FIRE PROTECTION Engineering

3RD QUARTER 2012
Issue No. 55

ACHIEVING COMPLIANCE

FIRE PROTECTION AT U.S. NUCLEAR POWER PLANTS

Fossil Fuel Facilities – A Fire Protection Analysis Challenge

Potential Impacts of Smart Grid on Fire Protection Engineering

Facing the Future: Alternative Energy and Fire Protection Engineering

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From the TECHNICAL DIRECTOR

New Specification for Principles and Practice of Fire Protection Engineering Exam

Beginning with the October 2012 examination, a new specification will be in place for the "principles and practice examination" (colloquially known as the "P.E. Exam") for fire protection engineering. This new specification is the result of an exhaustive process that is conducted every six to eight years that ensures that the examination is representative of the tasks performance by fire protection engineers and the knowledge necessary to perform those tasks. (For more information on the process used to develop the specification, see "Setting the Standard" by Anthony Militello in the 3rd Quarter 2011 issue of *Fire Protection Engineering* magazine.)

Specifications for P.E. exams identify the technical areas that are included on the exam and the fraction of the exam associated with each technical area. Beginning with the development of the last specification for the fire protection engineering P.E. exam, the exam specification has increasingly focused on the science and technology that underpins the practice of fire protection engineering. Similarly, the types of questions that are included on the examination have changed to better reflect the science and technology of fire protection engineering.

Technical Area	Approximate Percentage of Examination
Types of analysis	7.5%
Information sources for analysis	12.5%
Fire protection management	5%
Fire dynamics	12.5%
Water-based fire suppression systems	15%
Special hazard systems	10%
Fire detection and alarm systems	7.5%
Smoke management systems	5%
Explosion protection and suppression systems	2.5%
Passive building systems	10%
Means of egress	8.75%
Human behavior	3.75%

Table 1. Summary of Specification for Fire Protection Engineering P.E. Exam

Note: The complete specification is available from *http://www.ncees.org/Exams/PE_exam.php*

A summary of the specification is shown in Table 1.

Overall, the new exam specification is a modest change from the previous specification, which was approved in 2002 and became effective with the 2004 offering of the exam. Similarly, the recent changes are not much different when compared to those that were in place from 1999 – 2003. Water-based fire suppression systems represented 25% of the exam in 1999 and 15% in 2004. Non-water-based fire suppression systems (now called "special hazard systems") accounted for 12.5% of the questions on the exam in 1999 and 5% of the questions in 2004.

In the 1999 specification, fire dynamics and human behavior were not specifically identified (although problems from these areas could have been included on the exam as part of the specification area for "research and development of hazard and risk analysis" – which was 12.5% of the exam.) Beginning with the 2004 exam, fire dynamics questions were 10% of the exam, and human behavior questions were 5%.

While the subjects covered on the fire protection engineering P.E. exam have not changed tremendously over the last 13 years, the types of questions on the exam have changed. Largely gone are questions that could be answered simply by looking in a code or standard (although codes and standards might still be sources of calculation methods or information that would be used as part of a calculation). Collectively, the changes to the fire protection engineering P.E. exam during the last 13 years show a steady maturation of the field of fire protection engineering.

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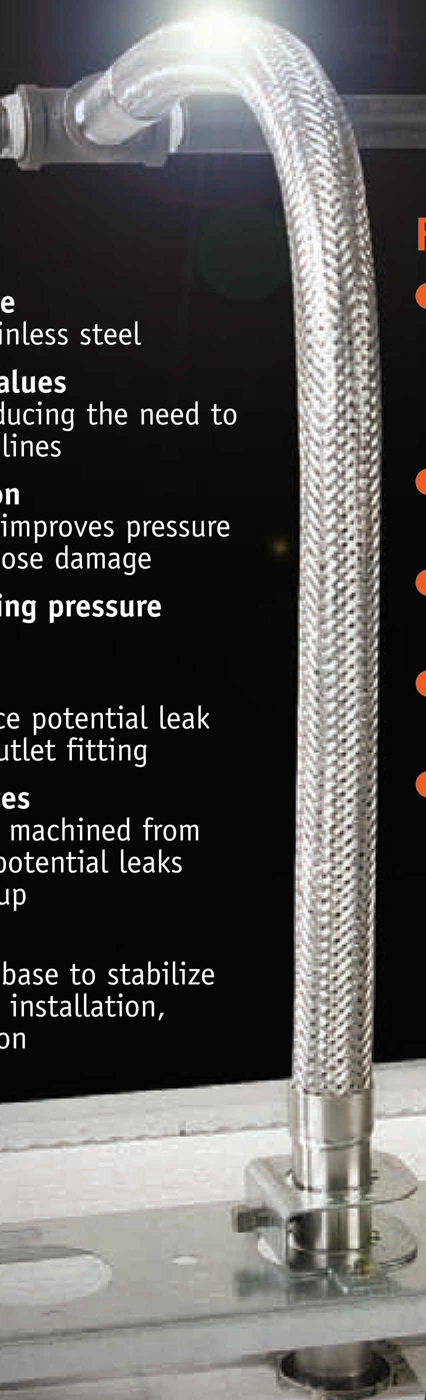

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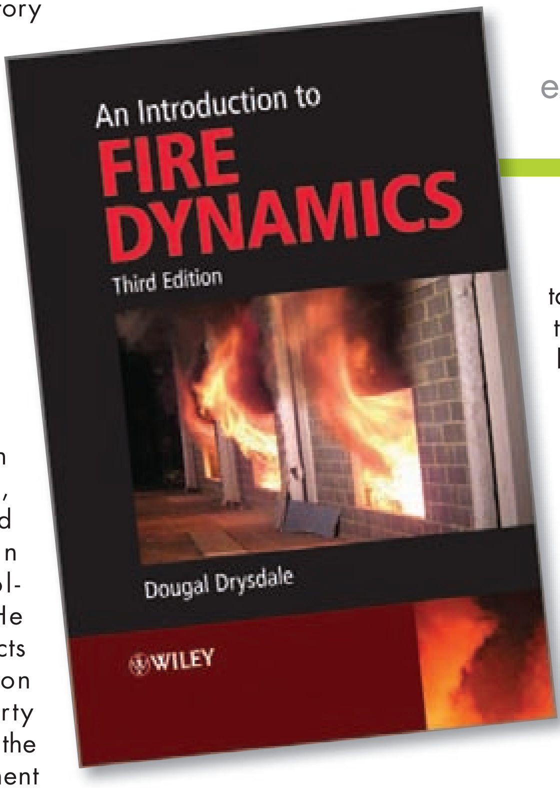
Review of *An Introduction to Fire Dynamics, Third Edition*, by Dougal Drysdale

By Nicholas A. Dembsey, Ph.D., P.E., FSFPE

With the publishing of the third edition of this now classic fire protection engineering textbook, Drysdale does not change the style of the text, but he does refine and strengthen the content from the second edition. New sections have been added on spill fires and burning of pressurized and cryogenic liquids; auto-ignition of liquid fuels; fire in large compartments; and toxicity of smoke. The third edition is 100 pages longer than the second edition.

What has made this a classic text is that it balances breadth and depth in the extensive topic area of fire dynamics in a manner that is useful for both new students and experienced practitioners. I have found this balance to be quite effective in my own teaching of fire protection engineering students at the advanced undergraduate and introductory graduate level.



In terms of breadth, Drysdale covers background areas, such as fire science and combustion, heat transfer, limits of flammability, and premixed flames and diffusion flames. Next, he covers key fire dynamics phenomena, such as steady-burning of liquids and solids, ignition: the initiation of flaming combustion, spread of flames, and spontaneous ignition with solids and smoldering combustion. He concludes with the effects of these phenomena on life safety and property protection with topics on the pre-flashover compartment fire, the post-flashover compartment fire, and smoke: its formation, composition and movement.

In terms of depth, Drysdale provides clear and concise discussion of each topic. He makes effective use of tables, figures, photos, and equations. The level of detail presented is consistent with well-founded understanding in the fire protection engineering community. For less well-developed topics, this involves qualitative discussion, where the mechanisms are described using scaling methods. For well-developed topics, this involves detailing analytical tools that the practitioner can use for engineered analysis and design.

What has made this a classic text is that it balances breadth and depth in the extensive topic area of fire dynamics in a manner that is useful for both new students and experienced practitioners.

For students new to fire dynamics, the qualitative discussions provide a great introduction to the topics. The practical examples and homework problems with select answers provide an effective means to learn the proper use of analytical tools. For the experienced practitioner, these items provide a good reminder of topics and tools that may not have been used for a while. The extensive reference list provides a great initial start to developing source documents when a topic needs to be understood in greater detail.

Based on my many years of teaching fire dynamics at WPI using previous editions of this book, I would strongly recommend the third edition for use by instructors and their students, and as a learning or reference text for practitioners' personal libraries. Moving forward, the fire protection engineering community benefits from Drysdale's wisdom to refine and strengthen his textbook in what has been and will continue to be an insightful investigation and survey of this important topic area.

Nicholas A. Dembsey is with Worcester Polytechnic Institute.

Coalition to Advance Public Safety in the Built Environment

The International Code Council (ICC) and the National Fire Protection Association (NFPA) have formed the Coalition for Current Safety Codes (CCSC). The coalition will advance public safety in the built environment by advocating that states and municipal jurisdictions adopt current building, fire prevention, sustainable, electrical, and life safety codes.

"For more than 100 years, the public and government on all levels have benefited from the life and property saving work of private standards developing organizations (SDOs)," said NFPA President Jim Shannon. "The CCSC is an effort to ensure those same parties are taking full advantage of the latest information in the most up to date codes."

"ICC and NFPA have a rich history and dedicated members who devote themselves each day to ensuring the development of safe and sustainable communities," said ICC CEO Rick Weiland. "The efforts of our memberships have dramatically strengthened codes and standards – protecting the public. This coalition is a great way to spread the word about how to protect the environment, and the health and welfare of our society."

ICC and NFPA will seek broad participation in the coalition from other SDOs, the construction and insurance industries, government, and the private sector to raise awareness about the importance of and steps needed to provide up to date buildings where people live, work, play, and go to school.

For more information, go to *www.coalition4safety.org*

New Publication Extends Comprehensive Treatment of Smoke Control

A new handbook providing comprehensive treatment of smoke control technology is now available.

Published by ASHRAE in cooperation with the Society of Fire Protection Engineers (SFPE), the International Code Council (ICC), and the National Fire Protection Association (NFPA), the *Handbook of Smoke Control Engineering* extends the tradition of the comprehensive treatment of smoke control technology, including fundamental concepts, smoke control systems, and methods of analysis. The handbook provides information needed for the analysis of design fires, including considerations of sprinklers, shielded fires, and transient fuels. It's also useful for practicing engineers, architects, code officials, researchers, and students.

Following the success of *Principles of Smoke Management* in 2002, this new book incorporates the latest research and advances in smoke control practice into 24 chapters with more than 500 pages of in-depth guidance. New topics in the handbook are: controls, fire and smoke control in transport tunnels, and full-scale fire testing. For those getting started with the computer models CONTAM and CFAST, there are simplified instructions with examples. In addition, this is the first smoke control book with climatic data for locations in the U.S., Canada, and throughout the world.

The cost of *Handbook of Smoke Control Engineering* is $129 ($109, SFPE & ASHRAE members). To order, visit *www.sfpe.org*.

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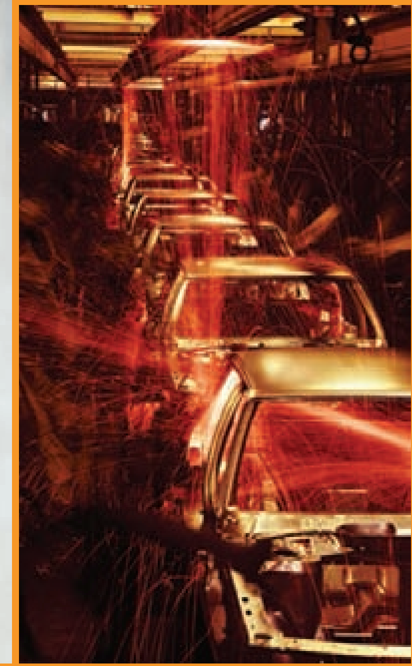

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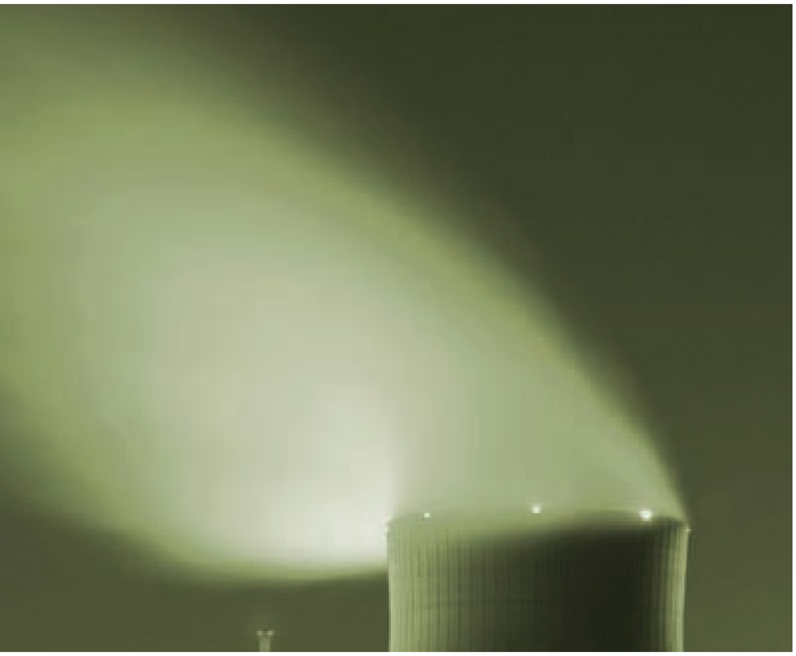
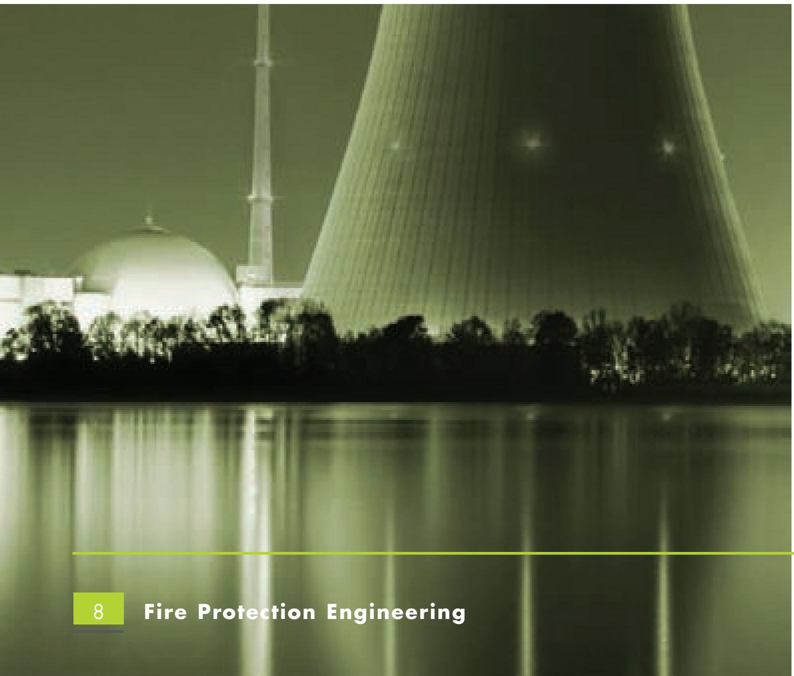
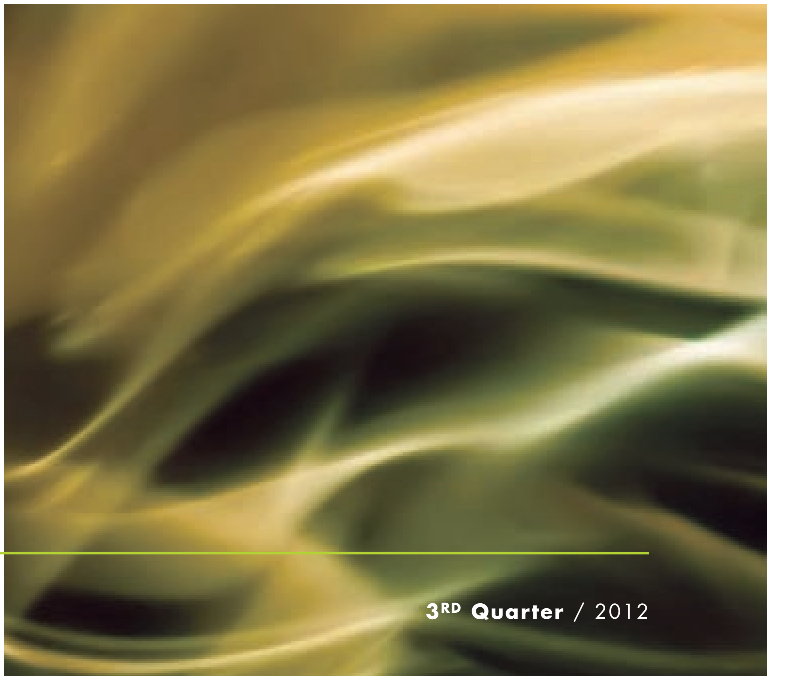


FIRE PROTECTION AT U.S. NUCLEAR POWER PLANTS

By Brian Metzger





At U.S. nuclear power plants, achieving compliance with fire protection regulations is a storied endeavor. Whether because a plant was constructed prior to the Nuclear Regulatory Commission (NRC) imposing detailed fire protection regulations or because the fire protection programs were so plant-specific, there is no generic way to describe how to comply with fire protection regulations.

In addition, since nuclear power plants are enormous buildings and all activities are highly regulated, it is expensive and challenging to retrofit, or backfit them with features after they're built. Also, since the level of understanding about certain phenomena has evolved over the years, compliance has further complicated the matter. Because of this, it has been challenging to bring all of the plants into compliance with deterministic requirements.

Therefore, the introduction of the new regulatory option, the National Fire Protection Association's Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants[1] (NFPA 805), has become more appealing.[2]

An analogy can be used to frame the subject of regulatory compliance as it pertains to fire protection in nuclear power plants. Imagine a very expensive new sports car. Next, imagine that a year into owning this new car, the local authority on automobile safety decides that the car isn't safe enough to have only two doors and mandates that all cars have at least four doors. This decision just changed the sporty coupe to a family sedan and cost a lot more money in the process. This was the 1980s for the U.S. nuclear industry, but instead of cars it was commercial nuclear power plants and instead of safety doors it was fire safety requirements known as Appendix R.[3]

BACKGROUND

The first fire protection regulation for nuclear power plants was adopted by the Atomic Energy Commission, the predecessor to the Nuclear Regulatory Commission (NRC), in February 1971. This regulation, known as 10 CFR 50, Appendix A, General Design Criterion (GDC) 3,[4] provided relatively high-level guidance, which stated that:

> Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat-resistant materials shall be used wherever practical throughout the unit, particularly in such locations as the containment and control room.

Figure 1. Browns Ferry Nuclear Plant, Athens, AL (courtesy of TVA)

The term, "important to safety," refers to equipment in the plant that is relied upon to safely shut down the reactor in the event of a problem at the plant. Nuclear plants in the U.S. have always been designed with the intent of having redundant systems available to bring the reactor to a safe and stable condition. GDC 3 required that the equipment used to bring the reactor to a safe and stable condition be protected from fires. At the time, GDC 3 was considered met through the use of fire protection design standards from the insurance industry model for special industrial facilities.

In 1975, a fire occurred at the Browns Ferry Nuclear Plant in Alabama, which damaged redundant "important to safety" equipment (see Figure 1). The fire displayed a number of phenomena and concerns that weren't considered in the industrial fire protection model that had been previously applied – specifically fire damage to electrical control cables causing spurious operations of equipment important to safety. This prompted the development of more explicit fire protection regulations for the nuclear industry.[5,6]

DETERMINISTIC STRATEGIES

Fire protection at nuclear power plants is a bit different than that to which many fire protection engineers might be accustomed. Instead of focus being placed on traditional fire protection issues, such as tenability, means of egress, property loss, etc., the focus is on protecting equipment important to safety in order to maintain or preserve the ability to place the reactor in a safe condition, i.e., safely shutdown.

It's not that the traditional fire protection issues don't matter, but that they are not the primary objective of plant fire protection engineers or the regulator, the NRC. What matters most at a nuclear power plant is the ability to shut down the reactor in an emergency. To protect important

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Figure 2. Cable Tray

> All plants have multiple success paths or "trains" of equipment to safely shutdown, but these success paths weren't originally designed to be separated from a fire exposure.

equipment, fire protection at nuclear power plants relies on what is known as a defense-in-depth (DID) concept, which employs multiple layers of protection so that no single failure results in a loss of control. Appendix R to Title 10 of the Code of Federal Regulations, Part 50[3] (Appendix R) defines DID as the ability to:

- Prevent fires from starting;
- Detect rapidly, control and extinguish promptly those fires that do occur;
- Provide protection for structures, systems and components important to safety so that a fire that is not promptly extinguished by the fire suppression activities will not prevent the safe shutdown of the plant.

To accomplish this, the NRC wrote a number of guidance documents that included information on topics such as administrative controls, fire brigade staffing, quality assurance, and even minimum levels of fire protection for specific plant areas. All licensees evaluated their plants in accordance with these guidance documents, which upon subsequent approval by the NRC comprises their fire protection licensing basis.

The most significant change that was required to existing plants – i.e., the additional doors in the car analogy above – was a prescriptive requirement to backfit protection for safe shutdown equipment. This requirement mandated that critical safe shutdown equipment be separated either by physical, fire-rated barriers or spatial separation in conjunction with fire detection, automatic fire suppression systems and alternative shutdown equipment. This was important because many plants were not initially designed with this level of protection, and significant plant modifications were required.

All plants have multiple success paths or "trains" of equipment to safely shutdown, but these success paths weren't originally designed to be separated from a fire exposure. For instance, some plants had trains of equipment that were electrically separate but not physically separate.

For example, Figure 2 shows a case where two redundant cables are located adjacent to each other in a single cable tray. A single fire near this particular cable tray could damage both trains whereas a single circuit failure in one of the cables might not. The modifications that many of the licensees had to make were to verify that they could rely on one train of shutdown equipment for most normal operating periods (credited) and one they could rely on in the event that the credited train is damaged or otherwise unavailable (redundant). This is akin to having a Plan A and a Plan B where Plan B is a fallback for Plan A and provides added safety in the form of redundancy.

In some cases, separation of the installed safe shutdown trains was impossible. For example, each plant was designed with a single main control room, so there was no way to provide separation of those controls without building a separate control room. The NRC understood that this was impractical, so the fire protection regulations included a provision for an alternative shutdown capability. When the use of redundant systems is not possible (because the equipment itself or the electrical cables associated with the equipment are both located in the same area), alternative shutdown configurations are required. For most plants, this alternative shutdown involved installing controls at a location remote and independent of the main control room, so that if a fire were to occur in the main control room, safe shutdown could be achieved from the alternate location.

In addition, plant owners had a third option, in addition to protecting a redundant train or installing alternative shutdown capability: submit a plant-specific exemption to the regulations. Most fire protection engineering professionals are likely more familiar with terms such as "modification" or "alternative methods and materials." However, their purpose is similar to the exemption process for nuclear power plants.

That is, prescriptive regulations rarely can anticipate all of the possible designs and circumstances related to a particular project, so alternate methods of compliance

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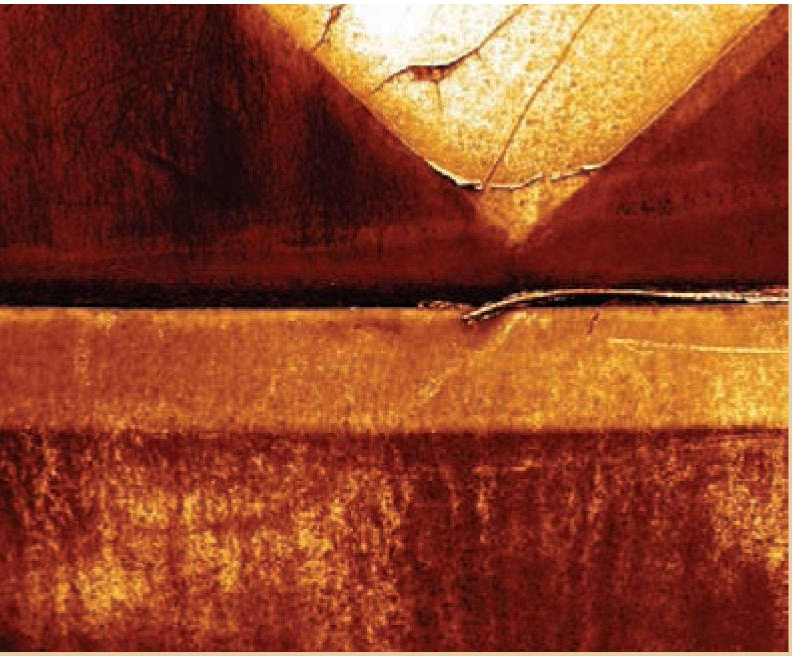

or processes are allowed in order to establish or maintain a consistent level of safety without meeting the strict letter of the regulation. In the nuclear industry, that process is the exemption process during which licensees, unable to comply with strict letter of the regulation and able to demonstrate special circumstances, can pursue an exemption to comply with the intent of the regulation even though they may not have all of the active or passive features required by the regulation. Since many plants had already been built, the NRC received hundreds of these exemptions. The agency approved many of them after performing a review and determining that the plant configuration was safe enough.

One common exemption requested by licensees to address fire-induced damage to electrical circuits, in lieu of physical protection as required by the regulation, was the use of operator manual actions (OMAs) to accomplish tasks needed to preserve safe shutdown capability in a plant. OMAs typically consist of a series of tasks – e.g., operating valves, switches, breakers, etc. – from outside the main control room in the event that monitoring or confirmation of actions performed in the main control room are unsuccessful or unverified. However, OMAs must be demonstrated to be feasible and reliable by the licensee and submitted to the NRC for review.

OMAs are considered part of a larger compliance strategy where DID is provided or maintained. An example of where an OMA might serve as a legitimate part of a plant's post-fire safe shutdown strategy would be if the cables for a required safe shutdown component (e.g., a motor operated valve) run through a fire area where that component is needed to achieve and maintain safe shutdown during and following a fire. In this example, an operator might turn a crank on the valve to open it, thereby providing an alternate means of operating the valve, aside from within the main control room, in the event that fire damages the cables running through the area.

Much of this regulatory framework was developed in response to the 1975 Browns Ferry fire and continued to evolve and mature throughout the 1980s and 1990s. Following the Browns Ferry fire, the NRC contended with a series of other important operating events such as the Three Mile Island accident in 1979 and the Chernobyl accident in 1986. The recent Fukushima Daiichi accident in 2011 will likely bring about more change within the nuclear industry to avoid future mistakes. By analyzing and scrutinizing past events, engineers often find it necessary to make adjustments to how they approach problems. Deterministic regulations are not always capable of integrating new information, so a performance-based strategy, which sets performance-based goals, is often more effective at integrating new information.

PERFORMANCE-BASED STRATEGY

Performance-based design is a method for designing buildings and other assets to achieve performance objectives or goals in lieu of meeting prescriptive requirements. Referring back to the car analogy, not all cars have a back seat let alone the ability to transport additional occupants to necessitate the addition of two more doors for safety purposes. The owner and driver of the car might argue that his or her circumstances don't entail the same level of risk or hazard that the new automobile safety requirements, i.e., two additional doors, were intended to address.

Therefore, one might use a probabilistic risk assessment to support his or her argument and show that not only does the car lack a back seat to warrant the extra doors but that those traveling in the sporty two-door coupe are just as safe as four people traveling in a four-door family sedan. In doing so, one would be making a performance-based (it's just the driver and perhaps one passenger), risk-informed (the driver and passenger are no less safe than those in a sedan) argument. Quantifying the possibility of an event and then calculating its probability to understand the risk associated with it is a tool used at the NRC as part of a performance-based approach to a problem, and is often called probabilistic risk assessment (PRA).

The use of risk information in design and engineering is not a new concept. It has been used in different industries for decades. Cost-benefit analyses, insurance, automobile safety, etc., all inherently deal with risks associated with various events occurring and the measures necessary to avert tragedy. Even high-profile government agencies, such as the National Aeronautics and Space Administration (NASA), use risk assessments to better inform their decisions on matters such as space travel and vehicle launches. They calculate the probability of certain failures occurring and include these probabilities in their evaluation of program objectives to decide which features or components should be included in a mission and which ones might provide minimal or maximum benefit to the overall mission success.

For the nuclear industry, performance-based fire safety regulation arrived in the form of NFPA 805 and with the NRC adopting the 2001 edition of the consensus code in 2004. NFPA 805 is a performance-based standard that also incorporates deterministic requirements, fire modeling and probabilistic risk assessment (PRA) into the decision-making process, i.e., risk-informed, performance-based.

Considering risk is important in the nuclear industry because in 2002 the NRC established that fire can be a potentially important contributor to overall plant core damage frequency (CDF), which is the annual probability of damage to the reactor core as a result of an accident. That is, fires in nuclear power plants have the potential to cause serious damage that could jeopardize the ability of plant operators to safely shut down the plant. By understanding the risk attributed to various fire-induced damage or failures, it is possible to make more informed decisions, both as an operator and a regulator, as to where to focus one's efforts and attention. Minimal risk then becomes one of many performance objectives to be achieved through performance-based design and regulations.

The way the Authority Having Jurisdiction (the NRC) has implemented NFPA 805 allows licensees to perform evaluations and changes without requesting NRC approval as long as the changes don't increase risk above established thresholds and safety margins and defense-in-depth are not affected. The NRC's primary mission is to ensure public health and safety, promote common defense and security, and protect the environment so long as the performance objectives, defined at the outset of the performance-based process, align with this mission and are maintained throughout the plant's operation. The licensee gains reduced regulatory burden and is considered compliant with their applicable fire protection regulations. As in other industries and applications, the performance-based approach is intended to provide equivalent protection to that intended by a more traditional, deterministic or prescriptive approach but with tertiary benefits such as financial economics, increased design or

operating flexibility, or increased plant safety.

In the nuclear industry, licensees identify areas of the plants where certain fires could affect safe shutdown. Licensees then make decisions about whether to make modifications, such as adding more sophisticated detection and suppression systems or improving the reliability of other equipment, to reduce the risk that such scenarios represent to an acceptable level. An approach that incorporates protective measures tailored to address specific hazards and an understanding of the risk significance of scenarios involving those hazards makes up a risk-informed, performance-based approach.

A purely performance-based example could be a plant area that has redundant safe shutdown trains passing through it, and in accordance with Appendix R, would require an automatic fire suppression system. Using fire modeling, fire protection engineers might determine that there are no credible fire hazards that could damage both trains. After evaluating the defense-in-depth and safety margins, the evaluation might conclude that there is sufficient protection without the suppression system, and therefore the licensee would be able to forego the financial outlay to install and maintain a system. To further support the analysis, engineers could also calculate the likelihood or probability of possible fires in the area as well as possible equipment damage or failures due to such fires in order to provide a quantitative understanding of the risks involved and enhance the decision-making process with this added risk information (risk-informed).

Licensees may elect to transition from the deterministic compliance strategy to the performance-based

Figure 3. Shearon Harris Nuclear Plant, New Hill, NC (courtesy of Progress Energy)

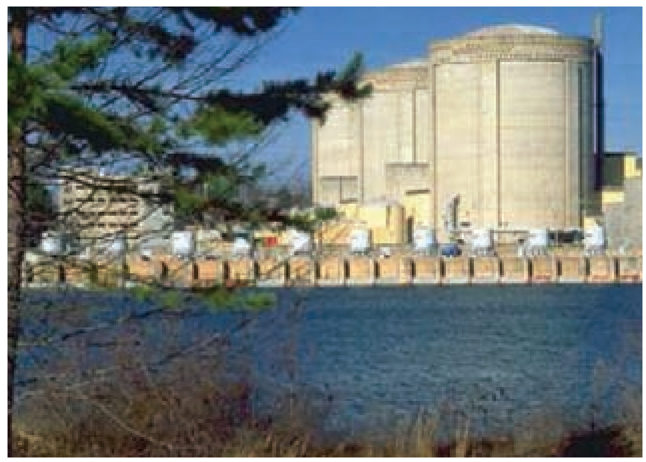

Figure 4. Oconee Nuclear Station, Seneca, SC (courtesy of Duke Energy)

strategy but are not required to do so. The licensees' decisions to transition depend on various factors, but the NRC remains committed to making sure that plants are safe. The NRC recently issued the first licenses for plants that have elected to transition to the NFPA 805 licensing and compliance methodology.

The first license was issued to Progress Energy's Shearon Harris Nuclear Plant located in North Carolina (Figure 3), followed by Duke Energy's Oconee Nuclear Station located in South Carolina (Figure 4).

These two particular plants were pilots for the new performance-based regulation; the NRC is currently reviewing additional requests to complete similar transitions. With roughly half of the operating fleet of plants having submitted letters of intent to transition to NFPA 805, the performance-based approach has the potential to resolve compliance challenges while preserving safety in a performance-based manner amongst U.S. nuclear power plants.

MOVING FORWARD

Transitioning plants to the NFPA 805 approach has identified several areas that require better understanding. As part of the process, many plants utilized calculation methods to quantify various factors, such as fire event frequencies, proper characterization of fire events or resultant fire damage. Several of these methods contained assumptions that resulted in conservatisms in determining the risk associated with fires as part of the risk-informed, performance-based approach.

For instance, some licensees found that several of the methods being used resulted in calculated risk values that were higher than operating experience seemed to indicate. Undue conservatism in risk-informed, performance-based analysis can mask more severe hazards by overstating the risk of less severe hazards. In an effort to reduce these conservatisms, several calculation methods used in NFPA 805 are being revised to increase realism and calculate more realistic risk numbers.

The NRC is unique as a federal regulatory agency in that it also performs research as needed to meet the needs of the agency. This arrangement was originally intended to provide confirmatory research (to independently verify research performed by industry or academia), but in many

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cases, the NRC has performed much-needed original research in areas critical to regulatory decision making. The NRC has completed many studies to better inform the regulatory process, and nuclear and fire protection industries, on fire protection issues. Many of these research activities directly relate to performance-based methods being used under NFPA 805.

Since the NFPA 805 standard has only been applied to two plants, and each plant is unique, the NRC is working with the nuclear industry to improve the process and the level of detail that goes into it. For instance, there is a new PRA standard[7] that both the staff and industry stakeholders are using for the first time along with new regulatory and industry guidance. In order to facilitate the application of all this new information, the NRC is working with the nuclear industry by holding monthly public meetings so that licensees are informed and able to use and apply it to determine fire risk and make regulatory decisions accordingly.

Of the 104 operating commercial power reactor units in the U.S., all are similar to the two-door coupe in the car analogy. Many have been retrofitted with the extra doors to meet the deterministic requirements. Currently, 48 nuclear units are planning to complete the transition to a performance-based fire protection program under NFPA 805. Over the next few years, a major focus of NRC fire protection engineers is to review the applications for these NFPA 805 license amendment requests and reconcile the remaining units with their respective deterministic regulations, thereby achieving compliance with fire protection regulations.

Brian Metzger is with the U.S. Nuclear Regulatory Commission. This paper was prepared by employees of the U.S. NRC. The views presented do not represent an official staff position.

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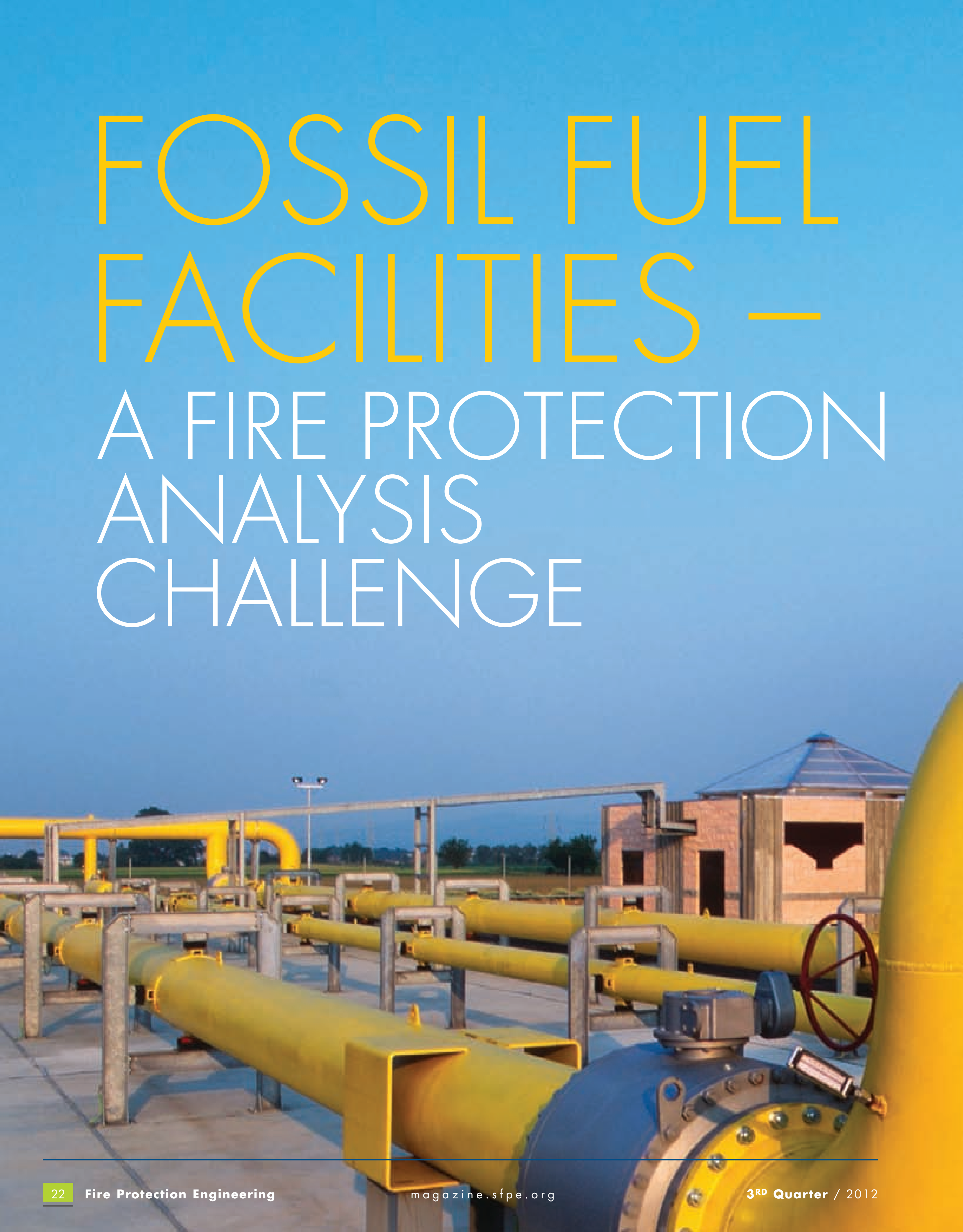
FOSSIL FUEL FACILITIES – A FIRE PROTECTION ANALYSIS CHALLENGE



By Marcelo D'Amico, P.E.

The demand for energy (and specifically, electricity) is at an all-time high as populations around the world grow. More communities are planned in remote locations where power generation is critical for infrastructure and business. Based on this need, multi-national companies are developing fossil fuel electricity generating power plants (natural gas, petroleum fuel, or coal) at a record pace.

While fossil fuel power plants are not new, modern facilities can be large and complex. Thus, it is up to the fire protection engineer to understand the risks and develop a fire protection basis of design according to an in-depth fire protection analysis (or performance-based design approach).

Fossil fuel power generating facilities pose a unique set of challenges for today's fire protection engineer. An engineer must take into account life safety and asset protection, as well as business continuity when developing a fire protection design strategy for a facility.

A power plant may include a diverse set of risks and areas such as (but not limited to):

- Administrative buildings
- Warehousing
- Water treatment
- Processing areas
  - Compressors
  - Pumps
  - Turbines
  - Boilers
- Electrical substations
- Fuel storage
- Conveyor belts

There are a variety of codes and standards that might be applicable to a fossil fuel power generating plant. Depending on location, these can range from National Fire Protection Association (NFPA) codes and standards, local building codes, funding organization requirements, and insurance requirements such as Factory Mutual, Chubb, etc. It is critical that a fire protection engineer fully understand all risks associated with the power plant in question and the minimum code requirements before beginning an analysis. Based on the minimum requirements of applicable codes and standards, the fire protection engineer must determine any areas where it is appropriate to exceed the minimum requirements of the codes and then communicate that to the owner/client for approval.

Many prescriptive codes and standards exist that will provide fire protection engineers guidance as to the minimum level of protection required for some hazards. A fossil fuel power generating facility can benefit from a proactive performance-based design approach due to its complexity, unique risks, and the economics of the installation of specific fire protection systems.

The first step in this performance-based design approach is executing a fire hazard analysis. The fire hazard analysis will determine areas where fire protection is required, what type of protection is needed, and how much protection should be provided. Fire protection requirements will focus on building construction, separation of hazards, ignition protection, process safety (e.g., control of releases), and detection and suppression. Additionally, other information should be sought by the fire protection engineer such as emergency response support from an internal fire brigade or local fire department. The fire protection engineer should interview fire brigade members and local fire department personnel to determine their ability to address the hazards present. This will play a critical role in the fire protection system's design phase of the project (manual response vs. fixed protection).

WATER SUPPLY

Many facilities do not make use of a public water distribution system for firewater supply (many facilities outside the U.S. lack this infrastructure). Therefore, the fire protection engineer must determine the worst case firewater demand scenario as a result of a fire hazard analysis. This information will be utilized to properly size the water

supply (i.e., body of water, tank, reservoir, etc.), fire pumps, and distribution system.

Based on results of the performance-based fire protection analysis, systems should be sized according to the facility's hazards. This can be a challenge if a fire protection engineer is designing based on the prescriptive codes and not a performance-based approach to fire protection engineering. That is, a fire protection engineer must take into account the type of hazard and determine the overall amount of water (or other suppression agent) required for firefighting during and after an event.

Specific fire hazards, such as coal, require that water not only be budgeted for firefighting during a fire, but also for a post-fire event if the area re-ignites. If the water source and pumping capacities were not adequately designed, this could pose a problem for emergency responders.

FIRE PUMPS

Fire pumps should be designed with a vision for future expansion and redundancy. Many power generation facilities expand as demand requires; therefore, the fire protection engineer should consider future projects when sizing fire pumps and distribution systems. Moreover, a facility's utilities should be studied carefully to determine whether diesel- or electric-driven fire pumps should be used. NFPA 20 and NFPA 70 handbooks[1,2] should be examined to fully understand what makes up a "reliable" electric grid for use of electric-driven fire pumps. Most power generation facilities should have at least one 100% redundant pump with alternate power generation, such as a diesel-driven fire pump.

Once the fire hazard analysis has been completed, and thorough performance-based design criteria set, the fire protection engineer should determine the best fixed or manual fire protection system to complement the firewater distribution system. In the case of power generating facilities, many choices exist, each with its own pros and cons. These systems include, but are not limited to, the following:

- Water spray
- Water mist
- CO_2
- Clean agent
- Foam (low expansion)

The systems listed above should be installed as part of fixed equipment, but some can be designed for manual operation if emergency response personnel are trained to combat the hazards involved. One example is water spray systems that are connected to both flame-detection and manual pull stations for activation by process personnel and emergency responders. Another example is the use of foam via manual monitors by emergency response personnel responding to a fire where foam has been used in emergency response plans.

As part of the overall fire protection strategy of a power generating facility, one of the key features should be the fire- and gas-detection system. Although NFPA provides prescriptive guidance[3] on where to install such detection devices, it does not approach the subject at a deeper level, such as recommending the execution of gas dispersion models to locate gas detectors, or fire and explosion models to locate flame detectors. That is, it is up to the fire protection engineer, through the performance-based analysis, to determine what detection device should be utilized and where. The key component of a fire and gas detection system is rapid detection and its logic.

A cause and effect matrix should be developed that sets forth the chain of events based on the activation of certain detection devices. For example, if two out of three flame detectors initiate near a boiler, the logic in the system may start the fire pumps and subsequently a water spray or other equivalent system.

Fossil fuel power generating facilities create a unique challenge for fire protection engineers. Life safety is always the number one priority, but fire protection engineers must take into account business continuity and asset protection when developing a fire protection strategy. Merely relying on prescriptive codes and the minimum required by the Authority Having Jurisdiction may not be sufficient depending on client needs and location of the facility. Thus, the fire protection engineer must execute a fire hazard analysis and performance-based design before specifying any solutions. The final goal is to keep people safe and the lights on.

Marcelo D'Amico is with Orcus Fire Protection LLC.

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POTENTIAL IMPACTS OF SMART GRID ON FIRE PROTECTION ENGINEERING

By Frederick W. Mowrer, Ph.D., P.E., FSFPE, Lonny Simonian, P.E., Thomas M. Korman, Ph.D., P.E., and David C. Phillips

INTRODUCTION

Historically, the generation, transmission, and distribution of electricity has largely been a one-way process, with electrical service providers sending electricity to consumers with little or no feedback from the consumer sites. That model is changing, however, with the modernization of the electricity delivery system to provide two-way communication between providers and consumers as a means to monitor and, in some cases, regulate electrical distribution. Another change is the more widespread use of on-site electrical generation, distribution, and storage systems.

These changes fall under the umbrella of what has become known as the "Smart Grid." The purpose of this article is to address some of the potential electrical and fire safety impacts of the Smart Grid that were identified as part of a research project conducted at the California Polytechnic State University (Cal Poly) on this topic (see page 30 sidebar).

WHAT IS SMART GRID?

Under the Energy Independence and Security Act of 2007, the National Institute of Standards and Technology (NIST) has "primary responsibility to coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems…."[1] Furthermore, NIST defines the term "smart grid" as:[1]

"a modernization of the electricity delivery system so it

Smart Grid and NFPA Electrical Safety Codes and Standards

Project Background

In 2009, NFPA was invited to participate in the National Institute of Standards and Technology (NIST) smart grid rapid standardization initiative to ensure that the safety of built infrastructure was appropriately addressed. This was a proactive initiative to ensure that *National Electrical Code*[2] (NEC) and other NFPA electrical safety standards kept pace with smart grid developments. An NFPA smart grid task force was formed and a grant request submitted to NIST for focused support of task force activity. This included accelerating interoperable codes and standards development for the smart grid. The grant request was approved in the summer of 2010.

Project research objectives included:

- **Technology Review and Safety Assessment** of the emerging technologies associated with smart grid implementation and their impacts on the safety features of the built environment
- **Regulatory Development and Needs Assessment** of current weaknesses/gaps in the U.S. fire and electrical safety codes and standards which will impede widespread implementation of this technology
- **Roadmaps** of needed specific codes and standards development/changes and areas where additional data/research on safety aspects is required

The project has received broad support from the fire protection community. The project steering committee consisted of members representing the National Electrical Manufacturers Association, Underwriters Laboratories Inc., International Association of Electrical Inspectors, International Fire Marshals Association, NEC Correlating Committee, Schneider Electric Company, NIST, National Fire Protection Association, and CSA-International.

A two-day industry workshop was conducted in Washington, D.C., in mid-March of 2011 to review preliminary results and solicit input from leaders within the NFPA safety standards development community on the project. The NEC Smart Grid Task Force also provided comments in consideration of the upcoming NEC code-change cycle.

The outcomes of the project included:

- The final report,[5] which is available for free download at *nfpa.org/foundation*
  - This will form the technical basis for submitted NEC changes related to the smart grid
- A 20-page inspector's guide[6]
- Presentations at IAEI section meetings
- Plans for future webinars

monitors, protects and automatically optimizes the operation of its interconnected elements – from the central and distributed generator through the high-voltage transmission network and the distribution system, to industrial users and building automation systems, to energy storage installations and to end-use consumers and their thermostats, electric vehicles, appliances and other household devices."

In this context, "thermostats, electric vehicles, appliances and other household devices" may be considered "utilization equipment." There are a wide range of energy management applications and electrical service provider interactions, including:

- On-site generation
- Demand response
- Electrical storage
- Peak demand management
- Forward power usage estimation
- Load shedding capability estimation
- End load monitoring (sub metering)
- Power quality of service monitoring
- Utilization of historical energy consumption data
- Responsive energy control

A Smart Grid Conceptual Model can be portrayed as a set of diagrams and descriptions that are the basis of discussing the characteristics, uses, behavior, interfaces, requirements and standards of the smart grid.[1] This conceptual model, shown in Figure 1, provides a context for analysis of interoperation and standards for the development of the smart grid architecture.

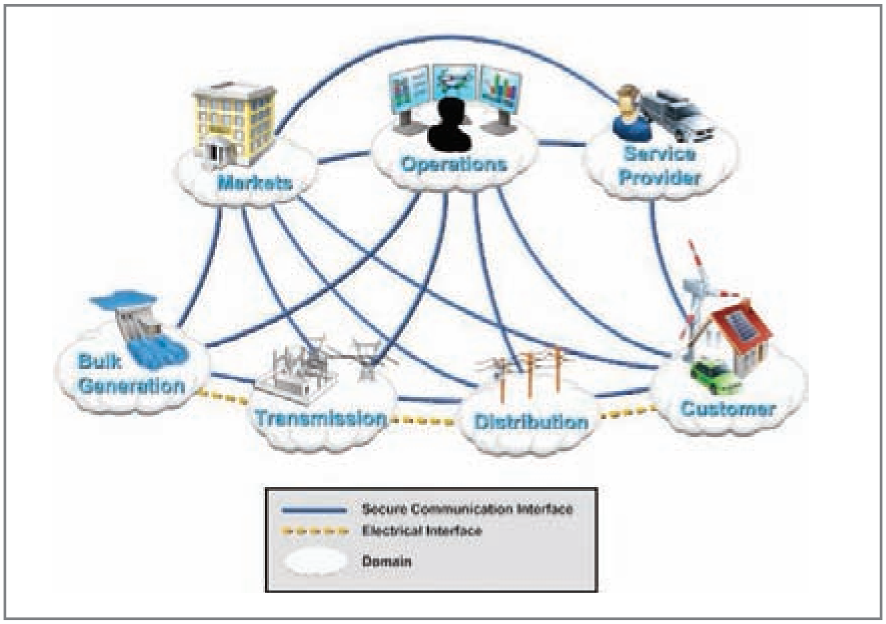

Figure 1. Smart Grid Conceptual Model[1]

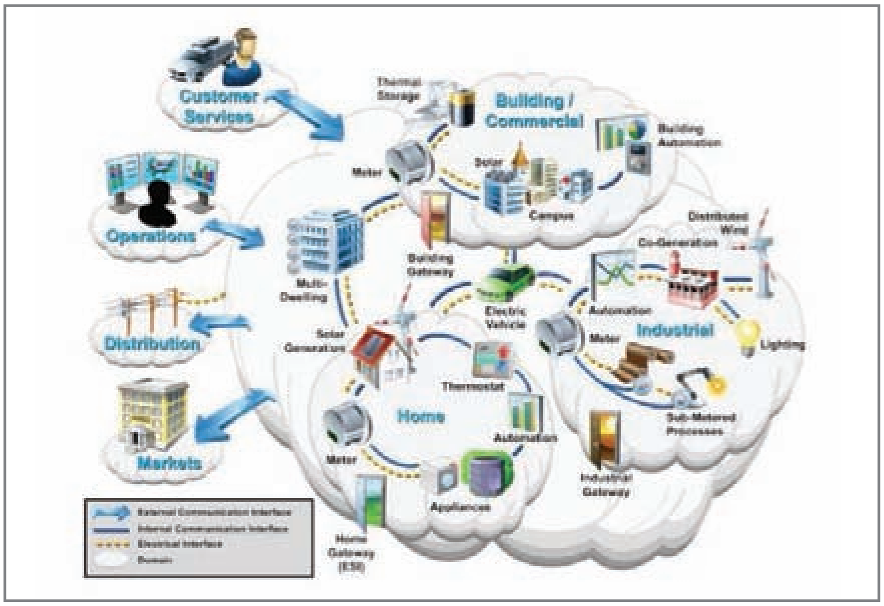

Figure 2. Smart Grid Customer Domain[1]

Within this model, "customers" are defined as the end users of electricity, but they may also generate, store, and manage the use of energy. Traditionally, three types of customers are identified, each with their own domain: residential (home), commercial (building/commercial), and industrial. In addition, the end user may be an institutional customer (such as schools, hospitals, etc.). This project focused on the end user, or customer, in the built environment as shown in Figure 2.

Implementation of the smart grid changes the nature of the electrical distribution system in ways that have a number of safety implications, including personnel, electrical, and fire safety. Because of these safety implications, it is important that relevant safety codes and standards, such as the *National Electrical Code*,[2] stay abreast of smart grid developments.

Before the smart grid, electrical power distribution to customers was largely a one-way process, with customers receiving electrical power generated at a bulk generation plant which was then transmitted and distributed via the existing grid. Under this scheme, a limited amount of instrumentation data could be transmitted from a customer to the service provider and, in some instances, remote control could be executed, such as remotely turning off residential air conditioners during periods of peak demand.

Under the smart grid, electrical power generation and distribution become a two-way process between the customer and the grid. To work effectively and safely, the processes of power generation and distribution, as well as those of instrumentation and control, must be closely coordinated and managed.

SMART GRID TECHNOLOGIES

Current and emerging smart grid technologies were reviewed and the implications that these technologies may have upon the built environment (such as a facility's safety features) were assessed wherever the *National Electrical Code*[2] (NEC) has

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jurisdiction. This included all power distribution and control systems throughout a facility. Specific areas of focus were:

- The electrical service or utility point of connection interface (smart meter)
- Energy generation and micro-generation systems (such as photovoltaic cells, wind power, micro hydro, emergency and standby generators, and fuel cells)
- Energy conversion/storage systems (such as batteries, uninterruptible power supplies (UPS), and thermal energy storage)
- Plug-in vehicles
- Community energy storage

Customers who adopt smart grid technology gain control over the amount and time of electrical load consumption. For residential customers, the smart meter is typically installed by the utility or service provider, and the customer may acquire additional devices/systems to take advantage of the information and communication provided by the meter.

For example, if these customers switch to a time-of-use pricing system, they can benefit by shifting non-time-specific loads to cheaper times, optimizing micro-generation systems for maximum output at high price times, and using on-site storage to supply the grid or the home at high-price times. The commercial customer may acquire additional devices/systems to take advantage of the information and communication provided by the meter.

Many commercial customers have already taken advantage of a time-of-use pricing system, in which they perform non-critical operations at times when that rate structure favors

ROOF DECK FACT CHECK

At one time, roof assemblies were assumed to be fire safe if the deck and its supports were of metal, particularly when the fire hazard of the building's contents were considered low to moderate. This type of roof construction was classed as "non-combustible" even though the vapor barrier, adhesive and roofing used were combustible.

A fire at the General Motors' transmission plant at Livonia, MI in 1953 proved the fallacy of this assumption. In that fire, highly combustible vapors from the asphalt roofing leaked through the metal deck, rapidly spreading fire along the underside of the "non-combustible" roof assembly. The uncontrolled roof fire quickly spread throughout the 34-½ acre building, collapsing the unprotected metal roof.

The GM fire prompted the development of tests to assess the performance of roof assemblies in this type of fire exposure. The performance is measured by exposing a sample assembly to a controlled fire for 30 minutes in a standard test furnace. For approval and subsequent Underwriters' Laboratories listing as Fire Classified, the flame spread must not exceed 60 ft. in the 100 ft. furnace or 14 ft. in the 25 ft. tunnel furnace. Thermal degradation and combustive damage to the assembly is also evaluated and must diminish at increasing distances from the immediate fire exposure area. These limits were established to determine the acceptability of improved metal decks supporting asphaltic roofing. Tunnel tests on a fire-retardant-treated plywood system called NM 501 at Underwriters' Laboratories in 1961 gave results well below these limits.

Subsequent full scale tests at the Underwriters' Laboratories on a 20 ft. by 100 ft roof assembly with ¾" fire-retardant-treated plywood on fire-retardant-treated 2 x 12 joists spaced 48" on center confirmed the suitability of this roof system to perform on a parity with "Fire Classified" unprotected metal decks. After one-half hour of severe fire exposure simulating the effects of highly combustible contents, flame spread was less than for the metal roof and the fire-retardant-treated plywood system maintained its structural properties and shape longer than steel systems exposed to the same test.

Neither of these previous tests nor their results should be confused with ASTM E84, Standard Test Method for Surface Burning Characteristics of Building Materials and its results. ASTM E84 is a standard method to assess the spread of flame on the surface of a material. Often referred to as the "Tunnel Test," ASTM E84 involves installing a sample of material 20 inches wide and 25 feet long as the ceiling of a horizontal test chamber. The material is exposed to a gas flame on one end of the tunnel for a period of 10 minutes. The rate of flame front progression on the material is compared to selected standards of cement board and red oak and calculations made to assign a numeric value or Flame Spread Index.

An often confusing issue is whether a fire retardant paint or coating on OSB with a Flame Spread Index of 25 or less is the same as fire-retardant-treated plywood. The distinction between these products becomes even more critical when the roof system is used in noncombustible construction. One of the most important aspects to remember is this: Pressure impregnated fire-retardant-treated plywood was developed as an alternative to metal roof decks, it is given comparable insurance rates and fire-retardant-treated wood roof systems are suitable for the same uses. On the other hand, OSB products which claim to be the same as fire-retardant-treated plywood have not been tested in the full scale test and their performance has not been evaluated in comparison to the Fire Classified unprotected metal deck.

For more than 100 years the wood preserving industry has produced wood pressure impregnated with fire-retardant salts to enhance wood's performance in fire. Pressure impregnating lumber and plywood with fire-retardant treatments imparts properties important to fire safety. Fire-retardant-treated wood does not support combustion and there is no significant glowing after flames are removed. Also, fire-retardant treatments substantially reduce the combustion rate of wood while at the same time limiting flame spread.

Device/System	Description	Possible NEC Issues
Smart Meters	A meter that monitors and automatically reports a customer's electricity consumption to the utility. Smart meters may also interface with customer's energy systems and devices to provide the customer with additional information, communications with the utility, and demand response or load shedding triggers.	• Increased wiring for communications • Life-safety circuits must not be affected by load shedding • Increased load center wiring • Adequate grounding and bonding provisions • Sensors for connecting smart meters and major electrical loads • Harmonics induced from Class 2 wiring • Security systems • Life support equipment
Energy Micro-Generation, Co-Generation, and Generation Systems (EMGS)	Some grid-connected electricity customers have the ability to generate their own electricity through photovoltaic systems, fuel cells, backup generators, etc. These systems may be used to power the customer's equipment or add energy to the grid, especially during peak hours for economic incentives or to help with load shedding. Currently, however, backup generators are not normally permitted to supply power to the grid.	• System interconnection requirements • Protection for fuel to energy conversion • DC from an EMGS to a building • Manual disconnect switches • Grounding system interconnection • Excess generation contingencies • Manual override of automatically controlled circuits • Use of DC from EMGS by consumers • Conversion of DC to AC for use or transmission to the grid • Limitations on inverter harmonics • Listed/certified equipment
Energy Storage Systems (ESS)	Storage systems may be used by customers to reduce demand during peak hours, as a backup in case of grid failure, or as a way to increase the flexibility of renewable energy.	• Overcharging of storage systems • Charging and discharging of ESS • DC to AC conversion for use or grid supply • Fuel cell placement and clearance • Ventilation requirements • Fault currents
Plug-In Vehicles	These vehicles have an energy storage system on-board. The storage can be charged by connection to the grid and may be able to supply the grid if needed.	• Battery charging and consumption meter/controller installations • Overcharging protection • Vehicle-to-Grid storage system charging and discharging • Charging and discharging • Listed/certified equipment
Community Energy Storage (CES)	A local energy storage with limited backup time that is available to a small group of customers. CES units allow excess energy from the customers to be captured and later re-dispatched.	• Voltage flicker provisions • CES unit guidelines • CES unit placement guidelines • Grounding and bonding provisions

Table 1. Summary of Smart Grid Technologies

Technology			Smart Meters and Energy Management					Energy Microgeneration, Generation, and Co-Generation						Energy Storage Systems				Plug-In Vehicles			Community Energy Storage	Large Switching Loads
NFPA Code	Chapter	Article/Section	Smart Meters	EMS	Smart Power Strips	TOU/Rate Structures	Demand Response	Photovoltaics	Small Wind Turbine	Micro Hydro	Fuel Cells	Microbial Fuel Cells	CHP and Micro CHP	Energy Storage	Batteries	UPS	Thermal Energy Storage	Plug-in Vehicles	Charging EVs/Stations	Vehicle-to-Grid Storage		
70[2]		90	√	√																		
	2	210.2																	√			
		210.11	√	√																		
	2	210.19 (A)																				√
		210.52																	√			
		215.2 (A)(4)																				√
		220.3							√		√								√		√	
		220.14																	√			
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		240.3							√		√								√		√	
		250.3							√		√								√		√	
	4	422.31	√	√																		
		424.19	√	√																		
		430.75	√	√																		
		440.11	√	√																		
		445.18	√	√																		
		480.5	√	√																		
	5	517.31					√															
	6	625.26	√	√																√		
	7	700.4	√	√			√															
		701.4	√	√			√															
		705	√	√			√															√
		Table 705.3							√	√		√										
		705.20	√	√			√															
		705.30							√	√		√										
		705.40	√	√			√															
		708.22	√	√			√															
		New 750	√	√			√															
70E[7]	1	100	√	√	√			√	√		√						√	√	√		√	
		120												√								
	3	320													√							
110[3]	5	5.2									√											
	6	6.2.2	√	√																		
		6.2.5	√	√																		
111[4]	6	6.2.4.2	√	√																		
		6.2.4.2.4	√	√																		
		6.2.4.5.1	√	√																		
	7	7.1.4	√	√		√	√															
	8	8.4.1	√	√		√	√															

Table 2. Summary Matrix

a lower rate. For example, a commercial customer may produce ice during the night to use during the day for a chilled water system.

Table 1 provides a summary of theses smart grid technologies and provisions that may need to be addressed by the NEC.

REVIEW OF NFPA 70

Based upon an assessment of current and emerging smart grid technologies, a review of the NEC was conducted and NEC sections were identified as candidates for revision. Some of these code sections may require revisions to address smart grid monitoring or control, such as chapter 4, "equipment," and chapter 6, "special equipment," while other code sections may require revisions due to utility interfaces (chapter 1, "general," and chapter 2, "wiring and protection"), emergency power (chapter 7, "special conditions"), or wired/wireless communication (chapter 8, "communication systems").

SUMMARY MATRIX

Table 2 links recommended code revisions to technologies that have evolved to prompt the change.

Acknowledgements

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This work was made possible by the Fire Protection Research Foundation (an affiliate of the National Fire Protection Association). The authors are indebted to the project steering committee members, smart grid task group members, and industry representatives for their valuable suggestions.

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FACING THE FUTURE:
ALTERNATIVE ENERGY AND FIRE PROTECTION ENGINEERING

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

The landscape for alternative energy technologies is rapidly changing. More and more consumers and businesses are turning to alternative energy sources and technologies. Developments in the field are proliferating at an ever-increasing rate, raising new questions about safety and reliability.

These new applications are introducing different challenges for fire protection professionals that require a higher level of attention. New approaches are emerging for handling society's energy supplies such as distributed energy resources and power isolation/shutdown requirements. These are causing a reevaluation of the relevant codes and standards.

These applications are manifesting themselves in all types of settings. For example, within the built infrastructure these include multiple types of occupancies (e.g., commercial, industrial, residential) and include non-building applications such as transportation, as well as combinations thereof, such as an electric vehicle connected to a charging station in a commercial parking structure.

UNDERSTANDING ALTERNATIVE ENERGY AND ALTERNATIVE FUELS

Alternative energy is a relatively broad concept whose precise definition partly depends on the specific context in which it is used. This includes recognition of baseline energy sources from which "alternatives" are measured. The predominant use of fossil fuels for many applications provides the *de facto* baseline from which today's alternatives are typically compared.

The various definitions of alternative energy in mainstream literature are often rooted in renewable energy sources. For example, the concept of alternative energy includes: "energy that is derived from sources that do not use up natural resources or harm the environment",[1] or "energy sources that have no undesired consequences"[2] (such as fossil fuels or nuclear energy), are renewable, and considered to be 'free' energy sources. The sources of energy that are normally considered to be "alternative," and which are the most commonly found among information sources addressing this topic, include the following: biopower, geothermal, hydropower, wind, and solar.

Sometimes specific alternatives are precisely defined in various public policy programs. This may contribute to the perceived confusion on the use of the term "alternative" when talking about alternative energy.

An example of the use of legislative requirements to define "alternative fuels" is the classification system used for motor vehicles that utilize gasoline or diesel fuel. This is set by the U.S. Environmental Protection Agency through the Clean Air Act Amendment of 1990 and Energy Policy Act of 1992, which recognize the following 10 classes of alternative fuels: (1) electricity; (2) hydrogen; (3) natural gas; (4) propane; (5) methanol; (6) ethanol; (7) reformulated gasoline;(8) clean diesel; (9) coal-derived liquids; and (10) biological materials.[3,4] In this case, some of the alternatives are fossil-based fuels that are not recognized as renewable sources.

TRADITIONAL SOURCES OF ALTERNATIVE ENERGY

In today's society, alternative energy sources are most often considered to include: biopower, geothermal, hydropower, wind, and solar.

Biopower is the derivation of energy from bio-products. This approach is not new, and historically includes the use of wood, peat, and other bio-materials. In modern society, biomass includes pulp and paper, municipal solid waste, landfill gas, corn-based ethanol, and similar fuels. The latest technological focus with biomass is on feedstock logistics, fuel sustainability, flue gas clean-up, and integration with other biomass applications such as integrated bio-refineries.

Biopower involves bio-based materials that might stand alone or be blended with conventional fuels, such as ethanol blended gasoline used with today's motor vehicles. Different fuels have different physical characteristics and present different fire protection challenges. For example, the water solubility of some liquid biomass fuels requires modified protection methods such as specialized firefighting foams.

Geothermal is an alternative energy source that utilizes natural heat within the earth for power generation. This is typically accomplished through the use of injection and production wells set into and out of the earth as a closed circuit steam generation loop.

A typical geothermal power plant involves capturing steam (or other media) from beneath the surface of the earth and channeling it through turbines or other machinery for the generation of power, such as electricity. These plants would have hazards similar to conventional electrical power generating plants (e.g., lube oil system), but without the combustion process and its related hazards.

Hydropower is an alternative energy source with noteworthy historical roots. The great industrial mills of the industrial era, for example, were typically built on rivers and other natural waterways to capitalize on mechanical and electrical power generation. Today, hydroelectricity is a direct contributor to the overall energy supply.

This is expanding beyond conventional applications of river ways, and involves tidal flows and other marine and hydrokinetic applications. Like geothermal, the fire protection challenges of hydropower tend to be less than that with other power generation facilities that require a combustion component as part of their power generation process.

Wind provides a clean and renewable power generation source that has been increasing in use through the proliferation of localized wind turbines. In their simplest form, these are electrical generators mounted on top of a tall structural support tower and equipped with large wind propellers. Larger wind turbines can exceed 2 MW per unit, and they are found both in separate installations and in groups within a wind farm facility.

The wind turbine unit itself presents the same fire protection challenges as an electrical generator in other installations, albeit at an elevated and less accessible location. Wind turbines do, however, present appreciable structural load considerations when installed on or near a building. Structural integrity is a serious consideration among other factors during building design or retrofit. These wind turbines are typically located on top of a tall structural tower and well removed from exposures if a serious fire occurs, though outdoor fires and similar exposure concerns are a possibility during a serious fire involving a wind turbine.

> For all types of solar systems, consideration needs to be given to maintaining full access by firefighters on rooftops and on other sections of a building where firefighters operate during an emergency situation.

Solar power is another technology that has proliferated in recent years, in part because of improved manufacturing methods that are making this approach realistically affordable and readily available. The three basic means of capturing the sun's energy are: passive solar (i.e., capturing the sun's energy in building design

and construction); solar thermal (i.e., sunlight converted to heat); and photovoltaic (sunlight converted to electricity).[5]

Of particular interest from a fire protection engineering perspective are solar thermal and photovoltaic systems. Solar thermal systems involve the heating of fluids in a circulating loop system, and they can add appreciable weight load to a structure. They can also introduce possible hazards to emergency responders such as rooftop tripping and scalds from hot liquids.

On the other hand, photovoltaic systems that convert sunlight into electrical energy present certain inherent hazards beyond the concerns with solar thermal systems. A critical consideration for emergency responders and others is that photovoltaic panels are electrically "on" when exposed to sunshine and other light. Power isolation is a technical challenge during an emergency, and complete power shutdown is normally not an option when exposed to sunshine.[6]

For all types of solar systems, consideration needs to be given to maintaining full access by firefighters on rooftops and on other sections of a building where firefighters operate during an emergency situation. Advancing solar technologies now include devices beyond traditional panels, such as photovoltaic fabrics and films that can be installed in any orientation (e.g., on a vertical surface) and that can introduce questions concerning flame spread. New products also include building components such as photovoltaic roofing shingles and tiles, which present hazards to firefighters and others that are not readily obvious.

THE BIG PICTURE

The societal advantages of alternative energy sources such as biopower, geothermal, hydropower, wind, and solar are appreciable, and any inherent hazards of these technologies can be readily managed. The use of these technologies follows two general tracks: smaller individual applications, and large-scale power generation facilities.

Wind and solar are the predominant technologies that are proliferating with smaller individual applications on separate buildings. This is creating challenges on the electrical grid as a result of distributed power supplies. Some systems, such as photovoltaic installations on the roofs of large mercantile stores, can create significant power generation equal to a small power generating facility. These require special attention by fire protection engineers and emergency responders alike.

When alternative energy approaches are used in a centralized manner for large-scale power generation, they present fire protection challenges that are similar to conventional large-scale power plants for engineers and emergency responders. For example, emergency responders might approach a wind farm or concentrated solar installation with significant pre-planning and in close coordination with the site owner and/or utility, similar to how they would approach a conventional power plant in their jurisdiction.

Interestingly, certain alternative energy applications are the power source of choice for some emergency management and emergency response applications. For instance, the use of solar power for emergency preparedness and disaster planning is an obvious

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application of alternative energy independent of the electrical power grid. An intriguing approach used in California is the installation of fire apparatus roof-top photovoltaic systems to accommodate deployment over long periods of time (e.g., a wildfire event), providing a dependable electrical power supply for radio operation and other critical electrical equipment.[7]

NEW APPROACHES AND THEIR CHALLENGES

Other approaches that modify or work in conjunction with primary sources of energy are a natural part of any discussion of alternative energy. This includes technology and programs that address the following: new power systems (e.g., fuel cells); energy storage (e.g., batteries); power supply enhancements (e.g., concentrated solar power); energy management (e.g., smart grid), and energy conservation (e.g., LEED).

One new type of power system that is satisfying today's energy needs is fuel cell technology. These units create electrical energy through membrane interaction and have no moving components. They often use hydrogen as an energy carrier in a process that leaves no adverse byproducts or residue, and they can use other carbon-based fuels, including bio fuels.

Fuel cells show great promise for the future, and the up-front higher equipment costs can be offset by minimal maintenance and clean and quiet operation. Hydrogen fuel cells have become the power source of choice for certain emergency power supply applications, such as remote telephone communication sites. One recent noteworthy application is a set of 12 fuel cells providing 4.8 megawatts of power for the new Freedom Tower and related towers at the World Trade Tower site in lower Manhattan.[8]

Energy storage is not a new concept, as exemplified by Article 480 of the *National Electrical Code*®[9] on battery storage, which first appeared in the 1897 edition. Today, battery systems are being taken to new dimensions, including large battery storage systems that are intended to boost access to distributed alternative energy sources such as wind and solar power supplementing the electrical grid. One example is a new storage cell unit used by a New England utility to coordinate peak energy loads, composed of a collection of 82,000 individual lithium-ion battery cells housed in a shipping container.[10]

Power supply enhancements are also appearing more often in the built infrastructure. One example is an approach referred to as "concentrated solar power," with large-scale photovoltaic systems that utilize additional features such as moveable panels that follow the sunshine or mirrors to enhance the energy yield of the panels. Some of these systems are not stand-alone facilities, but are appearing on the rooftops of large commercial or mercantile buildings.[11]

Energy management is another concept that has far-reaching consequences for how electrical power is used in today's world. Perhaps the most noteworthy example of an emerging concept with sweeping implications is the "smart grid" concept. This is a complete revision of how the electrical power supply is managed.[12] Instead of a continual one-way feed of electrical power from generation sites to the consumer, smart grid enables bidirectional flows of energy and two-way communication and control capabilities through the use of digital

computing and communication technologies within the power delivery infrastructure.[13]

Energy conservation is an important partner to alternative energy approaches, despite its relative passive nature. This discussion would not be complete without mention of energy conservation approaches that are sweeping the built infrastructure. Fire protection professionals are continually facing new and unusual characteristics, as they balance safety with green building design concepts such as Leadership in Energy and Environmental Design (LEED).[14]

HORIZONS OF TOMORROW

For all new alternative energy applications, fire protection engineers and other safety professionals are working diligently to maintain expected levels of safety for consumers, emergency responders, operators, maintainers, regulators, and others. The technological advances of tomorrow are making possible a wide spectrum of alternative energy sources. Some emerging technologies such as fuel cells are already showing great advantages, while others such as nanotechnology for enhanced battery design suggest significant promise for the future. The alternative energy applications of today and tomorrow are making the world a better place, and mitigating any hazards they pose is an important part of assuring their successful implementation.

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

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INNOVATION
AND WATER-BASED FIRE SUPPRESSION

By Andre W. Marshall, Ph.D.

Strategically delivering water to burning commodities is one of the most effective and robust means of suppressing accidental fires. Because of its unparalleled performance and versatility, water-based fire suppression is used extensively. Although the basic cooling (gas and surface) and O_2 displacement mechanisms associated with water-based fire suppression are easy to identify, developing detailed models to support fire suppression analysis remains a high challenge.

It is understandable that progress to establish analytical capabilities for evaluating suppression performance has been slow. However, the absence of this analytical capability has locked the fire safety industry into a costly empirical spiral that inhibits innovation.

In fact, water-based fire suppression could be viewed as the quintessential fire problem (i.e., water vs. fire). Historically, empirical observation and full-scale testing have been the answer to this problem, but as the practice of fire protection engineering develops beyond prescriptive codes and standards toward performance-based design, there is a need to equip researchers and designers with analytical tools based on fundamental knowledge to address the fire suppression problem. In addition to the need for fire suppression model developments, an experimental database would be useful to provide a comprehensive dataset and knowledge base to promote a more detailed and quantitative understanding of fire suppression phenomena by fire researchers and practitioners.

It should be noted that analytical tools are readily available for the design of water supply systems to ensure adequate flow to fire suppression nozzles. At the same time, analytical tools based on Computational Fluid Dynamics (CFD) have been widely adopted for evaluating fire behavior. Yet, at the center of the fire suppression problem is, of course, the nozzle of the fire suppression system, the "business end" of the system, so to speak. Following this point, a variety of fire suppression nozzles have been developed to contend with a myriad of fire scenarios. Despite their variety, these nozzles (and systems) are all designed with the goal of suppressing the fire by strategically dispersing the water. Strategies vary from surface cooling by transient localized flooding (hose and monitor systems), surface cooling by distributed uniform surface wetting (sprinkler systems), to gas cooling and dilution by gas wetting (mist systems).

Although the basic suppression strategies are straightforward, the underlying physics governing spray initiation (i.e., atomization) and the associated nozzle discharge characteristics are poorly understood. As a result, engineering analysis of these devices is riddled with empiricism – from design conceptualization to performance evaluation. Unfortunately, lack of knowledge regarding spray generation has limited the utility of computational tools for fire suppression problems. Admittedly, a number of problems (e.g., pyrolysis models for dry and wet materials) need to be solved before predictive capability of water-based fire suppression is realized. Nevertheless, the ability to accurately predict the spray generated for fire suppression is an obvious and unquestionable requirement as well as a natural starting point.

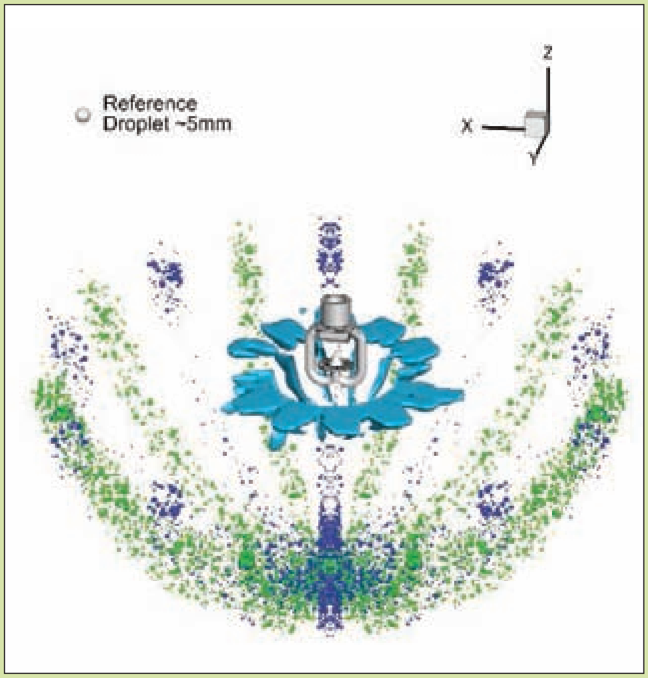

Figure 1. Representation of sprinkler spray

The uncertainty in defining the initial spray and related discharge characteristics makes analysis of spray dispersion and the associated fire suppression performance difficult from the very beginning. A number of recent advancements in the measurement and analysis of fire suppression sprays have been communicated in the literature.[1-5] These experimental and analytical advancements have provided clarity in characterizing these complex sprays while creating critical pathways for the development of computational-based approaches to support the design and evaluation of water-based fire suppression systems (Figure 1). In this body of research, it is the author's intention to demonstrate how advanced measurements and analytical capabilities can be used to achieve detailed descriptions of fire suppression sprays useful for insight, model development, and engineering analysis.

One could imagine, for example, a significant first step in the analysis of fire suppression would be to develop predictive capability for the volume flux of water delivered to a target area or region. Accomplishing this goal would not only be scientifically noteworthy, but practically useful because much of the fire suppression engineering practice and even regulation is based on the delivery of critical volume fluxes of water. It is the author's hope that recent advancements in sprinkler spray research, conducted by the author and others, will demonstrate that complex sprays do yield themselves to quantitative treatment and that this progress will inspire similar developments in other fire suppression applications.

Andre Marshall is with the University of Maryland.

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CASE STUDY

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Starting from the main panel, the network reaches out to four other fire alarm control panels across the complex using 40 remote modules to support fast data communications along the network's extensive serial communications line or SBUS. The SBUS enabled the remote mounting of panels, consequently reducing line voltage.

The facility is comprised of four buildings joined by an atrium in the center, with more atriums throughout, making audio intelligibility a challenge. The VIP-125 amplifier from Silent Knight was utilized to simplify voice evacuation system design. Containing its own power supply with battery backup and up to eight speaker circuits, the 125 watts of amplification power it produces pushes audio communications to speakers throughout mid- to large-scale fire alarm voice evacuation systems. This amplifier can be mounted up to 6,000 feet away from the main control panel.

Three pre-action suppression systems and two Honeywell IR (infrared) flame detectors were tied to the fire alarm network to coordinate the monitoring and response of all systems.

According to Haislip, a few slight modifications could make for an easy emergency communications system (ECS) upgrade. Silent Knight recently launched a line of integrated fire alarm and emergency communications systems, which is complementary to the system installed throughout this critical facility.

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A federal government agency that deals with environmental and energy issues was tasked with the clean-up and removal of outdated structures and subsurface waste materials from past projects/installations. Large tent-like enclosures were built over pits to facilitate the removal of buried wastes so they could be repackaged and shipped to new, better equipped locations. In this challenging environment, it became clear that an effective means of smoke and fire detection was needed in order to protect the people and equipment involved in the project.

Initially, an air aspiration system was installed to provide smoke detection. However, the system became ineffective due to the large amount of dirt in the air that caused the system inlets to become clogged. Workers with protective suits were sent in to clean the inlets but they quickly clogged again, forcing workers to make repeated trips into the hazardous area.

Nelson Fire, a Salt Lake City, UT, fire protection company, recommended a Signi*Fire* video image detection system be installed in a tent built over a second reclamation area. Signi*Fire* is Fike's state-of-the-art, camera-based detection system that visually identifies the presence of flame and smoke at its source, independent of airflow in the area. Nelson Fire recommended Signi*Fire* because the technology gives a critical advantage for early warning fire detection, especially for challenging environments like those seen in the project tents.

Ten Signi*Fire* cameras, housed in protective enclosures, were installed in the tent. Nelson Fire was able to take advantage of the pre-existing network infrastructure, which integrated interfaces for monitoring and managing the system at multiple buildings throughout the site. In addition, the Signi*Fire* system was networked to a fire alarm control panel with the ability to send an alarm to the onsite fire station when the facility was unoccupied.

The Signi*Fire* system was successfully commissioned and installed. It has been operational for several years and free of any problems shown in previous systems. Currently installed in five tents, additional installations are planned and will be incorporated into the existing user interface. With superior protection from Signi*Fire*, challenging environments and open area venues no longer have to bear the burden of ineffective fire protection.

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The new site continues to host the most current issue of *Fire Protection Engineering* magazine, as well as archived back issues. In addition, the site hosts current and archived editions of the *Emerging Trends* enewsletter, as well as case studies, news, departments, and events information.

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BRAINTEASER > Problem/Solution

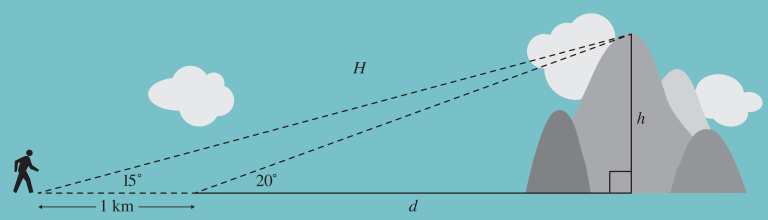
Problem

What is the sum of all integers from 1 to 101, inclusive?

Solution to Last Issue's Brainteaser

A woman is walking toward a mountain. When she looks at the top of the mountain, she measures the angle of elevation as 15 degrees. She walks one kilometer closer to the mountain, and when she looks at the top of the mountain again, she measures the angle of elevation as 20 degrees. How tall is the mountain?

If the height of the mountain is denoted "*h*" and the distance from the mountain is denoted "*d*," then trigonometry can be used to establish relationships between the height of the mountain and the distance as follows:



By the law of sines, for the obtuse triangle: $H = \dfrac{1 \text{ km} \times \sin(160)}{\sin(5)}$

For the larger right triangle: $h = \dfrac{H \times \sin(15)}{\sin(90)}$

Therefore, combining these two equations: $h = \dfrac{1 \text{ km} \times \sin(160)}{\sin(5)} \times \sin(15) = 1.02 \text{ km}$

Thanks to Jose Felipe Luevanos, EIT for contributing to this Brainteaser.

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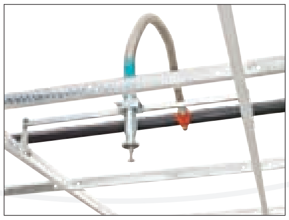
Corridor Sprinkler

Viking announces a new quick-response, extended coverage, horizontal sidewall sprinkler designed specifically to protect corridors, hallways, decks, walkways, and any other application where a wide spray pattern is optimal. The new model VK638, which is cULus Listed for Light Hazard occupancies and has a K Factor of 8.0 (115), is available in both recessed and domed concealed models. It uses patented flow-shaper technology to provide larger coverage areas at lower flow and pressure requirements.

www.vikingcorp.com
—Viking Corp.

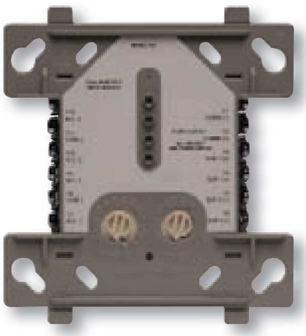
Sprinkler Fitting Bracket



Victaulic introduces the new Style AB1 Bracket, an extension to the AquaFlex® sprinkler fitting line of products. The AB1 Bracket eliminates the need for sprinkler installers to handle ceiling tiles, cut holes in ceiling tiles, and coordinate with the ceiling trade on the jobsite, reducing hands-on installation time by as much as 39%. The Style AB1 Bracket can be used with Series AQB Braided Systems (FM Approved) for suspended or hard commercial ceilings and is available in 24-in. and 48-in. lengths.

www.victaulic.com
—Victaulic

Two In/Two Out Module



New Two In/Two Out multi-function module combines two relay outputs and two monitor inputs into one device. The module is capable of Class B supervised wiring to the monitored devices. It also contains Form C relay contacts, allowing the panel to switch the contacts on command. There is a dedicated LED on the module for each input and output. The control panel can use these bi-color LEDS to indicate normal, alarm, and trouble conditions.

www.systemsensor.com
—System Sensor

High Fidelity Speakers

Wheelock Series EH speakers and speaker strobes produce high fidelity sound output in a low-profile design for indoor wall and ceiling-mount applications, where intelligible voice is required. With a frequency response range of 300 to 8,000 Hz, the Wheelock Series EH allows the speaker to reproduce frequencies closer to the original sound, improving the clarity and comprehension of the intended message. The UL-listed EH notification appliances feature dual voltage (25/70 VRMS) capability and field-selectable taps from 1/8 to 2 watts.

www.coopernotification.com
—Cooper Notification

Advanced Signal Analysis Fire Detection

Siemens introduces ASA*technology*™. ASA stands for Advanced Signal Analysis, a new, patented technology that provides reliable and false-alarm-resistant fire detection for a wide range of applications. ASA*technology* is a software-based solution that in real time, dynamically compares sensor signal data to sophisticated algorithms to accurately and reliably differentiate between a fire emergency and harmless smoke, steam, or dust.

www.usa.siemens.com/ASA4
—Siemens

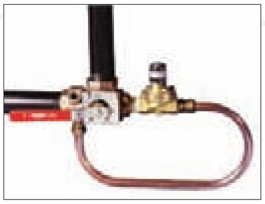
Aspirating Detector

Gamewell-FCI introduces the VLC-400 Aspirating Detector, which immediately senses and verifies the slightest traces of smoke and speed response to save lives and property, particularly within high-value and high-security facilities and in challenging environments. As many as 126 addressable VLC-400 detectors, made by Xtralis™, can connect directly to the signaling line circuit (SLC) of Gamewell-FCI's E3 Series® fire alarm and emergency communications systems, eliminating the common use of high-cost, standalone aspirating systems.

www.gamewell-fci.com
—Gamewell-FCI

PRODUCTS / LITERATURE >>>

Remote Wet-Pipe Testing



AGF Manufacturing has created a self-contained method to remotely fulfill the system inspector's test on a wet-pipe fire sprinkler system. The Model 1200 RemoteTEST incorporates a solenoid valve into the TESTanDRAIN valve. RemoteTEST allows a single operator at a single location to perform the inspector's test on multiple floors and multiple buildings through a local switch, an auxiliary panel, an addressable fire alarm control panel, or a LAN system. Meets NFPA 13 and NFPA 25 requirements for sprinkler water-flow alarm device testing and is UL listed/FM approved.

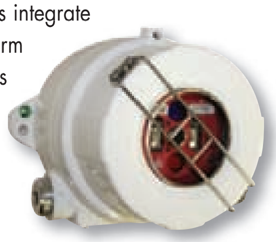
www.testandrain.com
—AGF Manufacturing

Potter's New Fire Panels

Potter has introduced two higher capacity addressable fire alarm control panels: the PFC-6200 and the PFC-6800. The PFC-6200 is a 127-point panel expandable up to 254 points, whereas the Potter PFC-6800 is a 127-point panel expandable up to 1,016 points. Both utilize the Potter/Nohmi device protocol that has a complete line of initiating and control devices, and the same features as the rest of the PFC Series line including system-wide synchronization, Ethernet connection and e-mail communication capability.

www.pottersignal.com
—Potter Electric Signal Co.

High-Tech Flame Detection



NOTIFIER's Fire Sentry line of flame detectors integrate with any version of the ONYX Series fire alarm systems for detection of true fire emergencies in a wide array of commercial and industrial applications. Fire Sentry flame detectors use a series of patented algorithms to speed detection of a real fire event while virtually eliminating false alarms. In addition to monitoring for spikes in the radiant energy of a flame, Fire Sentry detectors monitor the entire flame spectrum for inconsistencies to unequivocally verify an alarm.

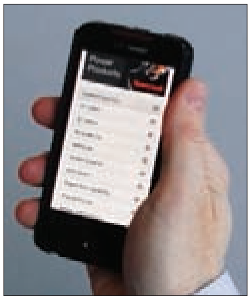
www.notifier.com
—NOTIFIER

Closet Flange Firestop Gasket

The SpecSeal® Closet Flange Firestop Gasket is a one-piece intumescent gasket specifically designed for sealing closet flanges. It installs quickly from the top and expands rapidly when exposed to heat to provide code-compliant firestop protection for toilet flange assemblies with plastic and metal pipes. The SpecSeal Closet Flange is code-compliant and ready to use. No tools are required.

www.stifirestop.com
—Specified Technologies Inc.

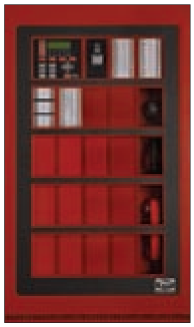
Power Supply Selector Web App



Honeywell Power Products' Power Supply Selector Web app helps installers and wholesalers quickly determine the appropriate power supply for fire alarm, video, intrusion, and access control systems. Users can narrow-down power supply options based on voltage and amperage requirements. Photos and descriptions, along with links to data sheets and installation manuals for more than 200 power supplies can be accessed. The app also features a cross-reference chart of competitive power supply offerings and a scannable bar code for salespeople to source inventory information.

Honeywellpower.com/webapp
—Honeywell Power Products

Integrated Voice Messaging



Fike's Integrated Voice Messaging system is listed to the new UL2572 Mass Notification Systems standard, making it an ideal foundation for mass notification or emergency communication systems. Features include an optional Local Operating Console (LOC) or remote microphone. The LOC enables the user to remotely page and/or initiate pre-recorded messages from a remote location. It can also be used with Fike's CyberCat® line of Fire Alarm products to provide voice capabilities within smaller applications.

www.fike.com
—Fike

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