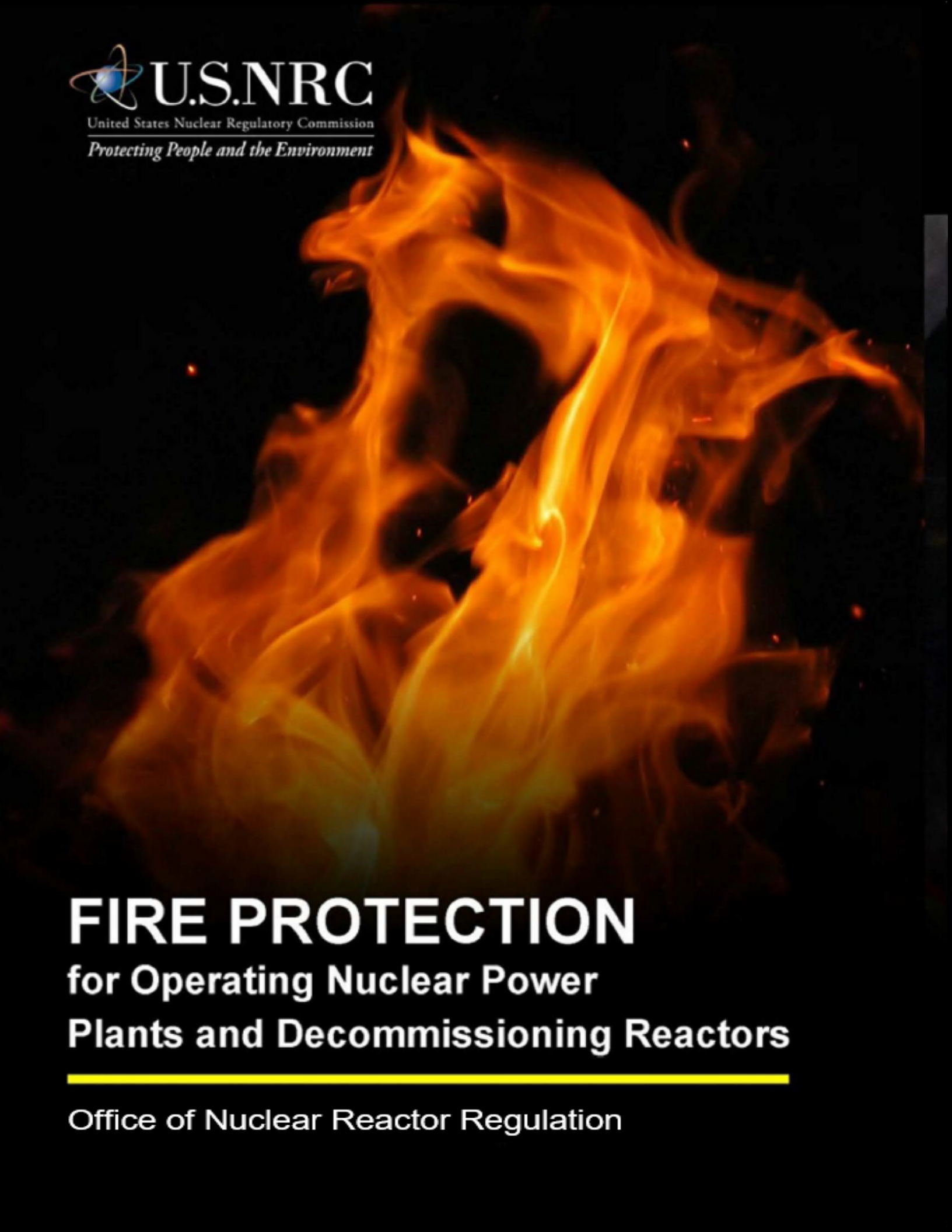


U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

FIRE PROTECTION
for Operating Nuclear Power Plants and Decommissioning Reactors

Office of Nuclear Reactor Regulation

TABLE OF CONTENTS

Fire Protection for Operating Nuclear Power Plants and Decommissioning Reactors

Background

Fires are a potential hazard at most large industrial facilities, including nuclear power plants. Fires are expected to occur over the plant's life and are treated as operational events rather than as design-basis accidents.

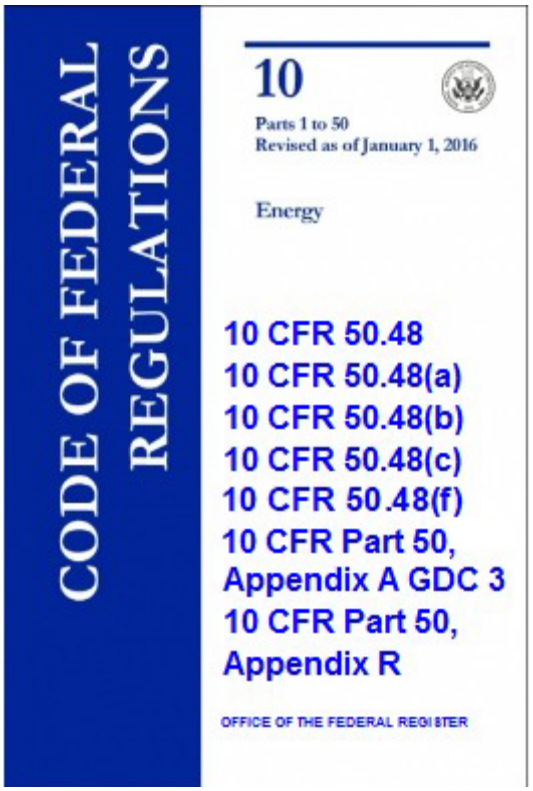
Flammable materials at nuclear power plants differ from those at conventional power generation facilities, fossil-fuel power plants (coal steam, oil or gas steam, combined cycles, and gas-fired simple-cycle combustion turbines), and many other industrial plants. A nuclear power plant does not have a constant flow of fuel (e.g., coal or oil) as the hazard. However, it may have similar fire hazards, such as grouped electrical cables and lubricating products.

The U.S. Nuclear Regulatory Commission (NRC) requires all operating commercial nuclear power plants and decommissioning power reactors to have a fire protection program. The goal for operating reactors is to minimize fire damage to structures, systems, and components important to safety and prevent a fire from causing a radiological release that adversely affects the public, environment, or plant personnel. This is to ensure the ability to safely shut down the reactor and to ensure it can maintain a safely shutdown condition. An operating reactor's fire protection program helps establish the basis for a similar program for the decommissioning phase. Its goal is to provide an appropriate level of defense-in-depth protection against the threat of fires.

The primary objectives of fire protection programs at U.S. operating commercial nuclear power plants are to minimize the probability of occurrence and the consequences of fire. Meeting these objectives through compliance with NRC fire protection regulations provides reasonable assurance, that a fire will not prevent the necessary safe-shutdown functions from being performed, and that radioactive releases to the environment in the event of a fire will be minimized. Defense-in-depth for fire protection involves a comprehensive program of administrative controls and physical fire protection features that ensure the protection of structures, systems, and components necessary to prevent or mitigate release of radioactive materials. This combination of elements reduces both the probability and consequences of fire events, and it ensures that if one fire protection element fails, other parts of the fire protection program will adequately compensate, thereby minimizing the risks to the public, environment, and plant personnel.

Title 10 of the *Code of Federal Regulations* (10 CFR) 50.48, "Fire protection," establishes detailed requirements for fire protection programs at commercial nuclear power plants. These programs include measures related to fire prevention, automatic detection, suppression, and response, as well as personnel administrative requirements and the protection of safety--related structures, systems, and components in the event of a fire. The regulation in 10 CFR 50.48(a) requires each operating nuclear power plant to have a fire protection plan that satisfies General Design Criterion 3, "Fire protection," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50, "Domestic licensing of production and utilization facilities." Under 10 CFR 50.48(f), a nuclear power plant licensee that has certified the permanent cessation of operations and the removal of fuel from the reactor vessel under 10 CFR 50.82(a)(1) must

maintain a fire protection program to address the potential for fires that could cause the release or spread of radioactive materials (i.e., result in a radiological hazard).



Nuclear Power Plant Fire Protection Regulations

Deterministic Fire Protection

Nuclear power plant fire protection programs in the United States follow either a traditional deterministic approach or a risk-informed and performance-based method.

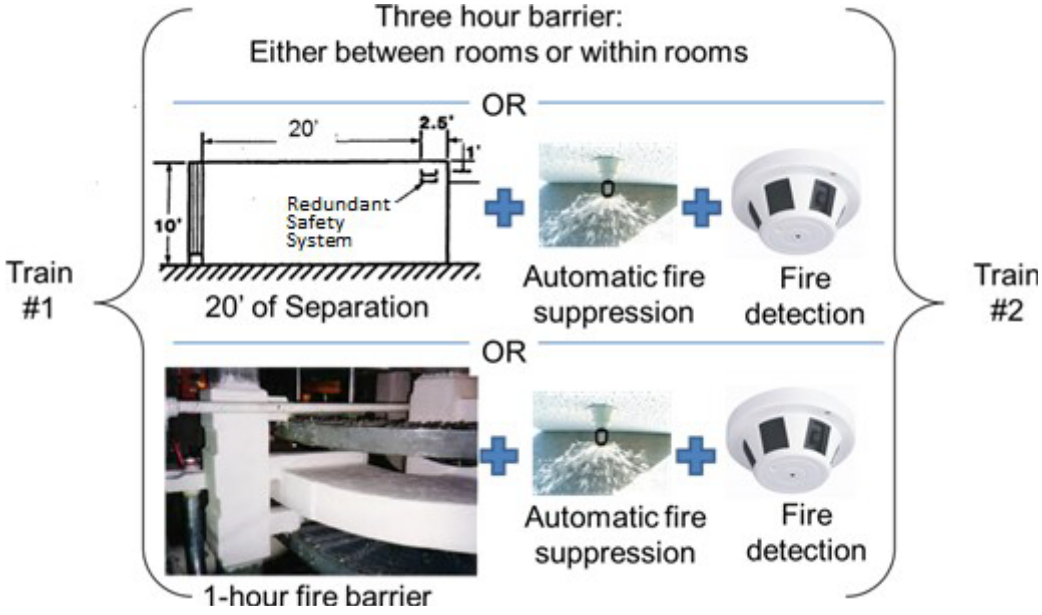
Shortly after the 1975 Browns Ferry fire (NUREG/BR-0361, Ref. 1), the NRC Executive Director for Operations established a Special Review Group to investigate the cause and potential effects of the fire and recommend changes to existing NRC fire protection policies and procedures. In May 1976, the NRC issued Branch Technical Position (BTP), Auxiliary and Power Conversion Systems Branch (APCSB) 9.5-1 (Ref. 2), which applied to plants that applied for a construction permit after July 1, 1979. This BTP incorporated recommendations from the Special Review Group (NUREG-0050, Ref. 3). The NRC, in establishing acceptable levels of fire protection at older operating plants without significantly affecting their design, construction, or operation, modified the guidelines in the original BTP and in September 1976 issued Appendix A, “Guidelines for Fire Protection for Nuclear Plants Docketed Prior to July 1, 1976,” to BTP APCSB 9.5-1. Regardless of the plant’s vintage, the new guidance was intended to establish a fire protection program that was based on defense-in-depth, a fundamental safety philosophy that provides multiple layers of fire protection to prevent and mitigate accidents.

The fire protection defense-in-depth concept is aimed at preventing fires from starting; rapidly detecting, controlling, and extinguishing those fires that do occur; and protecting structures,

systems, and components that are important to safety so that a fire that is not promptly extinguished by the fire protection activities will not prevent the safe shutdown of the plant.

By the late 1970s, the majority of operating plants had completed their analyses and had implemented most of the fire protection program requirements in Appendix A to BTP APCSB 9.5-1. In most cases, the NRC accepted the modifications proposed by licensees as a result of these analyses. In certain cases, however, the licensees and the NRC had technical disagreements, and several plants did not adopt specific recommendations contained in BTP APCSB 9.5-1.

The NRC determined that these issues posed a potential generic problem and deemed rulemaking the appropriate vehicle for resolving them and implementing Commission policy with respect to fire protection. The NRC therefore amended its regulations in November 1980, issuing 10 CFR 50.48 and Appendix R, “Fire Protection Program for Nuclear Power Plants Operating Prior to January 1, 1979,” to 10 CFR Part 50. Both 10 CFR 50.48 and Appendix R set forth Commission policy with respect to fire protection requirements.



Deterministic (Prescriptive) Fire Protection Requirements for Safe Shutdown Capability

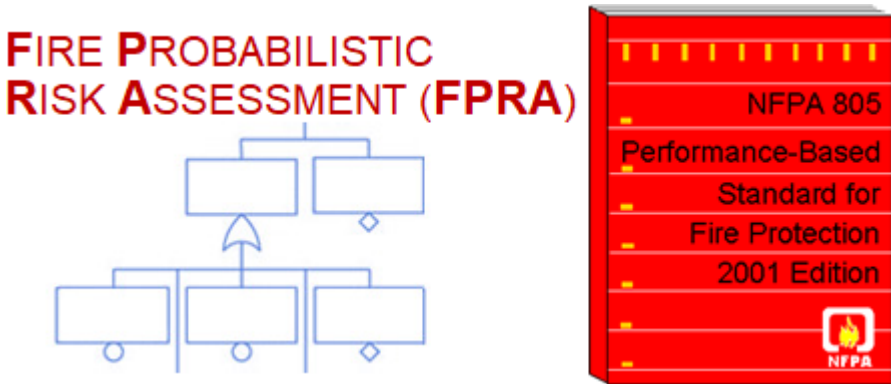
The NRC staff’s Regulatory Guide 1.189, (Ref. 4) provides comprehensive fire protection guidance that identifies the scope and depth of fire protection that the staff considers one acceptable way for nuclear power plants to meet agency requirements.

Risk-Informed, Performance-Based Fire Protection

The NRC developed many of its early fire protection regulations before tools were available to quantify risk. In the early 1990s the agency recognized that risk analysis tools had evolved to the point where they could be used as a tool in regulatory decisionmaking. In July 2004, the NRC amended its fire protection regulations in 10 CFR 50.48 to allow operating nuclear power licensees to voluntarily transition their deterministic fire protection programs to risk-informed,

performance-based requirements. This alternate fire protection requirement maintains safety while adding flexibility to the current fire protection regulations.

A new paragraph, 10 CFR 50.48(c), "National Fire Protection Association Standard NFPA 805," permits a nuclear power plant licensee to use the fire protection requirements contained in National Fire Protection Association (NFPA) Standard 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants," 2001 Edition, with a few exceptions, as an alternative to the deterministic, prescriptive requirements in Appendix R, 10 CFR 50.48(b), or the licensee's existing fire protection license condition. Issuing 10 CFR 50.48(c) was consistent with the NRC's ongoing transition to risk-informed, performance-based regulation. Also, the rule addressed comments from the nuclear industry and some members of the public that the prescriptive, deterministic fire protection regulations represented a significant regulatory burden that was unnecessary to achieve an acceptable level of safety.



Risk-Informed, Performance-Based Fire Protection Requirements

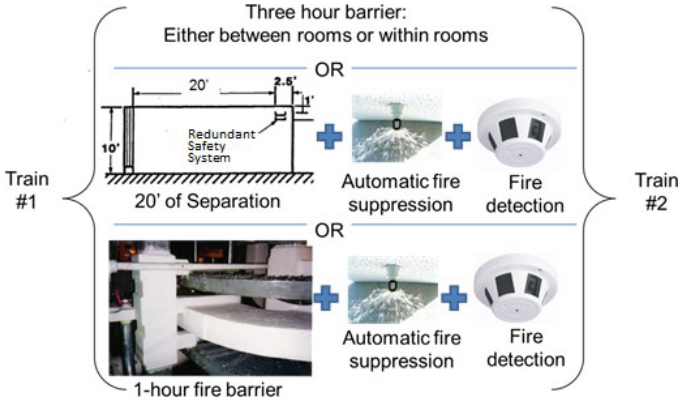
Under the NFPA 805 approach, nuclear power plant licensees can use tools, such as fire modeling and risk analysis, to determine the plant areas most at risk from fire. These realistic assessments of the risks due to potential fires help plants focus their resources where the most risk-significant issues exist, thereby improving the protection of public health and safety. Additionally, the NRC staff may independently consider such insights to help focus its safety reviews and resources on the most risk-significant issues. Consequently, a risk-informed, performance-based approach enhances the attention of the NRC and its licensees on safety while simultaneously reducing unnecessary burden. Once a licensee has implemented a performance-based fire protection program, changes to the plant are evaluated using risk-informed tools.

Regulatory Guide 1.205, (Ref. 5) provides guidance for use in complying with the NRC's requirements for risk-informed, performance-based fire protection programs that comply with 10 CFR 50.48(c) and the referenced 2001 Edition of NFPA 805. It endorses portions of Nuclear Energy Institute (NEI) 04-02, (Ref. 6) which includes methods acceptable to the NRC for implementing NFPA 805 and complying with 10 CFR 50.48(c). Should a conflict occur between NEI 04-02 and the regulatory guide, the regulatory positions in Regulatory Guide 1.205 govern.

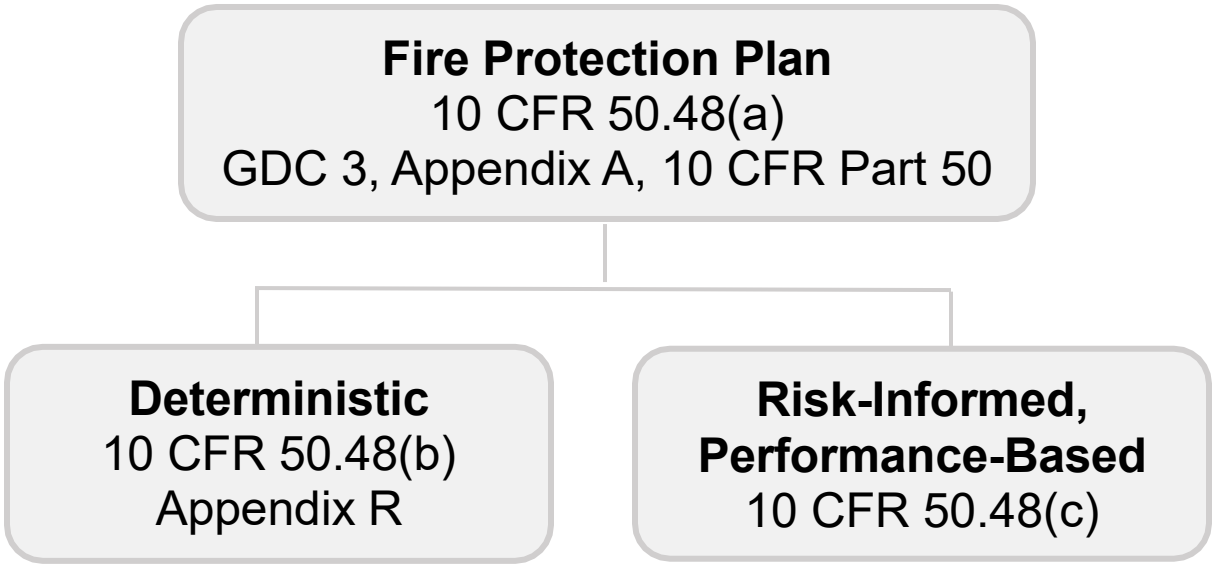
A total of 46 reactor units have transitioned to an NFPA 805 licensing basis. Three NFPA 805 plants, Fort Calhoun Station, Unit 1, Duane Arnold Energy Center, and Palisades Nuclear Plant, were permanently shut down.

Deterministic Requirements
Meeting fire protection regulations
through steps need to be taken to achieve the end goal

Performance-Based Approach
Meeting fire protection regulations
through performance measures

Deterministic Requirements	Risk-Informed, Performance-Based Requirements
Deterministic requirements contain prescriptive mandates, such as specific ratings for fire barriers (e.g., ability to withstand a fire for 3 hours), specific requirements for the installation of fire protection systems, and specifications for separation distances between redundant safe -shutdown equipment (e.g., 20 feet of separation without intervening combustibles). They specify a safe -shutdown end state.  	Risk-informed requirements consider risk insights and rely on a required outcome. Performance-based requirements allow for the use of any solution, as long as it meets the goal stated in the performance-based standard. In general, a performance-based rule identifies what is required but not how to meet the requirement. The performance-based rule allows the licensee to achieve and maintain plant conditions in a “safe and stable” end state following a fire, but the rule does not specify that end state.  $\Delta CDF \approx DF \times FIF \times SF \times NSP \times CCDP$
Safe-Shutdown Capability One train of systems necessary to achieve and maintain hot shutdown is free of fire damage.	**Nuclear Safety Performance Criteria** These criteria include provisions for ensuring that reactivity control, inventory and pressure control, decay heat removal, vital auxiliaries, and process monitoring are achieved and maintained.

Deterministic and Risk-Informed, Performance-Based Regulations



Fire Protection Regulations

Fire Protection for Decommissioning Power Reactors

Permanently shut down reactors have no fuel in the reactor vessel, presenting a significantly lower risk to public health and safety and the environment than an operating reactor. On July 29, 1996, the NRC amended its regulations on the decommissioning of nuclear power reactors by amending 10 CFR Part 50. These changes included an amendment to 10 CFR 50.48, which added 10 CFR 50.48(f) on fire protection for permanently shut down nuclear power plants. Before the decommissioning rule was published the NRC's fire protection regulations did not address nuclear power plants that permanently ceased operations or were planning to transition to a decommissioning status.

For shutdown and decommissioned reactors, fire protection is part of the overall review of the decommissioning plans and activities under 10 CFR 50.82, “Termination of license.” All operating power plant licensees are required to comply with 10 CFR 50.48(a) and 10 CFR 50.48(f) when permanently ceasing operations (i.e., after submitting a written certification to the NRC in accordance with 10 CFR 50.82(a)(1)).

The fire protection regulations in 10 CFR 50.48(f) require licensees that have permanently ceased operations and removed fuel from the reactor vessel to maintain a fire protection program to address the potential for fires that could result in a radiological hazard. Regulatory Guide 1.191, (Ref. 7) includes methods acceptable to the NRC staff for complying with the agency’s regulations.

Nuclear Power Plant Phases of Decommissioning

Under NRC regulations, the decommissioning must be completed within 60 years of permanent cessation of operations, unless otherwise approved by the Commission. The NRC's oversight and monitoring continue throughout the entire decommissioning process until the facility and site have been radiologically decontaminated. Once the licensee can demonstrate that it meets the criteria for site release in the regulations, the facility license is terminated. The NRC verifies the licensee's final radiation survey by reviewing it or conducting a separate survey, or both. In addition, the licensee must demonstrate that the facility has been dismantled in accordance with the approved license termination plan.

Fire Protection Defense-in-Depth for Operating Reactors

Defense-in-depth is a fundamental safety philosophy that provides multiple layers of protection to prevent and mitigate accidents. In nuclear safety, defense-in-depth means having multiple, redundant, and independent layers of safety systems or physical barriers to protect against the occurrence, as well as the consequences, of an accident. The aim is to reduce the risk to the public from a radiological accident.

Fire protection defense-in-depth relies on layered defenses; preventing fires from starting; rapidly detecting, controlling, and extinguishing those fires that do occur; and protecting structures, systems, and components that are important to safety so that a fire that is not promptly extinguished will not prevent the safe shutdown of the plant. The multiple levels of protection in the defense-in-depth philosophy minimize both the probability and the consequences of fires.

Section II, "General Requirements," of Appendix R to 10 CFR Part 50 states that the fire protection program shall extend the defense-in-depth concept to fire protection in fire areas that are important to safety, with three objectives:

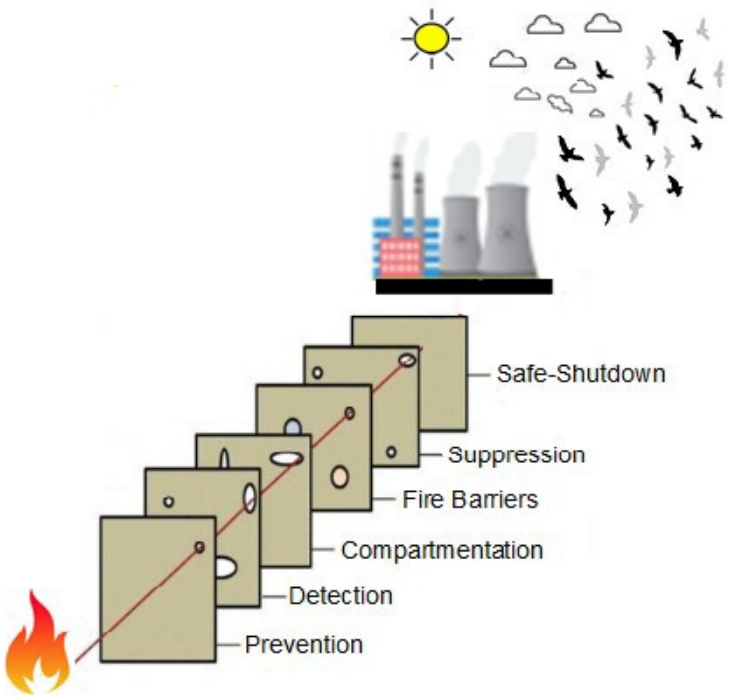
(1) Prevent fires from starting.

(2) Rapidly detect, control, and extinguish those fires that do occur.

(3) Protect structures, systems, and components that are 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.

Preventing fires from starting can be accomplished by limiting ignition sources that could initiate a fire and prevent any existing ignition sources from causing self-sustaining fires in combustible materials. Licensees establish administrative controls and procedures to minimize fire hazards in areas containing structures, systems, and components important to safety.

The second element of the defense-in-depth approach deals with rapidly detecting, controlling, and extinguishing those fires that do occur to limit potential damage. If a fire occurs, its spread can be limited by early detection and manual suppression or a combination of manual and automatic detection and suppression systems. The fire hazards present will determine appropriate levels of fire protection.



Fire Protection Defense-In-Depth Principles – A Simplified Swiss-Cheese Model Shows How Each Fire Protection Defense-In-Depth Layer Works. Each Layer Plays a Role in Preventing or Reducing the Severity of Fire, Multiple Layers Improve Safety

The third element of the defense-in-depth approach involves designing nuclear power plant structures, systems, and components to prevent significant damage if the first two elements fail, either partially or fully. This can be achieved by physically separating combustible elements by distance or with fire-resistant barriers. This aims to prevent a fire in one fuel package or area from spreading to any other fuel package or area.

Redundancy is a fundamental safety feature incorporated into the design of all U.S. commercial nuclear power plants. In essence, backup systems provide assurance that failures affecting one system will not have a significant impact on plant safety. To further increase that assurance, the safety equipment and cables of the redundant subsystems are typically segregated into divisions. The separate and redundant divisions of safety systems provide confidence that the failure of components or cables within one division will not adversely affect the plant's ability to accomplish required safety functions.

Fire Protection Defense-in-Depth for Decommissioning Power Reactors

For those plants that are permanently shut down, or undergoing decommissioning, the licensing basis changes in accordance with the requirements in 10 CFR 50.82.

The goal of the fire protection program for decommissioning power reactors is to provide an appropriate level of defense-in-depth protection against the threat of fires. Decommissioning defense-in-depth for fire protection involves a comprehensive program of administrative controls; physical fire protection features; emergency response capabilities; and protection of structures, systems, and components necessary to prevent or mitigate the potential of an unacceptable release of radioactive materials. This combination of elements reduces both the probability and consequences of fire events, and it ensures that the failure of any one element within the fire protection program is adequately compensated for by the others, thereby minimizing the risks to the public, environment, and plant personnel.

Fire Protection Oversight for Operating Nuclear Power Plants and Decommissioning Power Reactors

The NRC does not operate nuclear power plants. Rather, it establishes requirements for the design, construction, operation, oversight, decommissioning, and security of commercial nuclear power plants in the United States. The NRC fulfills its regulatory responsibility under the Atomic Energy Act of 1954,[1] as amended, by overseeing the operation of commercial nuclear power plants, consistent with the NRC mission to protect public health, safety,[2] and the environment. The NRC does this by applying and enforcing a set of technical requirements on nuclear power plant design and operations, described in the 10 CFR.

NRC Reactor Oversight Process – Significance Threshold

The NRC issues licenses to commercial nuclear power plants and oversees activities under such licenses to protect public health and safety, up to and including shutting down a plant if it fails to meet licensing conditions and poses an undue risk to public health and safety. Plant operators are responsible for safely operating their plants in accordance with their licenses. The NRC conducts inspections and investigations to enforce its regulations. It has established regulations, as well as guidance, including regulatory guides, standard review plans, and inspection guidance. These regulations and guidance, along with plant-specific licenses and technical specifications, form the basis by which the NRC provides continuous oversight of power plant operations.

Physical inspections are one of the main tools the NRC uses to oversee licensee performance. During these inspections, NRC inspectors verify the accuracy of the quarterly data for each performance indicator supplied by the licensee and assess aspects of licensee performance

1 This Act is the fundamental public law on civilian and military uses of nuclear materials. It provides for the development and the regulation of the uses of nuclear materials and facilities in the United States.

2 From a public health and risk standpoint, the integrity of the nuclear fuel is the main safety concern at nuclear power plants.

that are not directly measured by the performance indicator data—for example, confirming that fire protection equipment is in place and that certain maintenance operations have occurred. These inspections cover a wide variety of major systems and technical areas of nuclear power plants that the NRC considers most critical to meeting the overall agency mission of ensuring nuclear power plant safety.

The NRC performs a minimum "baseline" of inspections at all operating U.S. nuclear power plants, regardless of performance, to detect declining safety performance in each of the cornerstones and to review licensee effectiveness at identifying and resolving safety problems. The baseline procedures specify a range of sample activities to inspect (References 9 and 10). Additionally, a fire protection team inspection is performed every 3 years (every 4 years beginning in 2023), during which the NRC regional inspectors conduct onsite fire protection inspections of each nuclear power plant using Inspection Procedure (IP) 71111, Attachment 21N.05, (Ref. 8). Resident inspectors at operating power plant sites walk through plant areas to look at fire protection defense-in-depth elements used to mitigate the consequences of a fire using IP 71111, Attachment 05, (Ref. 9). NRC regional inspection staff conduct fire protection inspections using IP 64704 (Ref. 10) at a frequency in accordance with Inspection Manual Chapter (IMC) 2561 Appendix A (Ref. 11). These inspections determine whether the licensee has an effective fire protection program that is implemented and maintained to address the potential for fires that could result in a radiological hazard.

Fire Protection Regulatory Research

The NRC is unique as a federal regulatory agency in that it also performs in-depth regulatory research to support its regulatory mission. This arrangement was originally intended to provide confirmatory research (to independently verify research performed by industry or academia), but in many cases, the NRC has performed much-needed original research in areas critical to the regulatory decisionmaking process. The NRC has completed many fire protection research studies to better inform the regulatory process for the nuclear and fire protection industries. Many of these research activities directly relate to performance-based methods being used under 10 CFR 50.48(c), NFPA 805 transition reviews, fire probabilistic risk assessment methodology, fire human reliability analysis, fire-induced effects on electrical cables and circuits, nuclear power plant fire modeling, and high energy arcing fault research. These research studies have developed technical tools, analytical models, and experimental data to resolve fire protection regulatory issues.

Final Remarks

The NRC has established its regulatory requirements to provide reasonable assurance of adequate protection of public health and safety. The NRC's fire protection program for operating and decommissioning nuclear power plants includes the defense-in-depth approach in the application of administrative controls, fire protection systems and features, and post-fire safe-shutdown capability. Nuclear power plant licensees are required to protect plant equipment necessary for safe shutdown using a combination of methods to detect and control or extinguish fires.

The NRC fire protection oversight inspection program for operating nuclear power plants and decommissioning reactors focuses on the plant fire protection and post-fire safe shutdown

capability. NRC regional inspection staff and resident inspectors at the operating reactor sites perform fire protection inspections and walkdowns of plant areas to verify that the plant fire protection systems and features credited in the fire protection current licensing basis for mitigating the consequences of a fire are maintained.

References

1. NUREG/BR-0361, “The Browns Ferry Nuclear Plant Fire of 1975 and the History of NRC Fire Regulations,” February 2009, ADAMS Accession Nos. ML091250195.

2. BTP APCSB 9.5-1 “Guidelines for Fire Protection for Nuclear Power Plants,” May 1976, ADAMS Accession No. ML070660461.

3. NUREG-0050, “Recommendations Related to Browns Ferry Fire,” February 1976, ADAMS Accession No. ML070520452.

4. Regulatory Guide 1.189, Revision 4, “Fire Protection for Nuclear Power Plants, May 2021, ADAMS Accession No. ML21048A441.

5. Regulatory Guide 1.205, Revision 2, “Risk-Informed, Performance-Based Fire Protection for Existing Light -Water Nuclear Power Plants,” May 2021, ADAMS Accession No. ML21048A448.

6. NEI 04-02, Revision 3, “Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program under 10 CFR 50.48(c),” November 2019, ADAMS Accession No. ML19351D277.

7. Regulatory Guide 1.191, Revision 1, “Fire Protection Program for Nuclear Power Plants During Decommissioning,” January 2021, ADAMS Accession No. ML20287A199.

8. IP 71111, Attachment 21N.05, “Fire Protection Team Inspection (FPTI),” January 1, 2020, ADAMS Accession No. ML19084A040.

9. IP 71111, Attachment 05, “Fire Protection,” January 1, 2023, ADAMS Accession No. ML22154A390.

10. IP 64704, “Fire Protection Program at Permanently Shutdown Reactors,” January 1, 2021, ADAMS Accession No. ML20294A347.

11. IMC 2561, “Decommissioning Power Reactor Inspection Program,” dated March 6, 2018, ADAMS Accession No. ML20358A131.

Additional Resources

Fire Protection – NRC Fire Protection Public Website.

Fire Protection Defense-in-Depth – NRC Fire Protection Public Website.

Fire Protection for Operating Reactors – NRC Fire Protection Public Website.

NRC Fire Protection Program at Nuclear Power Plants – NRC Fire Protection Video.

Backgrounder on Fire Protection for Nuclear Power Plants – NRC Fire Protection Public Website.

NUREG/BR-0522, "Fire Protection Program for Operating Reactors," August 2014.

NUREG/BR-0312, "Alternate Fire Protection Rule for Light-Water Nuclear Power Plants," September 2004.

Reactor Oversight Process – NRC Public Website

Decommissioning of Nuclear Facilities – NRC Public Website

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