a WUI fire, both the fire exposure and ember assault at a given location will change with time. The fire and ember scales are intended to capture both



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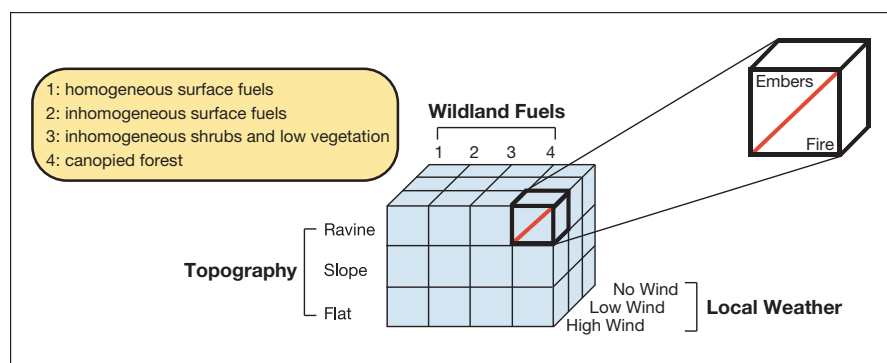


Figure 2. Capturing Exposure from Wildland Fuels

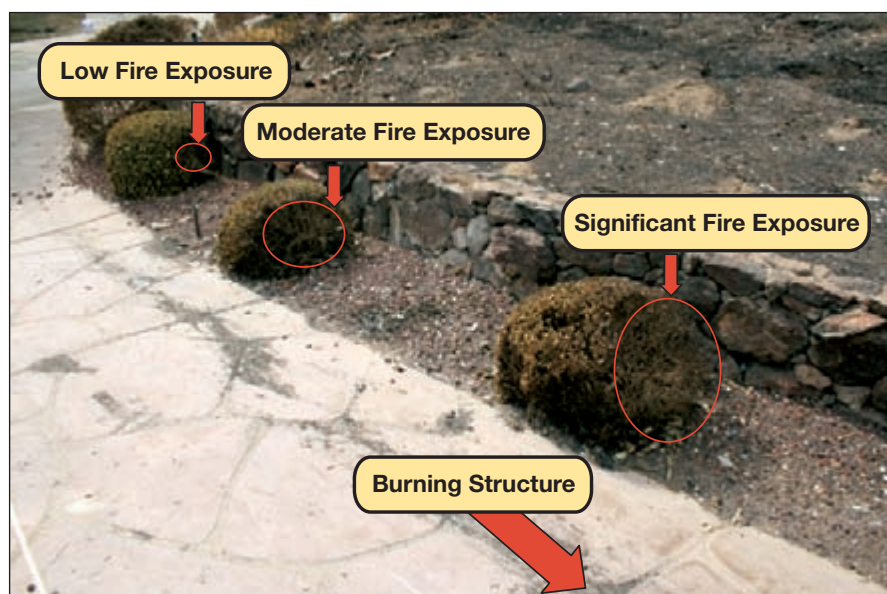


Figure 3. Fire Exposure from Burning Structure on Ornamental Vegetation – as a function of distance from the burning structure (NIST Photo, Witch/Guejito Fire, CA 2007)

the peak intensity and maximum duration of the exposure/assault.

The distance from the interface and width of each zone will be a function of fuel, topography and local weather (FTLW). The four zones selected for each of the fire and ember exposures are described next specifically as to exposure from the wildlands.

FIRE AND EMBER EXPOSURE FROM FIRE IN WILDLAND FUELS

Wildland fire and ember exposures in very high-risk areas can

result in significant structural losses at the perimeter of many communities. Field observations from first responders have identified burning homes as large ember generators, posing a significant threat to surrounding and particularly downwind structures and vegetation. By preventing the ignition of structures in very hazardous locations, significant reductions in further fire spread are achievable within WUI communities.

The proposed approach will therefore initially focus on fire and ember exposure from the fire in wildland fuels. Fire and ember exposure from burning structures, ornamental vegetation, or vehicles

will be considered at a later date following the same framework. This exposure framework, together with supporting updates to building codes and standards, will make the WUI scale directly applicable to new construction.

Additionally, the current approach will enable the WUI scale to be used for evaluating existing communities, highlighting weaknesses and identifying retrofit solutions. Figure 2 illustrates the fire and ember exposure matrix for wildland fuels. The proposed exposure matrix is developed using three categories for terrain: flat, steep slope, and ravine; and three categories for wind: no wind, low wind, and high wind. Four fuel categories will be used to provide an initial characterization: homogeneous surface fuels (such as prairie grasses), inhomogeneous surface fuels (such as palmetto), inhomogeneous shrubs and low vegetation (such as chaparral), and canopied forest (such as what is found in the Intermountain West). The selected topographical, weather, and fuel attributes, while not all-encompassing, provide realistic input ranges for the characterization of fire and ember exposures. Modeling and field data collection from prescribed burns will be used to define the specifics of the topography, weather, and fuel attributes.

In the future, a similar type of matrix will provide the fire and ember exposure from burning structures, ornamental vegetation, and vehicles in different local weather and topographical conditions.

ACKNOWLEDGMENTS

This work was made possible through technical collaboration with numerous organizations including but not limited to CAL FIRE, San Diego Building Codes Department, the International Code Council, and the National Fire Protection Association



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The authors also acknowledge Dr. Shyam Sunder, director, NIST Engineering Laboratory. This work is in part funded by the Joint Fire Science Program Project 11-1-3-29, "Evaluating the Effectiveness of Mitigations Activities in the Wildland Urban Interface."

Alexander Maranghides is with the National Institute of Standards and Technology. William Mell, Ph.D., is with the U.S. Forest Service.

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FIRE PROTECTION INSPECTION, TESTING, AND MAINTENANCE AND BUILDING FIRE RISK

By Francisco Joglar, Ph.D.

INTRODUCTION

Most, if not all of the codes and standards governing the installation and maintenance of fire protection systems in buildings include requirements for inspection, testing, and maintenance activities to verify proper system

operation on-demand. As a result, most fire protection systems are routinely subjected to these activities. For example, NFPA 25¹ provides specific recommendations of inspection, testing, and maintenance schedules and procedures for sprinkler systems, standpipe and hose systems, private fire service mains, fire pumps, water storage tanks, valves, among others. The scope of the standard also includes impairment han-

dling and reporting, an essential element in fire risk applications.

Given the requirements for inspection, testing, and maintenance, it can be qualitatively argued that such activities not only have a positive impact on building fire risk, but also help maintain building fire risk at acceptable levels. However, a qualitative argument is often not enough to provide fire protection professionals with the flexibility to manage inspection,



testing, and maintenance activities on a performance-based/risk-informed approach. The ability to explicitly incorporate these activities into a fire risk model, taking advantage of the existing data infrastructure based on current requirements for documenting impairment, provides a quantitative approach for managing

fire protection systems.

This article describes how inspection, testing, and maintenance of fire protection can be incorporated into a building fire risk model so that such activities can be managed on a performance-based approach in specific applications.

Fire risk is a quantitative measure of fire or explosion incident loss potential in terms of both the event likelihood and aggregate consequences.

RISK AND FIRE RISK

"Risk" and "fire risk" can be defined as follows:

- Risk is the potential for realization of unwanted adverse consequences, considering scenarios and their associated frequencies or probabilities and associated consequences.²
- Fire risk is a quantitative measure of fire or explosion incident loss potential in terms of both the event likelihood and aggregate consequences.³

Based on these two definitions, "fire risk" is defined for the purpose of this article as quantitative measure of the potential for realization of unwanted fire consequences. This definition is practical because as a quantitative measure, fire risk has units and results from a model formulated for specific applications. From that perspective, fire risk should be treated no differently than the output from any other physical models that are routinely used in engineering applications: it's a

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value produced from a model based on input parameters reflecting the scenario conditions. Generally, the risk model is formulated as:

$$Risk_i = \sum Loss_i \times F_i$$

where:

$Risk_i$ = Risk associated with scenario i

$Loss_i$ = Loss associated with scenario i

F_i = Frequency of scenario i occurring

That is, a risk value is the summation of the frequency and consequences of all identified scenarios. In the specific case of fire analysis, F and $Loss$ are the frequencies and consequences of fire scenarios. Clearly, the unit multiplication of the frequency and consequence terms must result in risk units that are relevant to the specific application and can be used to make risk-informed/performance-based decisions.

The fire scenarios are the individual units characterizing the fire risk of a given application. Consequently, the process of selecting the appropriate scenarios is an essential element of determining fire risk. A fire scenario must include all aspects of a fire event. This includes conditions leading to ignition and propagation up to extinction or suppression by different available means. Specifically, one must define fire scenarios considering the following elements:

- **Frequency** – the frequency captures how often the scenario is expected to occur. It is usually represented as events/unit of time. Frequency examples may include number of pump fires per year in an industrial facility; number of cigarette-induced household fires per year, etc.
- **Location** – the location of the fire scenario refers to the

characteristics of the room, building, or facility in which the scenario is postulated. In general, room characteristics include size, ventilation conditions, boundary materials, and any additional information necessary for location description.

- **Ignition source** – this is often the starting point for selecting

and describing a fire scenario, i.e., the first item ignited. In some applications, a fire frequency is directly associated to ignition sources.

- **Intervening combustibles** – these are combustibles involved in a fire scenario other than the first item ignited. Many fire events become “significant” because of

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secondary combustibles, i.e., the fire is capable of propagating beyond the ignition source.

- **Fire protection features** – fire protection features are the barriers set in place and are intended to limit the consequences of fire scenarios to the lowest possible levels. Fire protection features may include active (e.g., automatic detection or suppression) and passive (e.g., fire walls) systems. In addition, they can include “manual” features such as a fire brigade

or fire department, fire watch activities, etc.

- **Consequences** – scenario consequences should capture the outcome of the fire event. Consequences should be measured in terms of their relevance to the decision-making process, consistent with the frequency term in the risk equation.

Although the frequency and consequence terms are the only two in the risk equation, all fire scenario

characteristics listed previously should be captured quantitatively so that the model has enough resolution to become a decision-making tool.

The sprinkler system in a given building can be used as an example. The failure of this system on-demand (i.e., in response to a fire event) may be incorporated into the risk equation as the conditional probability of sprinkler system failure in response to a fire. Multiplying this probability by the ignition frequency term in the risk equation results in the frequency of fire events where the sprinkler system fails on demand.

Introducing this probability term in the risk equation provides an explicit parameter to measure the effects of inspection, testing, and maintenance in the fire risk metric of a facility. This simple conceptual example stresses the importance of defining fire risk and the parameters in the risk equation so that they not only appropriately characterize the facility being analyzed, but also have sufficient resolution to make risk-informed decisions while managing fire protection for the facility.

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Introducing parameters into the risk equation must account for potential dependencies resulting in a mischaracterization of the risk. In the conceptual example described earlier, introducing the failure probability on-demand of the sprinkler system requires the frequency term to include fires that were suppressed with sprinklers. The intent is to avoid having the effects of the suppression system reflected twice in the analysis, i.e., by a lower frequency by excluding fires that were controlled by the automatic suppression system, and by the multiplication of the failure probability.

MAINTAINABILITY AND AVAILABILITY

In repairable systems, which are those where the repair time is not negligible (i.e., long relative to the operational time), downtimes should be properly characterized. The term “downtime” refers to the periods of time when a system is not operating. “Maintainability” refers to the probabilistic characterization of such downtimes, which are an important factor in availability calculations. It includes the inspections, testing, and maintenance activities to which an item is subjected.

Maintenance activities generating some of the downtimes can be preventive or corrective. “Preventive maintenance” refers to actions taken to retain an item at a specified level of performance. It has potential to reduce the system’s failure rate. In the case of fire protection systems, the goal is to detect most failures during testing and maintenance activities and not when the fire protection systems are required to actuate. “Corrective maintenance” represents actions taken to restore a system to an operational state after it is disabled due to a failure or impairment.

In the risk equation, lower system failure rates characterizing fire protection features may be reflected in various ways depending on the

parameters included in the risk model. Examples include:

- A lower system failure rate may be reflected in the frequency term if it is based on the number of fires where the suppression system has failed. That is, the number of fire events counted over the corresponding period of time would include only those where the applicable suppression system failed, leading to “higher” consequences.

The probability of a fire protection system failure on-demand reflects the effects of inspection, maintenance, and testing of fire protection features, which influences the availability of the system.

- A more rigorous risk-modeling approach would include a frequency term reflecting both fires where the suppression system failed and those where the suppression system was successful. Such a frequency will have at least two outcomes. The first sequence would consist of a fire event where the suppression system is successful. This is represented by the frequency term multiplied by the probability of successful system operation and a consequence term consistent with the scenario outcome. The second

sequence would consist of a fire event where the suppression system failed. This is represented by the multiplication of the frequency times the failure probability of the suppression system and consequences consistent with this scenario condition (i.e., higher consequences than in the sequence where the suppression was successful).

Under the latter approach, the risk model explicitly includes the fire protection system in the analysis, providing increased modeling capabilities and the ability of monitoring the performance of the system and its impact on fire risk.

The probability of a fire protection system failure on-demand reflects the effects of inspection, maintenance, and testing of fire protection features, which influences the availability of the system. In general, the term “availability” is defined as the probability that an item will be operational at a given time. The complement of the availability is termed “unavailability,” where $U = 1 - A$. A simple mathematical expression capturing this definition is:

$$A = \frac{u}{u + d}, \quad U = \frac{d}{u + d} = 1 - A$$

where u is the uptime, and d is the downtime during a predefined period of time (i.e., the mission time).

In order to accurately characterize the system’s availability, the quantification of equipment downtime is necessary, which can be quantified using maintainability techniques, i.e., based on the inspection, testing, and maintenance activities associated with the system and the random failure history of the system.

An example would be an electrical equipment room protected with a CO₂ system. For life safety reasons, the system may be taken out of service for some periods of time. The system may also be out for maintenance, or not operating due to impairment. Clearly,

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the probability of the system being available on-demand is affected by the time it is out of service. It is in the availability calculations where the impairment handling and reporting requirements of codes and standards is explicitly incorporated in the fire risk equation.

As a first step in determining how the inspection, testing, maintenance, and random failures of a given system affect fire risk, a model for determining the system's unavailability is necessary. In practical applications, these models are based on performance data generated over time from maintenance, inspection, and testing activities. Once explicitly modeled, a decision can be made based on managing maintenance activities with the goal of maintaining or improving fire risk. Examples include:

- Performance data may suggest key system failure modes that



could be identified in time with increased inspections (or completely corrected by design changes) preventing system failures or unnecessary testing.

- Time between inspections, testing, and maintenance activities may be increased without affecting the system unavailability.

These examples stress the need for an availability model based on performance data. As a modeling alternative, Markov models offer a powerful approach for determining and monitoring systems availability based on inspection, testing, maintenance, and random failure history. Once the system unavailability term is defined, it can be explicitly incorporated in the risk model as described in the following section.

EFFECTS OF INSPECTION, TESTING, AND MAINTENANCE IN THE FIRE RISK

The risk model can be expanded as follows:

$$Risk_i = \sum U \times Loss_i \times F_i$$

where U is the unavailability of a fire protection system. Under this risk model, F may represent the frequency of a fire scenario in a given facility regardless of how it was detected or suppressed. The parameter U is the probability that the fire protection features fail on-demand. In this example, the multiplication of the frequency times the unavailability results in the frequency of fires where fire protection features failed to detect and/or control the fire. Therefore, by multiplying the scenario frequency by the unavailability of the fire protection feature, the frequency term is reduced to characterize fires where fire protection features fail and, therefore, produce the postulated scenarios.

In practice, the unavailability term is a function of time in a fire scenario progression. It is often set to 1.0 (the system is not available) if the system will not operate in time (i.e., the postulated damage



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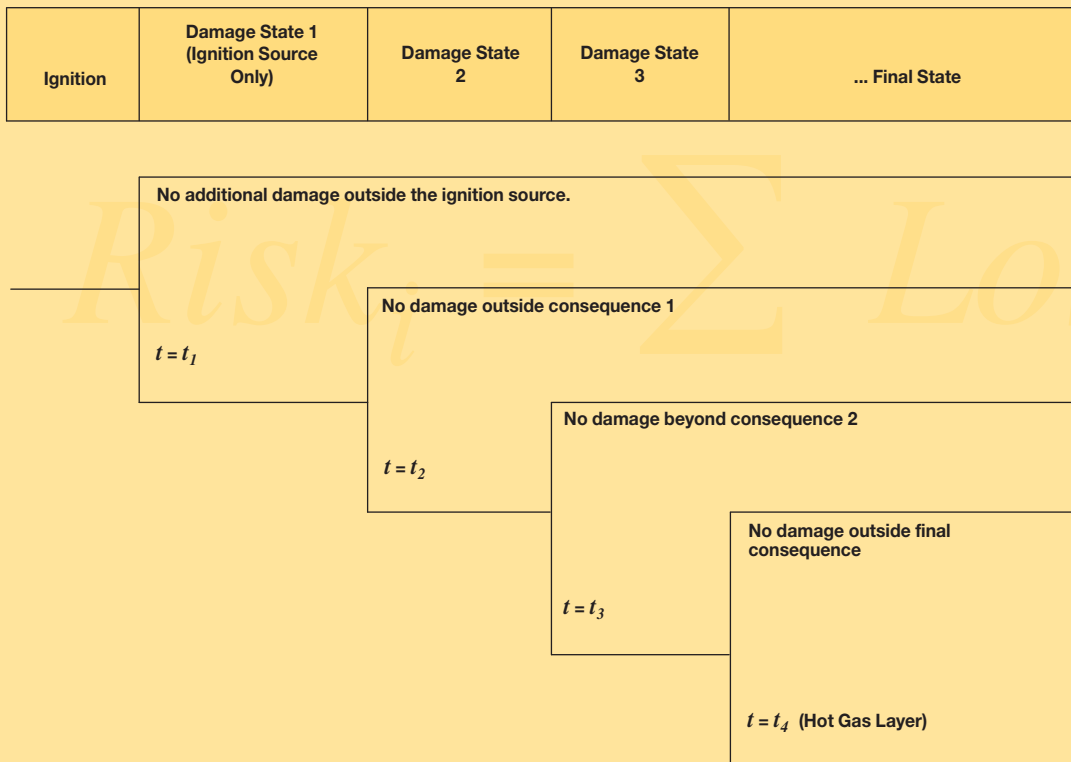


Figure 1. Example of a Fire Scenario Progression Event Tree

in the scenario occurs before the system can actuate). If the system is expected to operate in time, U is set to the system's unavailability.

In order to comprehensively include the unavailability into a fire scenario analysis, the following scenario progression event tree model can be used. Figure 1 illustrates a sample event tree. The progression of damage states is initiated by a postulated fire involving an ignition source. Each damage state is defined by a time in the progression of a fire event and a consequence within that time.

Under this formulation, each damage state is a different scenario outcome characterized by the suppression probability at each point in time. As the fire scenario progresses in time, the consequence term is expected to be higher. Specifically, the first damage state

usually consists of damage to the ignition source itself. This first scenario could represent a fire that is promptly detected and suppressed. If such early detection and suppression efforts fail, a different scenario outcome is generated with a higher consequence term.

Depending on the characteristics and configuration of the scenario, the last damage state may consist of flashover conditions, propagation to adjacent rooms or buildings, etc. The damage states characterizing each scenario sequence are quantified in the event tree by failure to suppress, which is governed by the suppression system unavailability at pre-defined points in time and its ability to operate in time.

Francisco Joglar is with Hughes Associates.

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- 1 NFPA 25, *Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems*, National Fire Protection Association, Quincy, MA, 2011.
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BATTERY CALCULATIONS FOR FIRE ALARM AND SIGNALING SYSTEMS



Poor planning and missing, incomplete or incorrect secondary power calculations are among the most common causes for rejection of a submittal to an engineer or to the authority having jurisdiction (AHJ). A previous article addressed the requirements for the features and performance of both primary and secondary power supplies.¹ The article showed how to determine the required demand and durations for the secondary power supply. This article shows how to use the demands and durations to calculate the net required capacity for batteries that are used as part or all of a secondary power supply.

Figure 1 shows that batteries will always be a part of a signaling system power supply. The most common configuration is where batteries are incorporated to provide separate, switched secondary power to the system. In that configuration, the batteries are connected in a way that allows the control unit power supply to switch from the primary source to the

secondary source when the primary is lost or disconnected.

The figure shows two arrangements for the use of batteries as a switched secondary power supply. The first is where the batteries supply the entire secondary power supply. The second is where the batteries back up a primary power supply that also includes a backup generator.

In the previous article, it was shown that the code permits a reduced duration for the operation of the batteries where the primary power supply includes a backup generator.² NFPA 72 does not refer to the UPS option as “secondary power”. Still, the batteries of the UPS provide that function. As noted in the previous article, the batteries on the UPS require the same duration, hence capacity, as those connected directly to the control unit. Operationally, the UPS is a Type 0 (per NFPA 111³) where the batteries always provide power to the system and are recharged by the primary power supply. Thus, there is no switchover that must take

place when primary power is lost.

For each of the three battery configurations permitted by NFPA 72, the code has specified the required duration (time, t) for battery operation. The load, or demand is the amount of current (I) supplied by the batteries at a particular time and is a function of the system design and configuration.

Most errors in calculating the required battery (and generator) capacity (stored energy, E) occur in determining the required load. The code specifies two types of loads (demands) and associated durations to be used for determining the required secondary supply capacity. The first is the normal, quiescent load. This is the amount of current that the system demands during its normal, non-alarm state. Depending on the type of system, the code requires that the batteries be capable of providing that amount of current for a specified period (see the first article). The code requires that at the end of the specified quiescent period, the system must be capable of supplying the alarm load for a specified period.

For general alarm systems, the demand current is based on the entire system operating in the alarm mode. This means that all notification appliances and emergency control function interfaces are operating. The demand for emergency voice alarm indication systems (EVACS) and mass notification systems (MNS) will actually vary over the required duration. Therefore, the code permits the capacity to be calculated using the full alarm load, but over a reduced duration in order to simulate the intermittent operation over a longer period. The total required capacity is determined by summing the capacity required to serve the quiescent load and the capacity required to serve the alarm load.

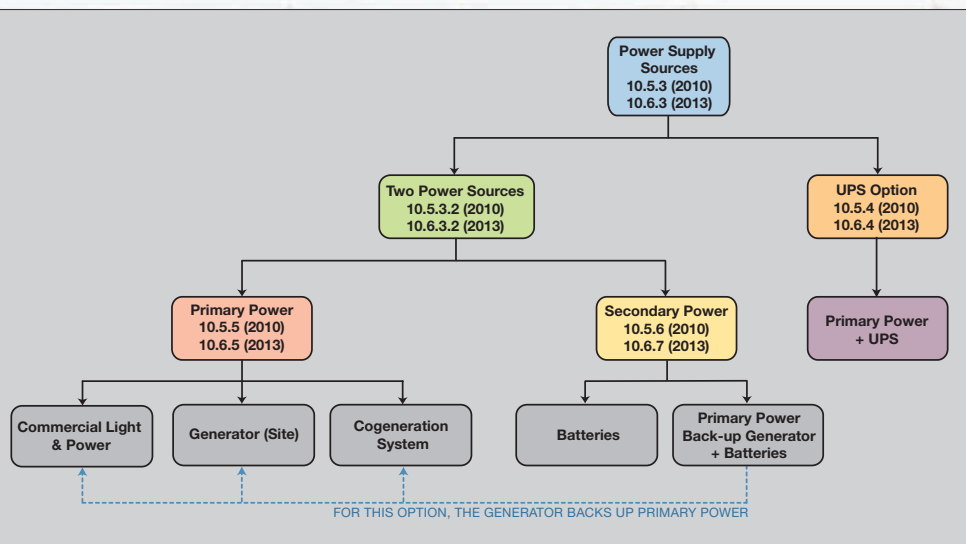


Figure 1. Power Supply Requirements

$$E_{Total} = E_{Normal} + E_{Alarm}$$

$$E_T = I_N t_N + I_A t_A$$

Where I is electrical current in amperes, t is the time in hours and E is energy in units of amp-hours.

As a minimum, the code requires that the batteries be sized to supply the actual (design) quiescent load and alarm loads for the specified durations. However, how often is the final installed quantity of devices and appliances the same as the original design? While calculations based on a design are a useful starting point, the code requires that the secondary power system be adequate for the final installed load. Therefore, engineers should do one of two things to assure compliance: 1) require recalculation after the final system configuration; or 2) require the capacity to be calculated using the full load capability of the system. If the first option is used, it is only fair that the contractor be compensated for any change orders that add load that must be accommodated for the completed installation.

The second option is the best practice, but is not required by code. For that option, if a circuit is rated for 2.0 amps by the manufacturer, the calculation would assume it is fully loaded even if only 0.75 amps of load is initially being installed. This would ensure that all future changes would not require a change in batteries. The same argument for the second option can be made for determining the required wire size.

To calculate the battery size using the minimum code approach, the quiescent and alarm loads must be tabulated and summed for all equipment, devices, and appliances connected to the power supply. If the second approach is used, the quantities of initiating devices and notification appliances is important only for determining the number of modules and circuits that will be provided to accommodate them. It is usually best to allow the installer and manufacturer to determine the number of modules and circuits because it is sometimes less expensive to install additional circuits

than it would be to use fewer, but longer circuits. Also, even if the load will be calculated using the full circuit capacity, it is best for the engineer to specify that the circuits not be loaded more than a certain percentage. This will further ensure that additional devices and appliances can be added without the need to add modules and circuits.

The battery calculations should be done by the installing contractor, system distributor or equipment manufacturer and then checked by the responsible designer and by the authority having jurisdiction (AHJ). The first step is to gather the manufacturers' published specification sheets for all devices, appliances, and equipment. It is necessary to list all components and the quantities used. For each item, the specifications will list the quiescent (normal, non-alarm) current (load) and the alarm current (load) in amps.

Table 1 is a simplified example for how the capacity of secondary batteries is calculated. For this example, the required duration is 24 hours in quiescent mode and five minutes (0.083 hours) in alarm mode. The calculation will be done for a specific system configuration with a specific quantity of devices and appliances. If the batteries are to be sized for full circuit loading (option 2), the list of initiating devices and notification appliances would be replaced with a listing of the circuits and their full load current capability.

The required capacity is calculated by multiplying the load by the required duration for both the quiescent condition and the alarm condition. In this example, for the quiescent condition, the total standby (quiescent) load of 0.9409 amps is multiplied by 24 hours to get 22.6 amp-hours of required quiescent capacity. The total alarm load of 4.6857 is multiplied by 0.083 hours to get a required alarm capacity of 0.4 amp-hours. They add together and round to a required capacity of 23 amp-hours. New in the 2010 edition of NFPA 72 is a required 20% factor of safety, bringing the net required capacity to 27.6, or 28 amp-hours after rounding.

Most manufacturers have calculation

programs to determine the battery capacity. In reality, most systems will have many more entries for panel components.

There are several entries in the above example worth discussing. The alarm current listed for the power supply is the current that the power supply uses as it supplies the other loads. The option 2 method could be modeled by simply assuming that the power supply is at full load. So, a power supply listed to provide a maximum of 4 amps would list 4 amps as the alarm load regardless of how many modules, circuits, devices, or appliances are actually connected to it.

For smoke detectors and any initiating devices that draw power, how many should be considered to be in alarm? This example has all 52 smoke detectors in alarm, but it is also common to use a number that represents the largest one or two fire areas in the building. The relays are shown to be energized in the non-alarm condition and dropping out (de-energized) upon alarm. Systems might also have relays that are normally not energized until there is an alarm.

The final step is to select a battery that has the required stored capacity and that can discharge at the required rates. In this example, a battery is needed that has a capacity of 28 amp-hours or more and that can discharge at a rate of 1 amp (0.9393 rounded) for 24 hours and then be able to discharge at a rate of 4.7 amps for a duration of 5 minutes.

An analogy might help. A gravity water tank has a certain maximum stored capacity. The flow rate from the tank is a function of the outlet and distribution piping and the height of water in the tank. When full, the hydraulic head is actually greater and the system will flow at a higher rate than when the tank is near empty. As the tank empties, the flow rate decreases.

The system (tank or batteries) must be designed to provide the required discharge at all stages of use. Battery manufacturers and suppliers can provide documentation regarding a battery's ability to discharge at certain rates at the end of the discharge cycle.

| Part # | Qty | Standby Current, Amps | | Alarm Current, Amps | |
|--------------------------------------|-----|-----------------------|------------------------------|---------------------|-----------|
| | | Unit | Sub-Total | Unit | Sub-Total |
| Panel Equipment | | | | | |
| Module A | 3 | 0.1000 | 0.3000 | 0.1700 | 0.5100 |
| Module B | 3 | 0.0261 | 0.0783 | 0.0267 | 0.0801 |
| Main Board | 1 | 0.1370 | 0.1370 | 0.3200 | 0.3200 |
| Power Supply | 2 | 0.1000 | 0.2000 | 0.1000 | 0.2000 |
| Initiating Devices | | | | | |
| Smoke Detectors | 52 | 0.0003 | 0.0156 | 0.0003 | 0.0156 |
| PB Smoke Det. | 2 | 0.0450 | 0.0900 | 0.0600 | 0.1200 |
| Notification Appliances | | | | | |
| Horns | 10 | | 0.000 | 0.0180 | 0.1800 |
| 15 cd strobes | 15 | | 0.000 | 0.0590 | 0.8850 |
| 110 cd strobes | 4 | | 0.000 | 0.1450 | 0.5800 |
| Horn/15 cd strobe | 10 | | 0.000 | 0.0830 | 0.8300 |
| Horn/110 cd strobe | 5 | | 0.000 | 0.1930 | 0.9650 |
| Other | | | | | |
| Relays | 4 | 0.0300 | 0.1200 | 0.0000 | 0.0000 |
| Net Standby Load, Amps: | | | 0.9409 | | |
| | | | Net Alarm Load, Amps: 4.6857 | | |
| Enter Required Standby Duration: | | 24 | Hours | | |
| Enter Required Alarm Duration: | | 5 | Mins | 0.083 | Hours |
| Total Standby, Amp-Hours: | | | | 22.5816 | Amp-hours |
| Total Alarm, Amp-Hours: | | | | 0.3905 | Amp-hours |
| Total Calculated Battery Capacity: | | | | 23.0 | Amp-hours |
| Required Factor of Safety: | | | | 20% | |
| Code Required Battery Size/Capacity: | | | | 28 | Amp-hours |
| Supplied Battery Size/Capacity: | | | | 36 | Amp-hours |
| Actual Factor of Safety: | | | | 57% | |

Table 1. Simplified Secondary Power Calculation Example

Batteries are required by NFPA 72 to be labeled with the date of manufacture. In prior editions of the code, there was a five-year replacement requirement. In the 2013 edition, replacement is required as recommended by the manufacturer or when the batteries fail during testing. The five-year requirement was removed in favor of "replacement as recommended by the manufacturer," which may be less than five years.

With respect to occupancy hazards and risks, engineers should consider that the secondary supply is only for the fire or signaling system control unit. Any transmitters or sub-panels used for

communications will have their own power supplies with the same requirements for secondary power. The public communications infrastructure is outside the jurisdiction of NFPA 72.

NFPA 72 recognizes that the Federal Communications Commission has jurisdiction over the installation requirements for parts of the communication infrastructure used to transmit signals from a protected premises to a supervising station. Traditional telephone central offices and managed facilities voice network (MFVN) facilities used by Internet service providers will typically have 24 hours or more of

standby battery capacity in addition to backup generators.

However, modern communications methods, including telephone and Internet service, may not be powered entirely from the central office. Instead, they may have in-building circuits powered from a network interface device at the property that requires primary power and includes a backup battery. Those backup batteries are a part of the communications system, not the fire alarm or signaling system, and are sized for only about eight hours of standby. Both traditional telephone and Internet services provided by an MFVN will usually have field-located concentrator units along the path from the protected premises to the central office or MFVN. These local concentrator units, which can frequently be seen on poles or in pedestals throughout a community, also have primary power and batteries for secondary power. So, while a fire alarm or signaling system designed in accordance with NFPA 72 might continue to operate during an extended power outage, its ability to communicate off premises might be limited to eight hours or less. This needs to be factored into emergency planning for the property.

While the actual selection of power supplies and calculations of battery capacity are not difficult, selecting the proper parameters and combinations of power supplies requires engineering consideration. The designer must consider the environmental conditions, hazards involved and the resulting risks when specifying power supply durations for fire alarm and signaling systems.

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One of the most challenging aspects of installation for Tech Systems was outfitting the arena's domed ceiling, reaching 52 feet at its peak, with speaker/strobes. Adding a performance-based design twist to the installation, fire protection consultant Glen McBride with Associated Design Group, Lafayette, La., performed a calculation to prove to the Authorities Having Jurisdiction that the ceiling-mounted strobes would provide the required candela at floor level.

To ensure intelligibility of the system's audio messages, more speakers were used, tapped at less wattage and strategically placed.

Relays were also incorporated into the addressable duct detectors for HVAC shutdown, and heat detectors were installed outside the shower area to keep the humidity from tripping smoke detectors.

The integration of multiple features into

one system was noted as a major factor in simplifying the design and installation of the Farenhyt system.

The school is currently utilizing its new IFP-1000ECS fire alarm and emergency communications system to send out pre-recorded voice evacuation messages. As many as eight Remote Command Units can be tied-in to provide authorized personnel quick access to a microphone for live paging and pre-recorded audio messages.

For larger facilities and multi-building campuses, Silent Knight offers the Farenhyt IFP-2000ECS combined fire alarm and emergency communications system that can network up to 16 panels to support as many as 10,176 points.

Overall, the combined capabilities and scalable design of Farenhyt systems make them an economical solution that can be easily expanded and upgraded to meet the facilities' future needs.

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- Raymond Grill, P.E., FSFPE, USA – *"The Role of Fire Protection Engineering in Sustainable Design"*
- James Golinveaux, USA – *"Significant Advancements in Water Based Fire Suppression for Storage Occupancies"*
- Stephen Kerber, P.E., USA – *"Evolution of the Residential Fire Environment"*
- Erica Kuligowski, Ph.D., USA – *"The Current State of Egress in Fire Engineering Design"*
- Ai Sekizawa, Japan – *"Challenges in Fire Safety in a Society Facing a Rapid Aging Population"*
- Piotr Tofilo, Poland – *"Fire Engineering Tools: Past, Present and Future"*
- Robert Zalosh, P.E., FSFPE, USA – *"Significant Fire Explosions that Influenced Industrial Fire Protection Engineering"*

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UPCOMING EVENTS

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Basel, Switzerland

Info: www.eurofireconference.com

October 22-23, 2013

Fire New Zealand Conference
and Exhibition
Auckland, NZ

Info: www.sfpe.org.nz

October 24-26, 2013

9th International Conference & Exhibition:
Fire India – 2013
Mumbai, India

Info: www.ifeindia.org

October 27–November 1, 2013

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Austin, TX, USA

Info: [www.sfpe.org/
SharpenYourExpertise/
Education.aspx](http://www.sfpe.org/SharpenYourExpertise/Education.aspx)

February 10-14, 2014

The International Association for Fire
Safety Science (IAFSS) 11th International
Symposium on Fire Safety Science
Christchurch, NZ

Info: [www.iafss.org/
symposium/11th-symposium/](http://www.iafss.org/symposium/11th-symposium/)

June 9-12, 2014

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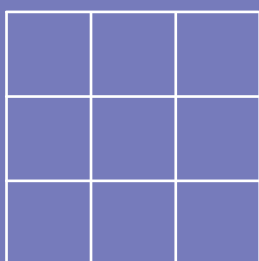
Info: [http://nfpa.typepad.com/
conference/](http://nfpa.typepad.com/conference/)

BRAINTEASER

[Problem / Solution]

Problem

How many
squares?



Solution to Last Issue's Brainteaser

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

The probability that others will not share a birthday can be calculated as:

$$\left(1 - \frac{1}{365}\right) \times \left(1 - \frac{2}{365}\right) \times \dots \times \left(1 - \frac{n-1}{365}\right) = \prod_{i=1}^{n-1} 1 - \frac{i}{365}$$

Where n is the number of students in the classroom.

Because having no students share a birthday is mutually exclusive from one or more students sharing a birthday, the probability that one or more students share a birthday is:

$$1 - \prod_{i=1}^{n-1} 1 - \frac{i}{365}$$

This equation yields a value of 50% when $n=23$.



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www.coopernotification.com

—Cooper Notification

Inert Gas Fire Suppression System

Fike announces the release of its PROINERT2 inert gas fire suppression system. In addition to other design improvements, PROINERT2 is now available with 300bar technology. There is more inert gas in each PROINERT2 cylinder, reducing the number of cylinders and accessory equipment necessary. In addition to a reduction in system cost, fewer cylinders translates into an inert gas solution that takes up less space. There is no change in PROINERT's efficient constant system flow rate, which allows for smaller-diameter, lower-pressure, less expensive piping.



www.fike.com

—Fike Corp.

Photoluminescent Marking Systems

For safe evacuation when power fails, the New ZERO system includes directional markings and door signage, designed to show the outlines of egress paths on floors, stairs, handrails, and obstacles. The strontium pigment material is non-electric and non-toxic. The photoluminescent strips and signs feature aluminum backing with foam tape for full adhesion to uneven surfaces or can be mechanically fastened.



www.zerointernational.com

—Zero International

Free Water Test Kit for Corrosion Testing

Potter is offering free water test kits to those interested in seeing



if Microbiologically Influenced Corrosion (MIC) is damaging their fire sprinkler system. Potter will provide one free water test kit to new customers to help educate them on how corrosion affects a fire sprinkler system. Potter will then test the sample water and provide a report. Appropriate actions are subsequently taken to reduce current corrosion and prevent future corrosion.

www.pottersignal.com

—Potter Electric Signal Co., LLC

Concealment Systems

Softi-Steel® and Interlock™ concealment systems — for concealing fire sprinkler systems, piping, plumbing, HVAC, ductwork, and cable — are FM Approved for the protection of BlazeMaster® Fire Sprinkler Pipe and exceed the UL Listing protection requirements of lay-in panels or tile. They are suitable for both retrofit and new construction projects, such as homes, commercial buildings, universities, jails/prisons, nursing homes, and more.



www.igius.com

—JG Innovations, Inc.

Fire Panel Enhancements

Siemens has made product enhancements to its FireFinder XLS fire panel. The responsive intelligent fire detection system, which can be networked and configured with or without optional voice evacuation and integrated smoke control functionality, now features a faster processor that fuels a full-color user interface with events color-coded by type and touch-sensitive keys. The new system also exceeds mass notification specifications, with digital capacity for up to 300 custom messages and the capability to play multiple messages simultaneously.



www.usa.siemens.com/firefinder-xls

—Siemens Industry, Inc., Building Technologies Div.

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www.systemsensor.com

—System Sensor



Intelligent Notification

SimplexGrinnell has introduced Simplex TrueAlert ES – a new family of intelligent notification appliances. Simplex TrueAlert ES (eServices) notification brings addressable technology to the systems that warn building occupants in the event of a fire or other emergency. It is the latest addition to SimplexGrinnell's suite of web-enabled eService solutions, which use the power and connectivity of the Internet to increase customer value and improve operational efficiency.

www.simplexgrinnell.com

—SimplexGrinnell



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www.statx.com

—Fireaway Inc.



Flat-Plate Concealed Sprinkler

Viking has extended its Freedom® residential fire sprinkler line to include a "small orifice," flat-plate concealed pendent sprinkler. The new model VK488 has a K Factor of 3.0 (43) and is cULus Listed with a flow rate of 8 GPM, and a pressure requirement of 7.1 PSI (0.49 bar), in a 12 x 12-ft room size. This new sprinkler is offered in addition to the model VK470, 3.0 K factor residential pendent sprinkler, which Viking introduced in 2012.

www.vikinggroupinc.com

—Viking Corp.



NOTIFIER's New Website

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

www.notifier.com

—NOTIFIER



Gas Detector Module

The VESDA ECO Ex, a gas detector module for use with VESDA smoke detection systems in Class I Division 2 classified hazardous locations, reduces the number of detectors required to cover an area, and provides easy access for routine maintenance. Each VESDA ECO Ex gas detector can house up to two gas sensors, and additional detectors can be added to the VESDA pipe network to monitor more gases if required. Seventeen different gas sensors are available, and re-calibrated sensor cartridges are easily replaced in the field.

www.xtralis.com

—Xtralis





Engineering Guide: Fire Safety for Very Tall Buildings Published

This new guide, co-published by the International Code Council (ICC) and Society of Fire Protection Engineers (SFPE), identifies critical fire safety challenges unique to very tall buildings. *Engineering Guide: Fire Safety for Very Tall Buildings* examines how these special challenges can be addressed worldwide through an integrated performance-based design.

This engineering guide was written in response to an increase in the global design and construction of very tall buildings. Building codes in some countries may not contemplate all aspects of fire safety in very tall buildings—some of which approach a half mile, or 800 meters, in elevation. Buildings that are hundreds of meters tall pose challenges far different from those in average-sized tall buildings.

The guide emphasizes the importance of taking an integrated approach to the design of fire safety in tall buildings based on expected fire performance. This integrated approach looks beyond compliance with codes and standards, and considers how the height of the structure impacts fire safety and how various fire safety systems complement each other to achieve fire safety goals. These systems include smoke control, fire suppression, building evacuation, structural fire resistance and fire fighter access.

The *Engineering Guide: Fire Safety for Very Tall Buildings* recommends performing a fire risk analysis to determine how best to address the fire safety challenges unique to a specific building. Although fire hazards in very tall buildings are similar to those in shorter buildings, the consequences of a fire can be more severe given the large numbers of occupants, the inherent limitations in egress, and the sheer height of the structure. The risk analysis will identify which hazards should be addressed by the design, where the hazards may include accidental fires, fires following earthquakes, or terrorist threats.

Engineering Guide: Fire Safety for Very Tall Buildings is available for purchase in hardcopy

\$49.95 for SFPE Members (\$59.95 for non-members)

Engineering Guide: Fire Safety for Very Tall Buildings

MAIL to SFPE at 7315 Wisconsin Ave., Suite 620E, Bethesda, MD 20814 or FAX to 301-718-2242

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