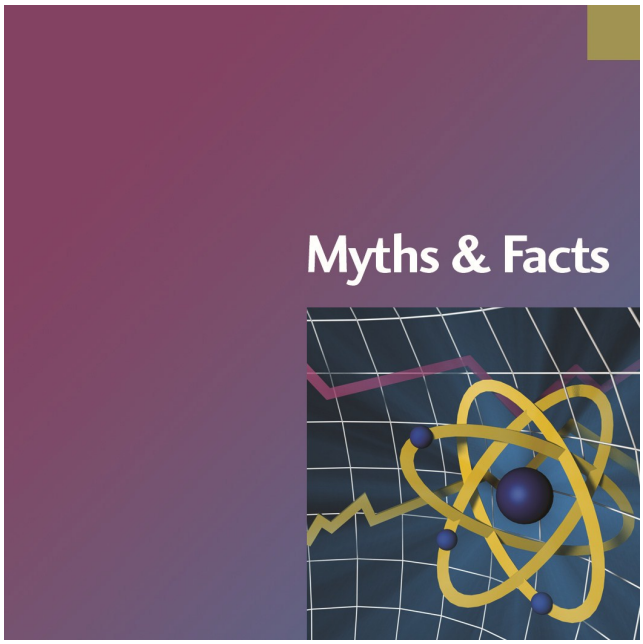

January 2012

Fire Protection

Myths

- **Some operating nuclear plants in the U.S. do not meet NRC fire protection safety standards.** *(See* Federal Requirements for Fire Protection in Nuclear Plants *on pages 5-6.)*
- **NRC waives enforcement of fire rules at nuclear plants.** *(See* Appendix R *on page 5.)*
- **New nuclear plant designs have not evolved to improve fire safety.** *(See* Fire Protection for New Plants *on page 7.)*

Facts

Fires can pose a significant threat at nuclear plants, just as they can at any large industrial facility. That's why nuclear power stations take a defense-in-depth approach to protect against fires. The key to this approach is creating multiple independent and redundant layers of defense to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is relied upon exclusively. Defense-in-depth includes the use of fire prevention, physical barriers, redundant and diverse safety functions, and emergency response measures such as fire brigades.

The industry and the U.S. Nuclear Regulatory Commission (NRC) also conduct research to advance understanding of fire protection and mitigation.

Origin and Evolution of Fire Protection Regulations

In 1971, the Atomic Energy Commission, NRC's predecessor, issued the first fire protection regulations for U.S. commercial nuclear power plants. Known as "General Design Criterion 3," these regulations provided basic design requirements and broad performance objectives, but contained no implementation guidance or assessment criteria. Fire protection at nuclear plants was at that time similar to that at fossil-fired power plants.

A March 22, 1975, fire at Unit 1 of the Browns Ferry nuclear plant in Alabama fundamentally changed

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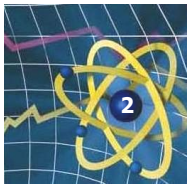
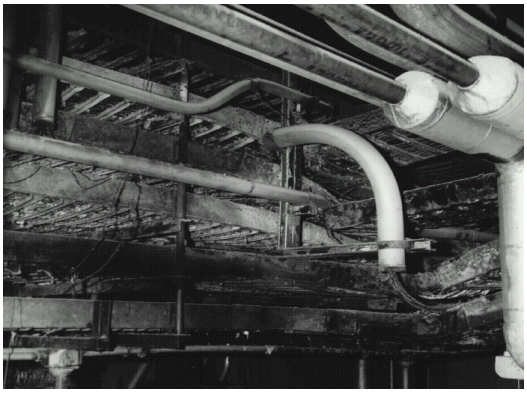


the concept of fire protection and regulatory requirements for U.S. nuclear power plants. Plant workers, using a candle to check cable penetrations for leaks, accidentally ignited a polyurethane foam penetration seal. The fire spread and damaged the electrical power, control and instrumentation cables that controlled the cooling systems for the reactor. Operators could not monitor the plant normally and had to perform emergency repairs on systems needed to shut down the reactor safely. Investigations after the fire revealed deficiencies in the design of fire protection features at nuclear power plants and plant procedures for responding to fires.[1]

No other fire at a nuclear plant, before or since, has threatened a U.S. nuclear reactor's ability to safely shut down. Despite being one of the worst fires at a plant in nuclear history, no-one was injured and no radiation was released to the environment.

After the Browns Ferry fire, the NRC responded with technical guidance and new requirements. These included Branch Technical Position (BTP) 9.5-1 in 1976 and its Appendix A, which included 59 specific guidelines in seven general areas of nuclear plant fire protection.



April 1975 photograph of fire damage to electrical cable trays at the Browns Ferry nuclear plant. Photo courtesy NRC.

In 1980, the NRC published Appendix R, which required plants licensed before January 1, 1979, to protect redundant electrical cables and equipment important for the safe shutdown of a reactor. These requirements resulted in the implementation of design features such as fire wraps, fire walls, and automatic detection and suppression systems. Appendix R also required emergency lighting.

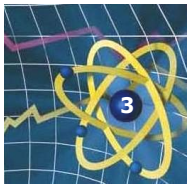
For plants that began operating after January 1, 1979, the NRC imposed or attached conditions similar to the requirements of Appendix R to these plants' licenses. Appendix R is described in more detail on page 6.

Industry activity in the mid- and late-1980s centered on completion of licensing requirements related to 10 CFR 50, Appendix R, NUREG-0800, and response to generic communications related to implementation of fire protection requirements.

In the early 1990s, industry fire protection activity shifted to gaining a better understanding of technical issues. Materials research and electrical analyses were conducted, which resulted in changes in fire protection materials requirements. Activity in the 1990s also included assessment of risk vulnerabilities related to fire as part of the Individual Plant Examination of External Events (IPEEE). The NRC's Reactor Oversight Process (ROP), implemented in 2000, included quarterly, annual, and triennial fire protection inspections.

The NRC's Fire Research Branch runs a state-of-the-art research program to develop and validate fire analysis methodologies and supporting data in cooperation with the industry-funded Electric Power Research Institute

[1] *Fact Sheet on Fire Protection for Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, March 2011, http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fire-protection-fs.html



(EPRI). The research provides the basis for recommending improvements in programs and/or processes to risk-inform regulations to achieve enhanced safety, efficiency, and effectiveness. Currently, the NRC is conducting extensive research on fire-induced circuit failures, fire barriers and post-fire operator manual actions. Through these research programs, the NRC and industry seek to constantly improve fire safety standards.

How are nuclear stations protected against fire hazards?

Fire protection at nuclear power plants is built on the concept of *defense-in-depth* to maintain plant, worker and public safety. Defense-in-depth encompasses multiple tiers of administrative controls, redundant fire protection systems and features, and safe-shutdown capabilities, in order to

- prevent fires from starting;
- rapidly detect, control and extinguish fires that do occur; and
- protect a nuclear reactor's structures, systems, and components important to safety so that a fire that is not promptly extinguished will not prevent its safe shutdown.

Most fires occur in areas that do not affect shutdown operations or happen during refueling outages, when plants are already shut down.

The most commonly reported cause of fires at nuclear plants is electrical failures, followed by maintenance-related causes and the ignition of oil-based lubricants or coolant. Although some fires are classified as significant events, and some damage or destroy equipment, none of these fires has degraded reactors' safe shutdown capabilities or resulted in damage to nuclear fuel or containment buildings.

Prevention

Fire prevention is the first line of defense. Prevention includes strict procedures for using and storing combustible materials. For example, various procedures prohibit storage of combustible materials in areas important to safety, designate storage areas with appropriate fire protection, and control use of specific combustible materials, like wood, in areas important to safety.

Other rules and practices at a nuclear plant are designed to control potential ignition sources. Ignition sources include electrical equipment, welding, cutting, grinding, high-temperature equipment and surfaces, reactive chemicals, and static electricity. Activity that involves the use of open flames or welding ("hot-work") is restricted, and requires a permit system, monitoring and documentation. People performing these activities receive training on how to prevent and fight fires. To ensure fires are reported immediately and suppressed as quickly as possible, employees qualified in performing fire watch duties, for example, monitor the work and ensure that appropriate fire-fighting equipment is readily available.

Detection and Suppression

Automatic heat, smoke and fire detection systems are installed in areas of the plant that contain or present a fire hazard to structures, systems, and components important to safety. These systems will work even during a

loss of offsite power. In the event that a fire detection system is down for maintenance, a fire watch team may be assigned to monitor the area temporarily.

Nuclear plants contain extensive, independent, redundant systems of pumps, pipes, connections, hydrants and standpipes that contain pressurized water available only to fight fires.

There are also additional suppression systems, including carbon dioxide, gaseous and/or halon extinguishing systems. Halon is a liquefied, compressed gas that stops the spread of fire by disrupting combustion chemically.


Fire-protected circuit. Photo courtesy NRC.

Preventing the Spread of Fires

A nuclear plant is a combination of thousands of high-technology and conventional components. Machines, pumps, pipes, motors, electrical switches and gears each pose different risks in the event of a fire. To ensure the vulnerabilities associated with different types of equipment and the hazards present in different areas of the plant are well understood, the plant is divided into fire areas that are analyzed separately.

Fire areas are a portion of a building or plant separated from other areas by rated fire barriers. To provide a more detailed fire risk analysis, fire areas may be subdivided into fire zones to analyze specific hazards. To prevent the spread of fires across areas, each fire area has fire barriers at its boundaries.

Independent laboratories rate fire barriers based on how long they can prevent fire from spreading past them. Typically, a fire barrier has a fire-resistance rating of three hours.

Barriers include components of construction (walls, floors, and their supports), including beams, joists, columns, penetration seals or closures, fire doors, and fire dampers. Schools and hospitals have fire doors but, at a nuclear facility, fire doors must remain closed. During operator rounds and NRC inspections, fire barriers, including fire doors, are checked to ensure they are in place to provide protection when needed.

Fire Brigade

Nuclear plant sites have a trained fire brigade or fire department on duty 24-7 to ensure adequate manual firefighting capability for all areas of the plant. Employees on the fire brigade receive firefighting training, are outfitted with firefighting equipment and participate in regular drills to hone their skills and response time. Nuclear plants also have established relationships with the nearest municipal fire departments, who provide back-up to site fire brigades.

Fire Hazards Analysis

In order to make sure nuclear plants comply with NRC requirements, a fire hazards analysis is performed to demonstrate that the plant will maintain

the ability to perform safe-shutdown functions and minimize radioactive material releases to the environment, in the event of a fire.

The analyses at each plant assume that each fire area or zone could have the most severe fire with the potential to affect structures, systems, and components important to safety. The analyses determine the effects of a fire in any location in the plant and specifies the measures for fire prevention, detection, suppression, and containment for each fire area containing important safety equipment.

Federal Requirements for Fire Protection in Nuclear Plants

The government allows nuclear facilities two regulatory options to govern fire protection:

1. Appendix R[2]; or
2. National Fire Protection Association Standard 805, known as NFPA 805.[3]

Local firefighters arrive for a joint drill at the Palo Verde nuclear power plant in Arizona. Photo courtesy Palo Verde Nuclear Generating Station.

As stated above, Appendix R is the Nuclear Regulatory Commission's codified fire protection regulation. In 2001, the National Fire Protection Association (NFPA) created a new fire protection standard, NFPA 805, for nuclear stations that is a risk-informed, performance-based alternative to Appendix R. In 2004, the NRC approved the use of NFPA 805 as an alternative method. Under this method, nuclear units can use tools, such as fire modeling and risk analysis, to determine which areas of the unit are the most important to protect. Currently, about half of the U.S nuclear plants are in the process of switching to NFPA 805.

Using either set of regulations, the NRC ensures nuclear facilities are designed and maintained to prevent and mitigate fires by enforcing fire protection regulations on every U.S. nuclear power plant.

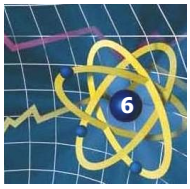
Appendix R

The fire protection requirements in Appendix R establish safety margins through the post-fire survival of the systems needed to shut down the reactor. These requirements are considered deterministic because they are based on a set of postulated serious fires. Appendix R was developed before the staff or the industry had the benefit of probabilistic risk assessments (PRAs) for fires that rely upon complex computer modeling. Risk insights from fire modeling are used to inform and implement Appendix R, but the basis of the regulation is a worst-case fire scenario for a model plant.

Appendix R is a highly prescriptive regulation that is used to set standards

[2] 10 CFR Part 50, Appendix R.

[3] National Fire Protection Association *NFPA 805: Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants*, 2001 Edition (Quincy, Massachusetts, 2001).



for fire protection. Since the 104 operating plants in the U.S. have unique designs, the plants may not have been constructed exactly as envisioned in Appendix R. In cases where strict compliance would not significantly enhance the level of fire safety, the NRC allows plant operators to apply for an exemption to Appendix R.

The NRC has a well-established process for reviewing exemption applications, which require a solid technical basis for approval. Before the NRC will grant exemptions from parts of Appendix R, the regulator must be satisfied that the plant has an appropriate overall fire protection program. An exemption depends on whether the nuclear plant can demonstrate to the NRC that existing or alternative fire protection features provide safety equivalent to those Appendix R imposes.

The NRC does not exempt nuclear plants from fire regulations or waive enforcement of fire rules. Waivers, or more properly, exemptions or deviations, are specific to particular sections of the regulations.

An exemption depends on whether the nuclear plant can demonstrate to the NRC that existing or alternative fire protection features provide safety equivalent to those Appendix R imposes.

Many exemptions are compensated for with other measures such as NRC-approved operator manual actions. Under these actions, plant staff manually activate or manage reactor operations from outside the control room, such as manually stopping a pump that malfunctions during a fire that could affect a unit's ability to safely shut down.

Recently, the federal court for the Southern District of New York upheld the NRC's process for reviewing exemptions. The court also acknowledged that the NRC will reject exemption requests if they do not provide sufficient technical justification.

National Fire Protection Association (NFPA) Standard 805

NFPA 805 describes a methodology for existing light-water nuclear power plants to apply performance-based requirements and fundamental fire protection design elements to establish fire protection systems and features for all modes of operation.

Not all fires carry the same risk, and the risk depends on the likelihood, size and location of a fire. NFPA 805 offers a way to customize fire protection for differing plant designs based on risk. For example, the risk of fire in an otherwise empty room with concrete walls with electrical cable trays is less than for the same room with other plant equipment. Under this new standard, plants use advanced fire analysis tools to determine where the threat of a dangerous fire is the highest.

If a nuclear facility chooses to transition to NFPA 805, its analyses may uncover new fire protection vulnerabilities. The NRC ensures those new insights are appropriately handled as they are identified. All new issues are accounted for with compensatory measures, and will be addressed by a change to the plant design if necessary.[4]

[4] *Clearing Away Some of the Smoke on Fire Protection Reporting*, NRC Blog, May 2011, http://public-blog.nrc-gateway.gov/2011/05/14/clearing-away-some-of-the-smoke-on-fire-protection-reporting/

NFPA 805 is designed to eliminate the need for exemptions and to focus resources on reducing the risk of fires. This program maintains reactor safety while adding appropriate flexibility to each facility's fire protection activities.

Oversight

In addition to daily walk-downs and monitoring performed by NRC resident plant inspectors at each site, there are key inspections targeted at fire protection programs and equipment. The NRC has two procedures that govern the inspection of fire protection at nuclear power plants. One procedure includes quarterly and annual inspections by resident NRC inspectors. The inspectors tour six to twelve plant areas important to safety as well as evaluate fire brigade performance by observing selected fire drills.

NRC inspectors. Photo courtesy NRC.

The second NRC procedure that governs fire protection inspections occurs every three years. This triennial inspection of the fire protection program involves a comprehensive review of the physical aspects of fire protection program implementation, as well as all of the underlying analysis of fire protection requirements. NRC inspectors ensure that modifications to systems and structures or changes in operating procedures have not decreased the level of safety in the plant. Inspectors also make sure that regular maintenance is performed on fire protection systems and that workers are adequately trained. As an added measure of oversight, an annual fire protection program audit is typically conducted by qualified company staff who are not directly responsible for the fire protection program, or an outside independent fire protection consultant.

Fire Protection for New Plants

New reactor designs have the benefit of incorporating industry experience and fire protection requirements into the planning and design phase for the plant.

New plants have better-designed fire areas to isolate potential fires and minimize the risk of the spread of fires. Some new plants also feature passive safety systems that do not require electricity to maintain plant safety, which reduces fire risk significantly. All designs offer improved separation of safety-related electrical cabling and power supplies, which ensures availability of systems required to shut down the plant safely.

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