Fire Brigade Staffing Analysis for Advanced Reactor Technology

Prepared by the Nuclear Energy Institute
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Revision Table

Revision	Description of Changes	Date Modified	Responsible Person
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Executive Summary

This document presents a regulatory and technical approach for a risk-informed, performance-based evaluation of the adequacy of fire response for the advanced reactor fleet. The process is technology inclusive. The report addresses:

- Historical perspective on the basis for the United States (U.S.) Nuclear Regulatory Commission (NRC) regulation and guidance regarding the five-person fire brigade.
- A review of regulation and guidance documents that are pertinent to a risk-informed, performance-based fire response evaluation.
- Reviews the regulation and guidance associated with licensing submittals and a risk-informed, performance-based fire response approach.
- Provides an overview of advancements in technology and fire analyses since the original decision on a five-person brigade.
- Provides a risk-informed, performance-based evaluation of the adequacy of fire response, including defense-in-depth, and its basis.

The report concludes the following:

- There are no regulations that require a specific classification (e.g., incipient or structural) and complement of fire brigade for the advanced reactor fleet.
- Regulatory Guide (RG) 1.189 suggests a five-person fire brigade, but an RG is considered one acceptable method of meeting regulatory requirements. In addition, more applicable and recent guidance in DANU-ISG-2022-09 acknowledges potential greater reliance on offsite fire response and encourages dialogue with the NRC during the application process.
- Guidance documents exist in the nuclear industry that establish a process for evaluating fire response needs (CSA N293, NEIL, IAEA).
- Advances in technology and analysis techniques support an approach to fire safety that places less reliance on onsite fire response.

The fire response evaluation process provides a structured process to determine one of the following outcomes, along with ensuring defense-in-depth and configuration control of the bases for these outcomes:

- Offsite Response Only
- Onsite Incipient Fire Brigade,
- Onsite Structural Fire Brigade

Table of Contents

Table of Figures

1 INTRODUCTION

The purpose of this document is to present a regulatory and technical approach to a risk-informed, performance-based evaluation of the adequacy of fire response for the advanced reactor fleet.[1] The process is technology inclusive. The report is organized into the following sections:

- Section 2 provides some historical perspective on the basis for the United States (U.S.) Nuclear Regulatory Commission (NRC) regulation and guidance regarding the five-person fire brigade.
- Section 3 provides a review of regulation and guidance documents that are pertinent to a risk-informed, performance-based fire response evaluation.
- Section 4 reviews the regulation and guidance associated with licensing submittals and a risk-informed, performance-based fire response approach.
- Section 5 provides an overview of advancements in technology and fire analyses since the original decision on a five-person brigade.
- Section 6 provides the risk-informed, performance-based evaluation of the adequacy of fire response, including defense-in-depth, and its basis.
- Section 7 summarizes the conclusions and recommendations.
- Section 8 provides references used in the report.
- Appendices A and B provide supporting information.

2 BACKGROUND

In 1977, the NRC provided licensees with a proposed interim Technical Specification that included a five-person fire brigade. This position was not without controversy, so much that it was included in Appendix R to 10 CFR 50, for licenses that had not closed out this issue. The NRC issued an *Evaluation of Minimum Fire Brigade Shift Size* on June 8, 1979. This document concluded:

1) *The specific actions for the control and extinguishment of potential fires vary greatly from area to area within a given plant;*
2) *The specific actions which the fire brigade may be required cannot be precisely defined prior to the fire;*
3) *Although the fire fighting actions as described previously in this report may not be applicable to each and every plant area, all plants contain areas important to plant safety which require consideration of these fire fighting actions.*

[1] For the purposes of this paper, the term "advanced reactor fleet" refers to non-light water reactors and small modular light water reactors generating 300 MWe or less (SMRs).

4) *Abnormal events cannot be precluded for each and every potential fire situation, some margin in brigade size is warranted to compensate for the potential unanticipated events such as:*

   a) *Failure of detection systems to promptly alert plant personnel of the onset of a fire condition.*

   b) *Failure of automatic suppression systems to actuate to limit fire damage.*

   c) *Personnel injury in the act of fire fighting.*

   d) *Failure of administrative controls of combustible materials in situations which could impact systems important to safety.*

5) *The minimum fire brigade shift size cannot be based only upon the potential fire consequences and their apparent impact on the capability to safely shutdown because this is contradictory to both the philosophy of defense-in-depth and the general design criterion requirement to minimize the adverse effects of fires.*

In Appendix A to the same document, the NRC addressed some licensee specific arguments:

Historical Fires

Some licensees argue that the majority of historical fires in nuclear power plants were either self-extinguished or were extinguished by a small response force. Further, a large number of these fires occurred during the construction phase of the plants.

The NRC does not deem the size of historical fires a significant factor in determining the size of the minimum fire brigade. The small fires that self-extinguish or the fires that are easily extinguished present little, if any, threat to public health and safety.

Further, the circumstances that lead to fires in the construction phase are not precluded after the plant goes into operation. New construction at the site, major plant modifications and maintenance activities produce similar circumstances at an operating plant.

It is the fires that do not self-extinguish because of "off-design" conditions or are not promptly extinguished at operating plant sites which may present a threat to the plants capability to achieve and maintain safe shutdown conditions. For example, a temporary breakdown in the administrative controls over the use of combustibles and ignition source, a failure to detect a fire early, or adverse unanticipated events which either delay prompt extinguishment or lead to rapid fire development may lead toward the development of a severe fire.

Because of the possibility of these fires, the staff deems it prudent to maintain a site fire brigade which can promptly extinguish such fires in safety related areas with sufficient margin in size to account for adverse conditions and events.

Offsite Assistance

Some licensees argue that the minimum fire brigade may be less than five persons because of substantial offsite assistance.

The NRC concludes that the delay in prompt fire extinguishment incurred by reliance upon support from offsite fire departments or the call back of plant personnel does not provide an acceptable alternative to meeting the minimum manpower requirements for an onsite fire brigade.

Offsite fire departments could be committed to fighting fire elsewhere when a call goes out for their assistance. In many areas weather conditions could delay the response of offsite fire departments as well as operating personnel called back for additional assistance. While the NRC recognizes the importance of a preplanned utilization of offsite fire departments and call back personnel, such assistance does not justify a reduction of an adequate onsite fire brigade to provide an immediate initial attack on a fire.

Availability of Onsite Personnel

Some licensees argue that the potential for fire is greater during times when there is more than the minimum complement of plant operating personnel, on onsite. In general, this is the period from about 8 to 5 on normal work days. It is during these periods during which normal maintenance operations are performed.

While the NRC recognizes the greater potential for fire during such time, this does not alleviate the need for an adequate fire brigade on the other shifts. It appears that there are sufficient personnel on site on all shifts to provide a five man fire brigade.

In its position paper on "Manpower Requirements for Operating Reactors" the NRC addressed the sharing of available onsite personnel such as the security forces as a means of meeting the manpower requirements for a five man fire brigade. The issue is not the availability of onsite personnel who could be utilized to combat fires; but rather the effective utilization of manpower resources to establish a trained team that responds to a fire and effectively performs those action which are essential to fire fighting.

The issues associated with NRC's position are addressed throughout this report.

3 REGULATORY REQUIREMENTS AND GUIDANCE

Section 3 is organized as follows:

- 3.1 Fire Protection Program Regulatory Requirements
- 3.2 NRC Fire Protection Guidance for Power Reactors
- 3.3 NRC Fire Protection Guidance for Non-Power Reactors
- 3.4 Other Nuclear Industry Guidance
- 3.5 Other Industry Guidance
- 3.6 Conclusions of the Regulatory Requirements and Guidance Document Review

3.1 Fire Protection Program Regulatory Requirements

The following regulations apply to the advanced reactor fleet:

- 10 CFR 50.48, "Fire Protection"
- Appendix A to 10 CFR 50, "General Design Criteria for Nuclear Plants," Criterion 3, "Fire Protection"
- Regulatory Guide 1.232, "Principal Design Criteria for Non-Light-Water Reactors"

3.1.1 10 CFR 50.48(a)[2]

(1) Each holder of an operating license issued under this part or a combined license issued under part 52 of this chapter must have a fire protection plan that satisfies Criterion 3 of appendix A to this part. This fire protection plan must:

(i) Describe the overall fire protection program for the facility;

(ii) Identify the various positions within the licensee's organization that are responsible for the program;

(iii) State the authorities that are delegated to each of these positions to implement those responsibilities; and

(iv) Outline the plans for fire protection, fire detection and suppression capability, and limitation of fire damage.

(2) The plan must also describe specific features necessary to implement the program described in paragraph (a)(1) of this section such as

(i) Administrative controls and personnel requirements for fire prevention and manual fire suppression activities;

(ii) Automatic and manually operated fire detection and suppression systems; and

(iii) The means to limit fire damage to structures, systems, or components important to safety so that the capability to shut down the plant safely is ensured.

(3) The licensee shall retain the fire protection plan and each change to the plan as a record until the Commission terminates the reactor license. The licensee shall retain each superseded revision of the procedures for 3 years from the date it was superseded.

(4) Each applicant for a design approval, design certification, or manufacturing license under part 52 of this chapter must have a description and analysis of the fire protection design features for the standard plant necessary to demonstrate compliance with Criterion 3 of Appendix A to this part.

[2] Note, the other sections of 10 CFR 50.48 do not apply to the advanced reactor fleet.

3.1.2 Appendix A to 10 CFR 50, Criterion 3., "Fire Protection"

> *Structures, systems, and components important to safety[3] 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 locations such as the containment and control room. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components.*

3.1.3 Regulatory Guide 1.232, "Principal Design Criteria for Non-Light-Water Reactors"

This RG provides guidance on how the requirements of the general design criteria in 10 CFR 50, Appendix A, may be adapted for non-light-water reactor (non-LWR) designs. Criterion 3 has been modified as follows (bold text indicates changes):

> *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* ***fire****-resistant materials shall be used wherever practical throughout the unit, particularly in locations* ***with structures, systems, or components important to safety****. Fire detection and fighting systems of appropriate capacity and capability shall be provided and designed to minimize the adverse effects of fires on structures, systems, and components important to safety. Firefighting systems shall be designed to* ***ensure*** *that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components.*

3.2 NRC Fire Protection Guidance for Power Reactors

The following regulatory guidance documents apply to the advanced reactor fleet:

- RG 1.189, "Fire Protection for Nuclear Power Plants"
- DANU-ISG-2022-09, "Advanced Reactor Content Application Project, Risk-Informed, Performance-Based Fire Protection Program (for Operations)"
- RG 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light Water Reactors, and Non-Power Production or Utilization Facilities"

3.2.1 Regulatory Guide 1.189, "Fire Protection for Nuclear Power Plants"

The following sections of RG 1.189 are noted for relevance to fire response:

Section A highlights the role of RGs and emphasizes that they are guidance, not regulation.

[3] 10 CFR 50.48 and Appendix A to 10 CFR 50 refer to SSCs important to safety. Guidance in RG 1.189 relates this term to the ability to shut down the plant safely. To avoid any confusion, the SSCs associated with the term 'important to safety' should be defined during the licensing phase.

Section A. Introduction, Purpose of Regulatory Guides

> *The NRC issues RGs to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated events, and to provide guidance to applicants. RGs are not substitutes for regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.*

Section C provides guidance on fire brigades. Note DANU-ISG-2022-09 refers to RG 1.189 for guidance on fire brigades.

Section C. Staff Regulatory Guidance, Section 1.1.f

> *The licensee should identify the plant's fire brigade positions with the following in mind (see also Regulatory Position 3.5.1 of this guide):*
>
> *(1) The plant fire brigade positions should be responsible for fighting fires. The authority and responsibility of each fire brigade position related to fire protection should be clearly defined.*
>
> *(2) The responsibilities of each fire brigade position should correspond to the actions required by the firefighting procedures.*
>
> *(3) Collateral responsibilities of the fire brigade members should not conflict with their responsibilities related to the fire brigade during a fire emergency. A collateral responsibility would be a required action or decision that would adversely affect the fire brigade member's ability to perform a required firefighting function.*
>
> *(4) The minimum number of trained fire brigade members available on site for each operating shift should be consistent with the activities required to combat credible and challenging fires but should be no fewer than five members. The size of the fire brigade should be based on the functions required to fight fires, with adequate allowance for injuries. Fire brigade staffing should account for all operational and emergency response demands on shift personnel in the event of a significant fire.*

Section 8 provides guidance for fire protection for new reactors and emphasizes the integration of fire protection requirements into the planning and design phase for the plant. Section 8.2 provides enhanced fire protection criteria, specifically for new reactor designs.

8.2 Enhanced Fire Protection Criteria

> *New reactor designs should ensure that safe shutdown can be achieved by assuming that all equipment in any one fire area will be rendered inoperable by fire and that reentry into the fire area for repairs and operator actions is not possible. Because of its physical configuration, the control room is excluded from this approach, provided that the design includes an independent alternative shutdown capability that is physically and electrically independent of the control room. The control room should be evaluated to ensure that the effects of fire do not adversely affect the ability to achieve and maintain safe shutdown. Designs incorporating reactor*

containment buildings should provide fire protection for redundant shutdown systems in the reactor containment building that will ensure, to the extent practicable, that one shutdown division will be free of fire damage. Additionally, new reactor designs should ensure that smoke, hot gases, or the fire suppressant will not migrate into other fire areas to the extent that they could adversely affect safe-shutdown capabilities, including operator actions.

3.2.2 DANU-ISG-2022-09, "Advanced Reactor Content of Application Project, Risk-Informed, Performance-Based Fire Protection Program (for Operations)"

This Interim Staff Guidance (ISG) from the Division of Advanced Reactors and Non-power Production and Utilization Facilities (DANU) addresses the application content and NRC staff review for the fire protection program for operations, including the following:

The program description should also describe specific features necessary to implement the program such as the following:

1. administrative controls and personnel requirements for fire prevention and manual fire suppression activities[5]

2. the means to limit fire damage to safety-significant SSCs so their capability to perform safety functions is maintained

The first bullet references the following footnote (bold text added for emphasis):

This ISG provides one acceptable approach to meeting regulatory requirements and was developed from guidance for large LWRs, including measures such as fire brigades to provide timely manual fire suppression responses. ***Applicants considering fire protection programs that do not rely on these measures (for example, an onsite fire brigade) should demonstrate their ability to safely shut down the facility and minimize radioactive releases to the environment in the event of a fire without the excluded measures. The NRC staff encourages preapplication discussions for facilities that primarily rely on offsite fire response. For LMP[4]-based plants, how fires are addressed in the full scope PRA could be part of the discussion because the response of the facility to fires could be a part of the justification for the primary reliance on offsite fire response****.*

In addition, RG 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities," issued November 2023 (ML23226A036), includes guidance for developing applicant emergency plans for offsite fire response organizations that may have onsite responsibilities. The RG includes development of procedures for notifying, training, and instituting drills for offsite fire response organizations that include the use of the fire suppression technology. RG 1.242 applies whether or not the applicant takes credit for an onsite fire brigade.

The ISG fire protection program description establishes the fire protection policy for safety significant SSCs at each plant and the procedures, equipment, and personnel required to implement the program

[4] LMP is defined as Licensing Modernization Project

at the plant site. The guidance also identifies that other approaches may be acceptable to the provision of an onsite fire brigade.

The ISG section B.2 Organization, staffing, and responsibilities, addresses emergency response, including fire brigades and offsite mutual aid. The ISG refers to RG 1.189 guidance on fire brigade staffing and training.

3.2.3 Regulatory Guide 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light Water Reactors, and Non-Power Production or Utilization Facilities"

This RG identifies methods and procedures that the NRC considers acceptable for use by applicants and licensees for SMRs, non-light-water reactors ,and non-power production or utilization facilities to demonstrate compliance with performance -based emergency preparedness requirements in 10 CFR 50.47, "Emergency Plans," 10 CFR 50.160, "Emergency preparedness for small modular reactors, non-light-water reactors, and non-power production or utilization facilities," and 10 CFR 50 Appendix E, "Emergency Planning and Preparedness for Production and Utilization Facilities." This RG includes guidance on interface with offsite organizations from an emergency preparedness perspective, including fire services.

3.3 NRC Fire Protection Guidance for Non-Power Reactors

The following guidance documents for non-power reactors and fuel facilities are related to fire protection program:

- NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors"
    - Part 1 – Format and Content
    - Part 2 – Standard Review Plan and Acceptance Criteria
- ANSI/ANS 15.17, "Fire Protection Program Criteria for Research Reactors," 1981

In NUREG-1537 Part 1, Format and content, the following statement applies to fire response:

> *The applicant should discuss the bases of any technical specifications, including testing and surveillance, as they relate to the fire protection systems and programs. The discussion should also include the relationship between fire protection plans, operating procedures, and the facility emergency plan.*
>
> *ANSI/ANS 15.17-1987 contains general information on fire protection. The applicant may also consult National Fire Protection Association, NFPA 802, 1993 Edition.*

In NUREG-1537 Part 2, Standard Review Plan and Acceptance Criteria, the following statement applies to fire response:

> *Section 9.3, Areas of Review*
> *The source of facility fire protection brigades and their training and the summary of the more*

detailed discussions of these personnel and offsite fire protection forces in the facility emergency plan.

Section 9.3, Review Procedures
The reviewer should evaluate the discussions of potential fires; provisions for early detection, including during those times when the buildings are not occupied; methods for isolating, suppressing, and extinguishing fires; passive features designed into the facility to limit fire consequences; response organization training and availability to fight fires as detailed in the emergency plan; designs of reactor systems that can ensure safe reactor shutdown in the event of fire; and potential radiological consequences to the public, the staff and the environment if firefighting efforts are unsuccessful.

Section 9.3, Evaluation Findings
Personnel training programs as described in the facility emergency plan and in Chapter 12, "Conduct of Operations," provide reasonable assurance that training for fire protection is adequately planned.

The ANS Standard states in Section 4.7(f)

A program of fire response actions, including fire brigade assignment and training, pre-fire planning, coordination of actions with outside fire fighting organizations, evacuation drills, and other supportive emergency response actions by utility, medical, health physics, or operations personnel.

The guidance for non-power reactors does not prescribe a classification or complement for fire response activities. The guidance in NUREG-1537 provides insights and could be more appropriate for the fire response for micro-reactors.

3.4 Other Nuclear Industry Guidance

Several other organizations provide fire protection guidance to the nuclear industry. The applicable documents from each of these organizations were reviewed to determine any specific guidance on fire brigade type (incipient or interior structural, etc.) and / or staffing.

3.4.1 Institute of Nuclear Power Operations (INPO)

The following Institute of Nuclear Power Operations (INPO) documents were reviewed:

- EPG-05, “Engineering Program Guide, Fire Protection, “Revision 1, December 2020
- INPO 11-004, “Guidelines for Excellence in Fire Protection Program Implementation,” Revision 3, September 2023
- INPO 20-003, “Guidelines for the Conduct of Fire Brigade Drills,” Revision 0, August 2020

INPO provides perspectives on best practices or implementations strategies beyond regulatory requirements. INPO documents do not contain a mandated fire brigade complement. In general, the documents are written from a structural fire brigade perspective (e.g., self-contained breathing

apparatus, turnout gear). However, INPO 11-004, Section C, "Fire Event Emergency Response," states in part:

> *Fire response teams are comprised of an appropriate complement as determined by occupancy, hazards, and needs to ensure protection of nuclear safety, plant reliability, and personal protection.*

3.4.2 Canadian Standards Association (CSA), CSA N293, "Fire protection for nuclear power plants"

The Canadian Standards Association (CSA) does not dictate a mandated fire brigade complement. The standard requires a fire response needs analysis (FRNA). The most recent revision of the CSA standard recognized the uniqueness of Small Modular Reactors (SMRs) by providing the following guidance:

> ***Section 12.1.2.2 SMRs***
>
> *Fire response capability shall be provided based on the analysis of Clause 12.1.3.*
>
> *Notes:*
>
> *1) The intent of this Clause is to provide a fire response capability and capacity commensurate with the hazards and risks associated with the technology, location or siting (e.g., taking into consideration the local response capability), environmental protection needs, protection of personnel, protection of occupants, and protection of the public.*
>
> *2) Where manual fire response is required based on the analysis of Clause 12.1.4, this may be provided via a dedicated FFB[5], facility operation personnel, municipal fire departments, other off-site fire response, or a combination of these organizations.*
>
> *3) Where an FFB is determined to be required by Clause 12.1.4, the brigade should meet the requirements for firefighting in this Standard.*
>
> *4) The fire response capabilities provided are required to address the unique needs of the hazard associated with the technology to achieve the goals of this Standard.*

The CSA standard expanded on the FRNA requirements and provided additional context in the corresponding annex.

> *Section A.12.1.3 Fire Response Needs Analysis (FRNA)*
>
> *This analysis should consider fire growth, fire size, and any difficulties responding to or accessing a fire. The fire response analysis should be performed to:*
>
> - *define the most demanding fire hazards and risks specifying fuel, maximum credible fire size, extent in terms of area/geometry, impact on exposures, impact on life safety, and likely impact on the public in terms of nuclear safety;*

[5] FFB as used in the CSA standard is defined as facility fire brigade

- *determine the requirements for extinguishment by all available means, including automatic or manual, and use of water, foam, dry chemicals, and inert gas;*
- *determine the required equipment to deliver the appropriate extinguishing agent;*
- *determine whether an on-site firefighting organization is required, based on the distance to the nearest local public fire department, response time, external aid assistance plan, or other considerations;*
- *determine personal protective equipment requirements;*
- *determine training requirements; and*
- *determine the site's fire response capabilities and expectations.*

3.4.3 Nuclear Electric Insurance Limited (NEIL)

Section 5.3.11.1 of the Nuclear Electric Insurance Limited (NEIL) Loss Control Manual (2024) provides the following guidance:

5.3.11 Fire Brigade

5.3.11.1 An ACCEPTABLE structural Fire Brigade SHALL be provided.

The station may elect to have another recognized fire suppression organization respond to emergencies as the primary responder. This is ACCEPTABLE to NEIL if ACCEPTABLE response plans are written and implemented. As a minimum, fire response plans utilizing organizations other than the recognized plant Fire Brigade SHALL include the following:

- *When there is an indication of a fire (e.g., report of smoke or fire, fire suppression system activation, multiple fire detection alarms, etc.) the off-site fire suppression organization SHALL be notified immediately.*
- *Name of the outside organization to be called in the event of a fire, such as the local municipal fire department.*
- *Verification through periodic response drills that the responding organization will arrive at the site within an ACCEPTABLE period from the time the alarm is received at the central alarm station.*
- *Verification that the responding organization will respond in full turnout gear with at least five (5) qualified members within the ACCEPTABLE response period.*
- *Verification that the responding organization will respond to the site with the equipment equivalent to that specified for the site Fire Brigade and that their equipment is compatible with plant fire protection equipment.*
- *A written fire pre-plan SHALL be made available to the responding organization for each NEIL insured building, structure, or area for which they are responsible.*

- *A fire drill SHALL be conducted at least annually involving the organization responsible for fire response to NEIL insured buildings, equipment, and areas. The fire drill may be witnessed by NEIL during regularly scheduled plant evaluations.*

The NEIL specified verifications of response, equipment, training, and site/plan familiarity of an offsite response organization are essentially performing a risk assessment that is consistent with current regulatory guidance.

3.4.4 International Atomic Energy Agency (IAEA)

The Canadian Standards Association (CSA) Standard N-293, Fire protection for nuclear power plants, references the following IAEA publications:

- INSAG Series No.10, 1996, "Defence in depth in nuclear safety"
- INSAG Series No.12, 1999, "Basic safety principles for nuclear power plants," 75-INSAG-3, Rev 1
- Safety Reports Series No. 8, 1998, "Preparation of Fire Hazard Analysis for Nuclear Power Plants"
- Safety Reports Series No. 10, 1998, "Treatment of internal fires in probabilistic safety assessment for nuclear plants"
- Safety Reports Series No. 46, 2005, "Assessment of defence in depth in nuclear power plants"
- Safety Standards Series No. NS-G-1.7, 2004, "Protection against internal fires and explosions in the design of nuclear power plants," has been superseded by SSG-64, "Protection against Internal Hazards in the Design of Nuclear Power Plants"
- Safety Standards Series No. NS-G-2.1, 2000, "Fire safety in the operation of nuclear power plants," has been superseded by SSG-77, "Protection Against Internal and External Hazards in the Operation of Nuclear Power Plants"

None of the documents cited above specify a specific complement of fire brigade. However, the following documents reference a "needs analysis" to determine the appropriate fire response organization:

- Safety Standards Series No. NS-G-1.7, 2004, "Protection against internal fires and explosions in the design of nuclear power plants"

  5.63. Manual fire fighting forms an important part of the defence in depth strategy for fire fighting. The extent of reliance on on-site and off-site fire brigades should be established at the design stage. The location of the site and the response time of any off-site fire brigade will affect the necessary level of provision for manual fire fighting. Manual fire fighting capabilities are discussed in Ref. [2][6]

[6] Reference 2 is IAEA NS-G-2.1, 2000

- Safety Standards Series No. NS-G-2.1, 2000, "Fire safety in the operation of nuclear power plants"

  8.2. Plant documentation should provide a clear description of the manual fire fighting capability provided for those areas of the plant identified as important to safety. The manual fire fighting capability may be provided by a suitably trained and equipped on-site fire brigade, by a qualified off-site service or by a coordinated combination of the two, as appropriate for the plant and in accordance with national practice.

  8.3. If reliance is placed on off-site response, designated plant staff in each shift should be assigned the responsibility to co-ordinate and liaise with the off-site fire fighting service and to establish a clear line of authority at the fire scene. Appropriate plant staff should be designated even in situations in which the off-site response is supplementary to a primary response by a qualified on-site fire brigade.

  8.4. Where full or partial reliance for manual fire fighting capability is placed on off-site resources, there should be proper co-ordination between the plant personnel and the off-site response group in order to ensure that the latter is familiar with the hazards of the plant. The responsibilities and lines of authority for manual fire fighting personnel should be documented in a fire fighting plan.

  8.5. If an on-site fire brigade is established to provide a manual fire fighting capability, the fire brigade's organization, minimum staffing level, equipment (including self-contained breathing apparatus) and training should all be documented and their adequacy should be confirmed by a competent person.

3.5 Other Industry Guidance

3.5.1 National Fire Protection Association (NFPA)

3.5.1.1 NFPA 600, "Standard on Facility Fire Brigades"

The purpose of this standard is to provide the minimum requirements for the organization, operation, training, and occupational safety and health of (industrial) facility fire brigades. NFPA 600 is referenced in RG 1.189.

NFPA 600 includes a provision for classification of facility fire brigades, including a classification of "Incipient stage fire fighting," defined as: "Fire fighting performed inside or outside of an enclosed structure or building when the fire has not progressed beyond incipient stage."

The incipient stage fire is defined in NFPA 600 as "A fire which is in the initial or beginning stage and which can be controlled or extinguished by portable fire extinguishers, Class II standpipe, or small hose systems without the need for protective clothing or breathing apparatus."

With respect to minimum fire brigade staffing, NFPA 600 offers the following guidance in Appendix A: "The minimum number varies depending on the operational limits of the facility fire brigade. As the duties increase, the number of members might need to be increased. A facility fire brigade doing interior structural fire fighting should logically have at least five members: two for work in the hot zone, two for relief and safety in the warm zone, and one managing the fire-fighting activities."

Once the classification of the fire response organization has been decided this standard may be used to define requirements.

3.5.1.2 NFPA 1081, "Standard for Facility Fire Brigade Member Professional Qualifications"

This standard specifies the minimum job performance requirements for various levels of fire brigade members including incipient fire brigades, advanced exterior brigades, and interior structural fire brigades. Currently the standard five-person brigade used at U.S. nuclear power plants would fall under interior structural fire brigades.

Once the classification of the fire response organization has been decided this standard may be used to define requirements.

3.5.1.3 NFPA 1001, "Standard for Fire Fighter Professional Qualifications"

This standard specifies the minimum job performance requirements for professional firefighters qualification as Firefighter 1 or Firefighter 2 commonly used in training Career Professional firefighters (Full Time FDs). In many volunteer fire departments members are encouraged to or required to obtain FF1 and FF2 certification based on their position in the organization, but volunteer department standards are not generally legally mandated.

Once the classification of the fire response organization has been decided this standard may be used to define requirements.

3.5.1.4 NFPA 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants"

For operating nuclear power plants in the U.S., all of which are light water reactors (LWRs), 10 CFR 50.48(c), "National Fire Protection Association Standard NFPA 805," establishes the requirements for using NFPA 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants, 2001 Edition," as an alternative to the requirements associated with 10 CFR 50.48(b) and 10 CFR Part 50 Appendix R, or the fire protection license conditions for plants licensed after January 1, 1979. This regulation incorporates by reference NFPA 805, with certain exceptions, clarifications, and expansions. In general, the fire protection program operational requirements appear in NFPA 805, Chapter 3, Fundamental Fire Protection Program and Design Elements.

The scope of NFPA 805 includes deterministic requirements for fire brigade staffing, specifying a minimum of five plant fire brigade members.

3.5.1.5 NFPA 804, "Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants"

NFPA 804 provides guidance on fire protection programs for advanced light water reactors, including fire brigade, specifying a minimum of five plant fire brigade members. However, NFPA 804 is not endorsed by the NRC.

3.5.1.6 NFPA 806, "Performance-Based Standard for Fire Protection for Advanced Nuclear Reactor Electric Generating Plants Change Process"

NFPA 806 provides guidance limited to risk-informed, performance-based change evaluations for advanced reactors, primarily reflecting the change evaluation process developed in NFPA 805 for existing light water reactors. In does not contain any specific deterministic requirements and does not address minimum fire brigade staffing. This standard is not endorsed by the NRC.

3.5.2 Occupational Safety and Health Administration (OSHA) 29 CFR 1910.156, "Fire Brigades"

OSHA 29 CFR 1910.156, "Fire Brigades," is a federal regulation in states that do not have their own state Occupational Safety and Health Standards. In practice, many state standards contain many or all the requirements of the federal standard. It is also worth noting that unless there is a conflict with specific regards to Reactor Safety or Radiological Safety of the public, OSHA standards are applicable and are not exempted by NRC regulations.

1910.156 contains the requirements for the organization, training, and personal protective equipment of fire brigades (extends to fire departments also) whenever they are established by employers but does not specify fire brigade size.

Once the classification of the fire response organization has been decided, this regulation along with others (e.g., 1910.134) may be used to define requirements for the onsite fire brigade.

3.6 Conclusions of the Regulatory Requirements and Guidance Documents Review

The following conclusions can be made based on the review of the documents in Section 3:

- There are no regulations that require a specific classification and complement of fire brigade for the advanced reactor fleet.

- The existing NRC guidance does specify a five-person fire brigade. However, as stated in RG 1.189:

  The NRC issues RGs to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated events, and to provide guidance to applicants. RGs are not substitutes for regulations and compliance with them is not required. Methods and solutions that differ from those set forth in RGs will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

- DANU-ISG-2022-09, "Advanced Reactor Content of Application Project, Risk-Informed, Performance-Based Fire Protection Program (for Operations)," provides guidance regarding potential acceptance criteria for alternate fire response strategies:

  Applicants considering fire protection programs that do not rely on these measures (for example, an onsite fire brigade) should demonstrate their ability to safely shut down the facility and minimize radioactive releases to the environment in the event of a fire without the excluded measures. The NRC staff encourages preapplication discussions for facilities that primarily rely

on offsite fire response. For LMP-based plants, how fires are addressed in the full scope PRA could be part of the discussion because the response of the facility to fires could be a part of the justification for the primary reliance on offsite fire response.

- Guidance documents exist in the nuclear industry that establish a process for evaluating fire response needs.

Therefore, a technical process for evaluating the need for, and if necessary, the classification and complement of the fire brigade should be developed. This process should build upon the current guidance that considers the nuclear safety enhancements in the design of the advanced reactor fleet. Section 6 of this report provides the suggested process.

4 REGULATORY SUBMITTALS AND APPROVAL PROCESS[7]

The advanced reactor fleet can currently be licensed under either:

- 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," or
- 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants"

The NRC is also developing an optional performance-based, technology-inclusive regulatory framework for licensing nuclear power plants designated as 10 CFR Part 53, "Licensing and Regulation of Advanced Nuclear Reactors." This effort is still in development and is not addressed in this report.

The NRC points out in SECY-22-0052, "Proposed Rule: Alignment of Licensing Processes and Lessons Learned from New Reactor Licensing," that there are key differences in the submittal requirements between Part 50 and Part 52, specifically:

- *Under Part 52, applicants for a DC, a COL, an SDA, or an ML are required to provide information describing the fire protection design features necessary to comply with GDC 3 and § 50.48. In addition, under Part 52, an applicant for a COL is required to describe how its fire protection program will be carried out.*
- *Part 50, specifically § 50.34, has no explicit equivalent requirement for an applicant for a CP or an OL. For a CP applicant, § 50.34(a)(3)(i) only requires that the preliminary safety analysis report include the preliminary design of the facility including the principal design criteria of the facility. Although the principal design criteria include the GDC, and therefore GDC 3, the requirement in § 50.34(a)(3)(i) lacks the specificity of the part 52 requirements to provide a description and analysis of the fire protection design features necessary to comply with GDC 3.*
- *A similar lack of clarity exists on application requirements under Part 50 for the OL phase. Section 50.34(b) states that each application for an OL shall include an FSAR, but unlike part 52, there is no specific requirement in § 50.34(b) stating that the applicant needs to provide information about how they meet GDC 3 or § 50.48 requirements not addressed at the CP stage.*

[7] The following acronyms are used in the quoted documents in this section: DC (Design Certification), CP (Construction Permit), COL (Combined Operating License), GDC (General Design Criteria), ML (Manufacturing License), OL (Operating License), SDA (Standard Design Approval)

In addition, unlike for COL applicants in § 52.79(a)(40), there is no clear requirement for OL applicants to describe the implementation of the fire protection program required by § 50.48.

In the SECY, the NRC proposed to amend 10 CFR 50.34(a) to add a provision requiring the applicants for a Construction Permit to provide information about how the fire protection design features comply with GDC 3, and to amend 10 CFR 50.34(b) to add a provision requiring the applicants for an Operating License to provide information about how the fire protection design features comply with General Design Criterion and 10 CFR 50.48. Specifically:

- *§ 50.34(a)(iv) A description and analysis of the fire protection design features for the plant necessary to comply with General Design Criterion 3 of appendix A to this part.*
- *§ 50.34(b)(6)(vii) A description and analysis of the fire protection design features for the plant necessary to comply with § 50.48 and a description of the fire protection program required by § 50.48 and its implementation.*

Therefore, regardless of the path chosen, the information provided to support the fire protection program will be similar.

5 ADVANCEMENTS IN TECHNOLOGY AND ANALYSIS TECHNIQUES

Many advancements have occurred since the NRC's original position on the five-person fire brigade from 1977 (See Section 2) was made. This section contains an overview of these changes in the context of the impact on fire response.

- Inherently safe system design, and physical separation
- Fire hazards and the potential for fire hazards to rapidly grow and damage systems important to safety
- Plant design features to provide early warning, and limit spread to adjacent areas
- Advancements in fire science
- Risk insights available during the design process

5.1 Inherently Safe System Design, and Physical Separation.

In accordance with the guidance of RG 1.189 Section 8.2, the advanced reactor fleet designs should ensure that safe shutdown can be achieved by assuming that all equipment in any one fire area will be rendered inoperable by fire and that reentry into the fire area for repairs and operator actions is not possible.

The control room is excluded from this approach, provided that the design includes an independent alternative shutdown capability that is physically and electrically independent of the control room. Designs incorporating reactor containment buildings should provide fire protection for redundant shutdown systems in the reactor containment building that will ensure, to the extent practicable, that one shutdown division will be free of fire damage.

The criteria for advanced reactors are more conservative and restrictive than the criteria applied to the operating U.S. fleet, either during original design or imposed following design/construction. **Therefore, alignment with the guidance for advanced reactors in Section 8 of RG 1.189 provides safety improvements, including less reliance on active fire protection systems/features and operator actions than the existing U.S. fleet.**

5.2 Fire Hazards and the Potential for Fire Hazards to Rapidly Grow and Damage Systems Important to Safety

The advanced reactor fleet should incorporate the Fire Modeling concept of Zone of Influence (ZOI) (developed for Fire Probabilistic Risk Assessment (Fire PRA)) in the design phase to minimize the potential for fire propagation outside an ignition source. The ZOI is the space surrounding an ignition source in which targets may be affected by a fire initiated in that ignition source. The term “target” refers to damaged items (e.g., cables or plant equipment) that will directly affect the outcome of a fire scenario (fires developing beyond the incipient stage). The plant design, to the extent practical, should maintain the zone of influence around ignition sources free of secondary combustibles such that fire propagation beyond the ignition source would not be expected.

Specific attention should also be given to high hazard fire sources (turbine fires, transformer fires, switchgear, etc.) and separating these hazards from equipment important to safety. These fires would not be expected to require a fire response greater than that provided by an incipient fire brigade, and therefore additional echelons of defense-in-depth should be provided.

5.3 Plant Design Features to Provide Early Warning, and Limit Spread to Adjacent Areas

Fixed suppression and detection design for the advanced reactor fleet should be installed based on insights from the Fire Hazards Analysis (FHA), Fire Safe Shutdown Analysis (FSSA), and Fire PRA (if performed) in accordance with the applicable NFPA Standards.

The advanced reactor fleet should design passive fire barriers (including penetration seals, doors, and dampers) in accordance with guidance provided in RG 1.189 and should be or commensurate with the hazard in the fire area.

5.4 Advancements in Fire Science

Considerable advancements have been made over the past several decades in the design and regulatory requirements for fire safety, in fire protection technology, and in related analytical techniques. Substantial efforts have been undertaken in the U.S. and worldwide to implement these advancements. Specific organizations in the U.S. such as the Electric Power Research Institute (EPRI), the NRC Office of Nuclear Regulatory Research, National Institute for Standards and Technology's, Building and Fire Research Laboratory (NIST), and Sandia National Laboratory (SNL) have been active in the development and implementation of fire research projects that help:

- Develop and validate fire analysis methodologies and supporting data, and
- Use the research results as the basis for recommending improvements to risk-inform NRC regulations and industry guidance.

The most prominent area of advancement in the context of this fire response evaluation is in Fire PRA methods and data, which has advanced significantly, particularly in the last 20 years. Areas of advancement include standards, methods, and guidance associated with the development and maintenance of Full Fire PRAs. In addition, research and advancements have been substantial in nuclear power plant fire modeling, cable behavior in response to fire, human reliability analysis, and high energy arcing fault behavior. This research is supported by data from fire events, which has improved with operating experience and is utilized to gain a more realistic prediction of the frequency and consequences of fire events. Even if a fire PRA is not developed, these tools can be used to inform the design.

5.5 Risk Insights Available During the Design Process

Unlike the existing nuclear fleet, the advanced reactor fleet has the advantage of including insights gained from the FSSA and Fire PRA (if performed) into the design. This allows the designers to focus on the risk significant scenarios and the factors that are driving that risk. Additionally, the sensitivity to manual suppression, given all the other factors, can also be assessed.

6 SUGGESTED RISK-INFORMED, PERFORMANCE-BASED FIRE RESPONSE EVALUATION PROCESS

6.1 Process Summary

To begin the risk-informed, performance-based fire response evaluation process the plant design and supporting analyses need to be in a stable state, including the:

- FSSA
- Fire PRA (if performed)
- FHA (documenting ignition sources, risk significant fire scenarios, fire area boundaries, fire suppression and detection)

These documents will provide the bases for assessing the fire response needs.

The fire response evaluation process will result in one of the following outcomes:

- Offsite Response Only
- Onsite Incipient Fire Brigade,
- Onsite Structural Fire Brigade

In the case of both the ‘Offsite Response Only’ and the ‘Onsite Incipient Fire Brigade,’ the response evaluation also needs to assess the acceptability of the offsite response capability and the maintenance of defense-in-depth and the fire protection program. See Figure 6-1.

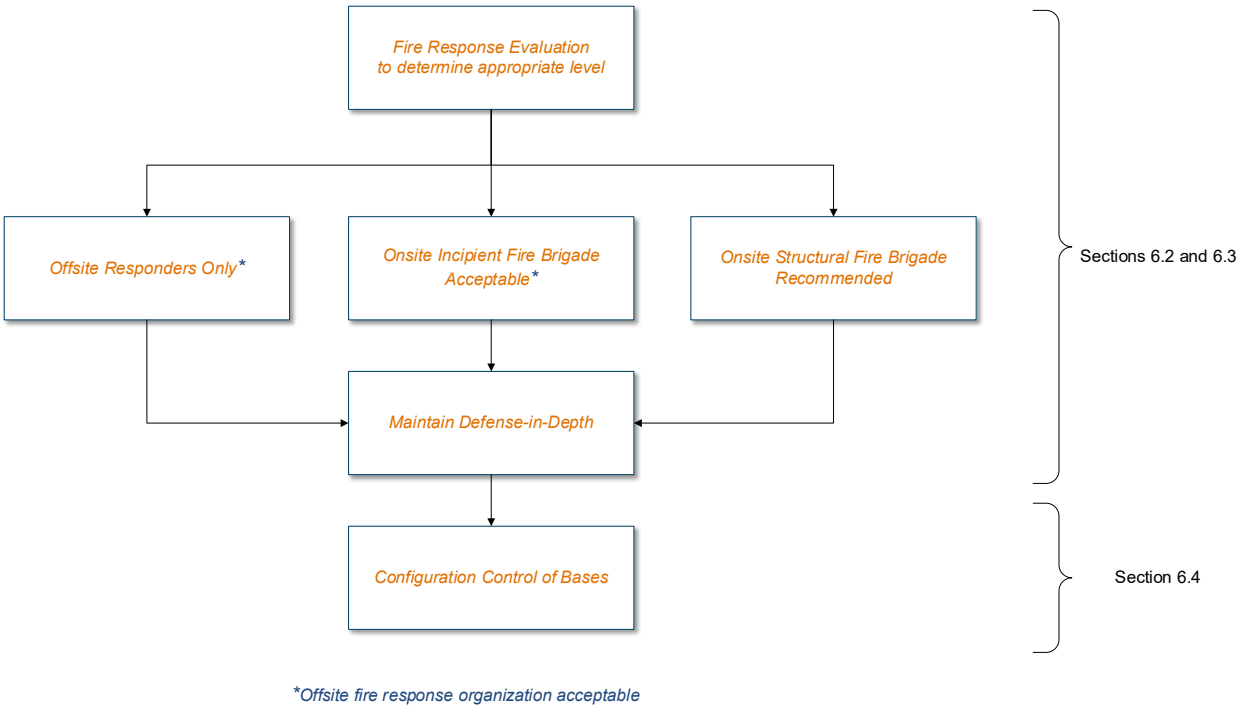

Figure 6-1 Fire Response Evaluation Outcomes

Regardless of the approach chosen for the fire response, the ability to achieve and maintain safe shutdown, given a fire in any area is a critical input to the analysis. This is discussed in Section 6.2.1.

The fire response evaluation has been divided into the following steps:

- Determine the need for onsite fire response (Section 6.2.2)
- Given the need for onsite fire response, determine if an Onsite Incipient Fire Brigade response is acceptable (Section 6.2.3)
- If either offsite response or an onsite incipient fire brigade are determined to be acceptable, evaluate the acceptability of the offsite fire response organization (Section 6.2.4)

Two additional considerations are applicable regardless of the outcome of the fire response evaluation.

- Ensure the adequacy of defense-in-depth (Section 6.3)
- Ensure the fire protection program maintains the basis for acceptability of the evaluation (Section 6.4)

6.2 Evaluation Steps

6.2.1 Safe Shutdown Ensured

One of the primary goals of the fire protection program is to identify the means to limit fire damage to SSCs so their capability to achieve safe shutdown is maintained for a fire in any fire area. RG 1.189, "Fire Protection for Nuclear Power Plants," Section 8.2 states in part:

> *New reactor designs should ensure that safe shutdown can be achieved by assuming that all equipment in any one fire area will be rendered inoperable by fire and that reentry into the fire area for repairs and operator actions is not possible.*

Given that meeting this goal is a prerequisite for the design, radiological release is not postulated due to fire damage. This concept is essential when determining the appropriate brigade size and complement.

6.2.2 Determine the Need for Onsite Fire Response

In the event of very small reactors approved to operate for specific applications (e.g., micro-reactors), the safety features of the design could allow for sole reliance on offsite fire response.

Micro-reactors are more like research and test reactors as recognized in the Supplementary Information in the publication of the final rule for Emergency Preparedness for Small Modular Reactors and Other New Technologies (10 CFR 50.33(g)(2)(i)). Research and test reactors do not require on site fire response.

If the ability to achieve and maintain safe shutdown is ensured, given a fire in any fire area without operator intervention, and alternative onsite operations staffing has been approved by the NRC, then offsite fire response could be utilized and is presented in Figure 6-2.

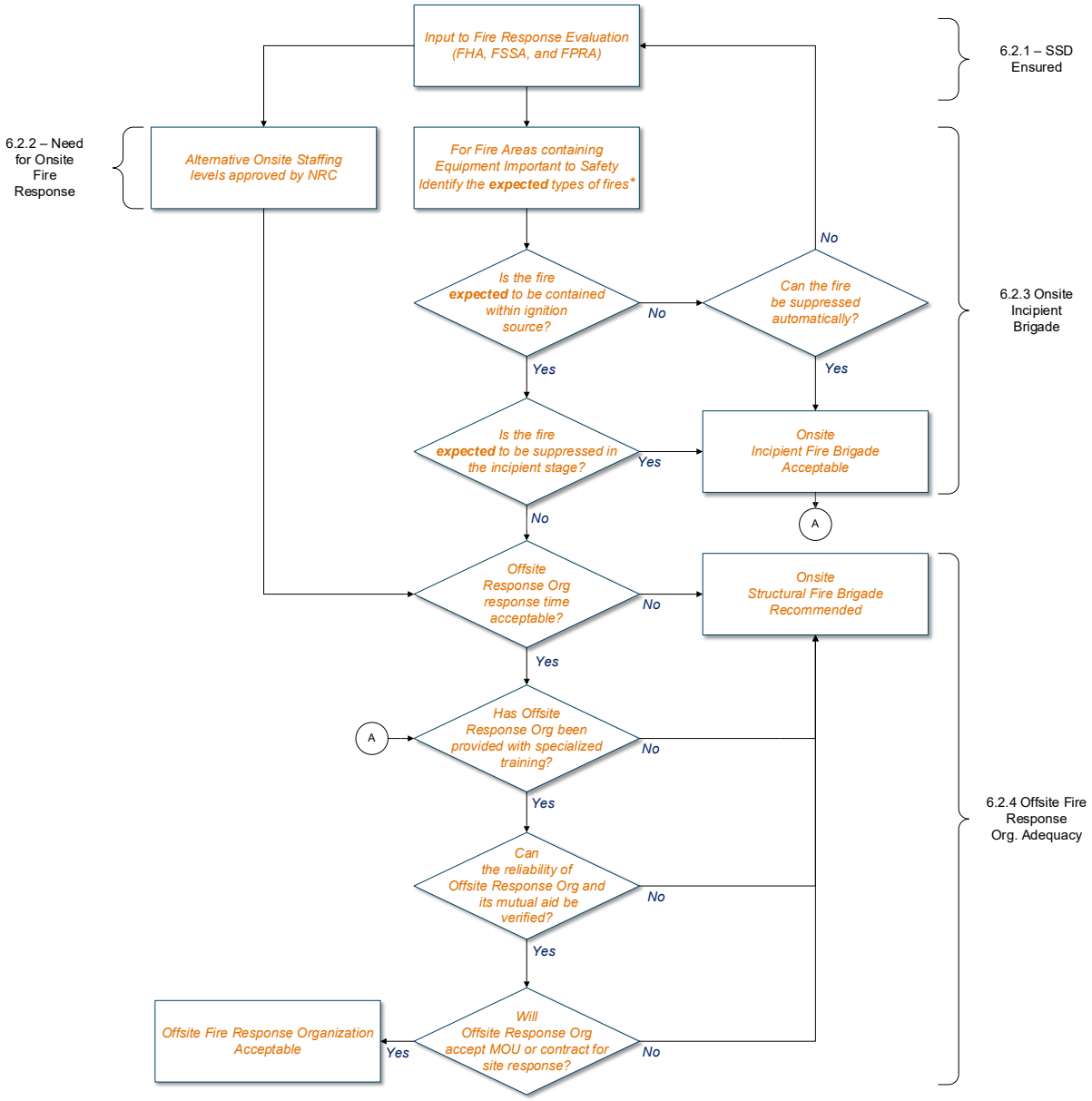

Figure 6-2 Risk-Informed, Performance-Based Fire Response Evaluation Process

6.2.3 Onsite Incipient Fire Brigade Evaluation

If the need for some level of onsite fire response is determined to be necessary, two questions should be answered to determine if an onsite incipient fire response is appropriate:

1. Are the fires that affect equipment important to safety, expected to progress beyond the incipient stage, and if they do, what are the fire-induced consequences and the risk sensitivity to manual suppression?

   and

2. From a fire fighting perspective, is the offsite fire response organization an acceptable alternative? (The evaluation of question 2, is outlined in Section 6.2.4.)

As identified in Section 3.5.1, the incipient stage fire is defined in NFPA 600 as:

> *A fire which is in the initial or beginning stage and which can be controlled or extinguished by portable fire extinguishers, Class II standpipe, or small hose systems without the need for protective clothing or breathing apparatus.*

The focus of the evaluation is on fire areas that may affect equipment important to safety. Other fire areas may contain hazards that would challenge an incipient fire brigade, but if there is reasonable assurance that these scenarios will not challenge equipment important to safety, offsite fire response would be appropriate.

For each fire area[8] that contains or may present an exposure to equipment important to safety, the expectation that a fire will propagate beyond the ignition source should be assessed. The following information should be documented in the evaluation:

- The types of fires expected in the fire areas of concern.

  This information can be obtained from the FHA, which should include ignition sources, combustible material, and fire scenarios.

- Whether the types of fire can propagate beyond the ignition source.

  Based on the information contained in the FHA and the Fire PRA (if performed), and the plant design (factored in ZOIs), an assessment can be made of the fires that are expected to propagate beyond the ignition source (e.g., fires propagating outside of an electrical cabinet such that it could potentially damage adjacent cabinets/cable trays).

- Is the fire expected to be identified in the incipient stage?

  Based on the types of fires identified, an assessment can be made to determine if the fire is expected to be identified and suppressed in the incipient stage. Appendix A of this report provides data from INPO and the EPRI Fire Events Database to support this assessment.

- If the fire is expected to progress, evaluate the detection and/or automatic suppression to address uncertainty.

  Appendix A of this report provides data from INPO and the EPRI Fire Events Database to support this assessment.

If the evaluation concludes that fires in areas that affect equipment important to safety are expected to develop beyond the incipient stage and suppression / containment is not provided, then an onsite structural brigade would be appropriate. Additional discussion of the onsite structural brigade is not provided in this document since the existing guidance is well established.

[8] Note this analysis can be performed by grouping similar fire areas together.

6.2.4 Offsite Fire Response Organization Adequacy

Once the initial evaluation has been made that an incipient fire brigade may be acceptable, the adequacy of the offsite fire response organization should be addressed to supplement the incipient fire brigade. The following questions can be used to assess adequacy of the offsite fire response organization:

- Identify the desired fire response time given the most limiting evaluation.
- What is the distance of the facility from response organization and response time?
- Do the postulated fires require specialized training beyond offsite fire response organization's capabilities? Are there any special fire risks that exist in the plant even if not directly related to equipment important to safety?
- Can the reliability of the offsite responders be verified?
    - Do the primary offsite responders have any other high hazard coverage response duties or multiple industrial facilities?
    - Is the response organization comprised of career firefighting professionals or volunteer firefighters?
        - If not career professionals, what is the level of certification or training?
    - Is the normal availability of the offsite response agencies understood?
    - Is there a statutory duty to respond in the location of the plant?
- Will a memorandum of understanding (MOU)/contract need to be entered into to guarantee response and service level?

If the response to these questions is satisfactory, then the offsite fire response organization is an acceptable supplement to the onsite incipient fire brigade or as the primary response. If the capability and reliability of the offsite fire response organization is not acceptable, then an onsite structural fire brigade is recommended.

6.3 Evaluation of the Adequacy of Defense-in-Depth

One of the original concerns of the NRC regarding establishing a five-person fire brigade in 1977 (See Section 2), was:

> *…The minimum fire brigade shift size cannot be based only upon the potential fire consequences and their apparent impact on the capability to safely shutdown because this is contradictory to both the philosophy of defense-in-depth and the general design criterion requirement to minimize the adverse effects of fires.*

The guidance provided in RG 1.189 regarding defense-in-depth states the following (bold text added for emphasis):

> *In accordance with 10 CFR 50.48, each operating nuclear power plant must have a fire protection plan. The plan should establish the fire protection policy for the protection of SSCs important to safety at each plant and the procedures, equipment, and personnel required to implement the program at the plant site.* ***The primary objectives of FPPs at U.S. nuclear plants are to minimize both the probability of occurrence and the consequences of fire. To meet these objectives, the FPPs for operating nuclear power plants are designed to provide reasonable assurance, through defense-in-depth, 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.***
>
> *The FPP should extend the concept of defense-in-depth to fire protection in* ***fire areas important to safety****, with the following three objectives:*
>
> *a. Prevent fires from starting.*
>
> *b. Detect rapidly, control, and extinguish promptly those fires that do occur.*
>
> *c. Provide protection for SSCs 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.*

Regardless of the outcome of the fire response evaluation, fire protection defense-in-depth should be maintained. Appendix B of this report provides considerations for that analysis.

The defense-in-depth objectives are accomplished through a combination of design features and programmatic controls. Balancing the defense-in-depth echelons will be key to determining the need for an onsite fire brigade and if necessary, the appropriate fire brigade classification and complement.

6.4 Fire Protection Program Maintains Basis for Acceptability of Evaluation

In addition to the response to the evaluation above, the bases for the fire response evaluation will need to be maintained. The site fire protection program plan should identify:

- An individual with overall responsibility for the fire protection program.
- An individual with the necessary level of understanding of the plant be available to oversee the fire response.
- A process for maintaining configuration control of the fire protection program.
- A method for ongoing demonstration of capability of the onsite incipient fire brigade and the offsite fire response to effectively respond to fire events.

7 CONCLUSIONS

The fire response evaluation is summarized below:

- There are no regulations that require a specific classification and complement of fire brigade for the advanced reactor fleet.

- RG 1.189 suggests a five-person fire brigade, but an RG is considered one acceptable method of meeting regulatory requirements. In addition, more applicable and recent guidance in DANU-ISG-2022-09 acknowledges potential greater reliance on offsite fire response and encourages dialogue with the NRC during the application process.

- Guidance documents exist in the nuclear industry that establish a process for evaluating fire response needs (CSA N293, NEIL, IAEA).

- Advances in technology and analysis techniques support an approach to fire safety that places less reliance on onsite structural fire brigade response.

- This fire response evaluation provides a structured process to determine one of the following outcomes, along with ensuring defense-in-depth and configuration control of the bases for these outcomes:

    - Offsite Response Only

    - Onsite Incipient Fire Brigade,

    - Onsite Structural Fire Brigade

8 REFERENCES

The following references were used in the development of this report.

1. 10 CFR 50.48, “Fire protection, Appendix R, Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979.”

2. 10 CFR 50.65, “Requirements for monitoring the effectiveness of maintenance at nuclear power plants.”

3. 10 CFR 52, “Licenses, Certifications, and Approvals for Nuclear Power Plants.”

4. ANSI/ANS 15.17, “Fire Protection Program Criteria for Research Reactors, 1981.”

5. Appendix A to 10 CFR 50, “Criterion 3 for Light Water Reactors.”

6. CSA N293, “Fire protection for nuclear power plants,” April 2023.

7. U.S. NRC DANU-ISG-2022-09, “Risk-Informed, Performance-Based Fire Protection Program (For Operations),” March 31, 2024 (ML23277A147).

8. INPO EPG-05, “Engineering Program Guide, Fire Protection,” Revision 1, December 2020.

9. U.S. NRC, “Evaluation of Minimum Fire Brigade Shift Size,” June 6, 1979 (ML19208D065).

10. INPO 11-004, “Guidelines for Excellence in Fire Protection Program Implementation,” Revision 3, September 2023.

11. INPO 20-003, “Guidelines for the Conduct of Fire Brigade Drills,” Revision 0, August 2020.

12. IAEA, INSAG Series No.10, 1996, “Defence in depth in nuclear safety.”

13. IAEA, INSAG Series No.12, 1999, “Basic safety principles for nuclear power plants 75-INSAG-3,” Rev 1.

14. NFPA 1001, “Standard for Fire Fighter Professional Qualifications,” Current Edition 2019.

15. NFPA 1081, “Standard for Facility Fire Brigade Member Professional Qualifications,” Current Edition 2024.

16. NFPA 600, “Standard on Facility Fire Brigades,” Current Edition 2020.

17. NFPA 804, “Standard for Fire Protection for Advanced Light Water Reactor Electric Generating Plants,” Current Edition 2020.

18. NFPA 805, “Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants,” Current Edition 2020.

19. NFPA 806, “Performance-Based Standard for Fire Protection for Advanced Nuclear Reactor Electric Generating Plants Change Process,” Current Edition 2020.

20. Nuclear Electric Insurance Limited Loss Control Manual, 2024.

21. NUMARC 93-01, “Industry Guidelines for Monitoring Effectiveness of Maintenance at Nuclear Power Plants,” Revision 4f, April 2018. (ML18120A069)

22. NUREG-1537, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors, Part 1, Format and Content, and Part 2, Standard Review Plan and Acceptance Criteria, Section 9.3, Fire Protection Systems and Programs,” February 1996.

23. Regulatory Guide 1.160, “Monitoring the Effectiveness of Maintenance at Nuclear Power Plants, Revision 4,” August 2018. (ML18220B281)

24. Regulatory Guide 1.189, “Fire Protection for Nuclear Power Plants,” Revision 5, October 2023. (ML23214A287)

25. Regulatory Guide 1.232, “Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors,” Revision 0. (ML17325A611)

26. Regulatory Guide 1.242, “Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light Water Reactors, and Non-Power Production or Utilization Facilities,” Revision 0. (ML23226A036)

27. Regulatory Guide 1.247 (for Trial Use), “Acceptability of Probabilistic Risk Assessment Results for Non-Light-Water Reactor Risk-Informed Activities.” (ML21235A008)

28. IAEA, Safety Reports Series No. 10, 1998, “Treatment of internal fires in probabilistic safety assessment for nuclear plants.”

29. IAEA, Safety Reports Series No. 46, 2005, Assessment of defence in depth in nuclear power plants.

30. IAEA, Safety Reports Series No. 8, 1998, Preparation of FHA for Nuclear Power Plants.

31. IAEA, Safety Standards Series No. NS-G-1.7, 2004, Protection against internal fires and explosions in the design of nuclear power plants.

32. IAEA, Safety Standards Series No. NS-G-2.1, 2000, Fire safety in the operation of nuclear power plants.

33. SECY-22-0052, Proposed Rule: Alignment of Licensing Processes and Lessons Learned from New Reactor Licensing, June 2022. (ML21159A055)

34. OSHA 29 CFR 1910.156, Fire brigades.

35. EPRI Report 3002005302, Fire Events Database Update for the Period 2010-2014, May 2016.

36. Email from Daniel Timmons, INPO to Alan Campbell NEI, FP Raw Fire Data 2020-2024(April 15), dated April 15, 2024.

37. Federal Register Notice Emergency Preparedness for Small Modular Reactors and Other New Technologies, November 16, 2023.

APPENDIX A. FIRE EVENTS INFORMATION SOURCES

Both INPO and EPRI publish analyses of fire events at nuclear power plants. This data provides the basis for assessing the probability of a fire progressing beyond the incipient stage.

A.1. EPRI Fire Events Database

The latest EPRI report, Fire Events Database Update for the Period 2010–2014, was issued in May 2016. The next update to this report (adding events from 2015-2020) is expected to be published in 2024. The Fire Events Database (FEDB) is developed by EPRI with review support from the NRC and is the principal source of fire incident data for use in Fire PRAs. The report uses the fire event data collected by INPO and stored in the INPO Consolidated Event System (ICES) database for the years 2010–2014. The fire severity classifications were determined in cooperation with the NRC's Office of Nuclear Regulatory Research under a memorandum of understanding between the NRC and EPRI.

The following table from the EPRI report characterizes the severity classifications of the fires evaluated in the FEDB.

Table 4-1
Event classifications and subclassifications [1]

Event Classification	Event Subclassifications
Challenging (CH) One of the following:	Damage to or ignition of an adjacent object, cable, or component occurred. This includes ignition of secondary combustibles.
	Damage to or ignition of an adjacent object, cable, or component would have readily occurred had the fire been in a different location.
	Damage to or ignition of an adjacent object, cable, or component could have occurred if significant suppression actions[1] had not been taken.
Undetermined (PC-CH)	At least a *potentially challenging* fire, with insufficient information available to make a definitive *challenging* finding.
Potentially challenging (PC) Not *challenging* and one of the following:	Damage to or ignition of an adjacent object, cable, or component could have occurred if minor suppression actions[1] were not taken in a timely manner. Delayed detection could lead to a delay in taking such actions.
	Damage to or ignition of an adjacent object, cable, or component could have occurred if the fire were in a different location and if minor suppression actions[1] were not taken in a timely manner. Delayed detection could lead to a delay in taking such actions.
Undetermined (NC-PC)	Potentially a fire, with insufficient information available to make a definitive *potentially challenging* finding.
Not challenging (NC) Not *potentially challenging* and one of the following:	Overheat condition only; no smoldering or flaming combustion.
	Smoldering fire self-extinguishes without any active intervention.
	Fire involves an ignition source that would not be expected in any area of interest to the FPRA or in a location that has no relevance to plant operations or safety.
	Other specific smaller fire incidents with specific characteristics.[2]

Note 1: Significant suppression actions include the manual use of hose streams and the automatic/manual activation of sprinklers, deluge systems, Halon systems, or CO_2 systems. Minor suppression activities include lesser actions, such as the use of a single portable extinguisher or other relatively simple and prompt actions to suppress the fire. Section 4.3 and Appendix B of EPRI 1025284 provide additional discussion and examples.

Note 2: See Table 4-3 of EPRI 1025284 for a list of specific potentially challenging-to-not-challenging override types of fire events and Appendix B for discussion of the specific criteria used to determine potentially challenging-to-not-challenging override classifications.

Figure A-1 Fire Event Classifications (Table 4-1 EPRI Report 3002005302)

Section 5 of the EPRI report provides an overview of the types of fires / extent of damage and the detection/suppression characteristics. These are summarized in the excerpted Figures A-2 and A-3 below. The appendices of the EPRI report provide more detailed summaries of the events, event attributes, severity evaluation, event timeline and suppression.

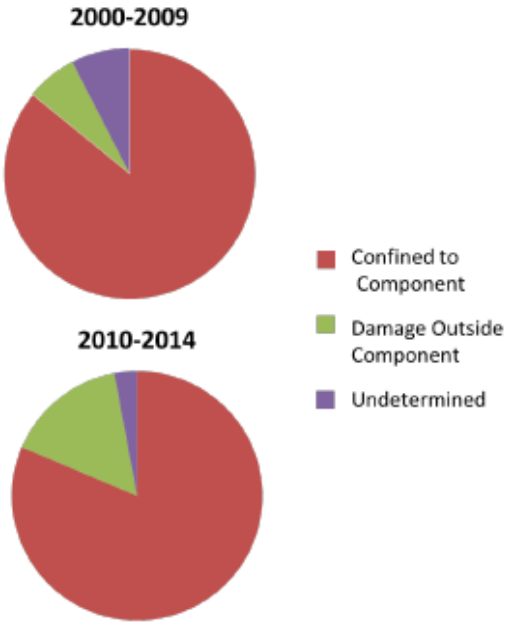

Figure 5-1
Extent of damage for fires, excluding hot work and transient fires

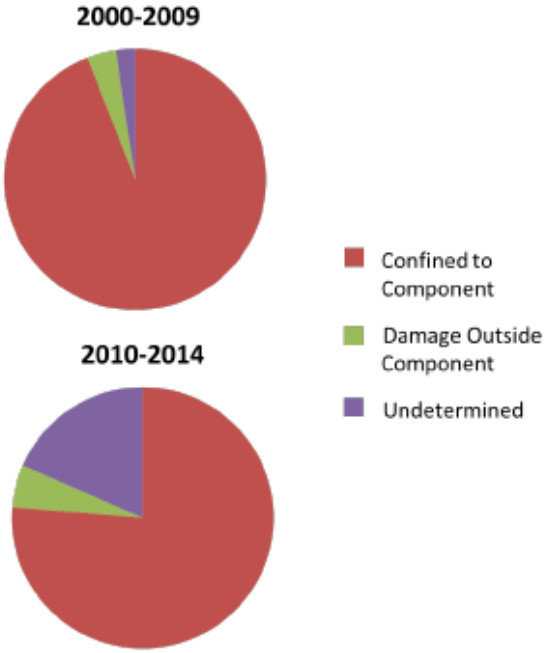

Figure 5-2
Extent of damage for hot work and transient fires

Figure A-2 Extent of Damage (Tables 5-1 and 5-2 EPRI Report 3002005302)

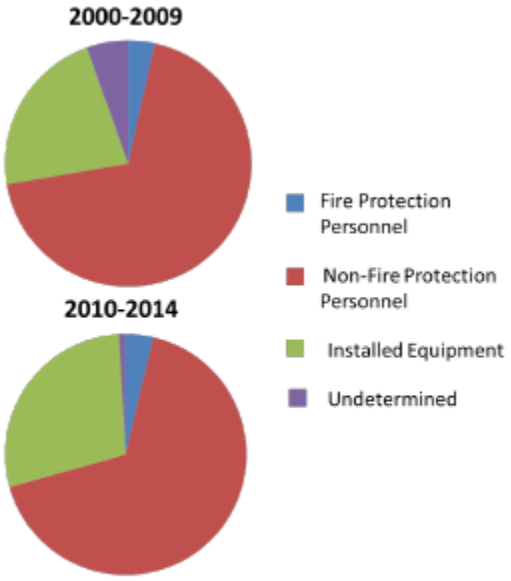

Figure 5-3
Fire detection method (first indication), excluding hot work and transient fires

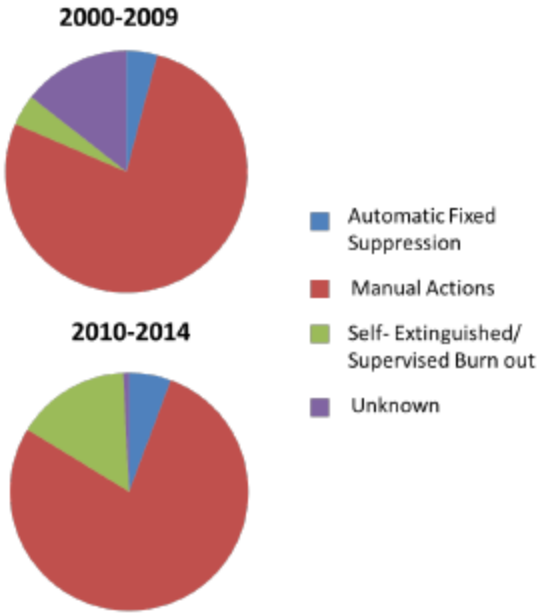

Figure 5-4
Fire suppression method, excluding hot work and transient fires

Figure A-3 Detection and Suppression Method (Tables 5-3 and 5-4 EPRI Report 3002005302)

These figures support the premise that most fires are discovered in the early stages and suppressed by workers manually. The analyst can use the details in the report to support decision-making on the expectation that the fire will be discovered and extinguished in the incipient phase. These insights can then be used as part of a defense-in-depth review.

A.2. INPO Recent Fire Event Information

INPO issues Event Reports to its members to provide data and insight regarding Fire Events and Trends. INPO Event Report IERL4 22-2 was issued on January 21, 2022. NEI was provided with updated data for use in this report in an email dated April 15, 2024. This data covers events from 2021 through April 10, 2024.

The total fire events per year are consistent with the EPRI Fire events for the period from 2010-2014, and consistent with the data provided in IERL4 22-2.

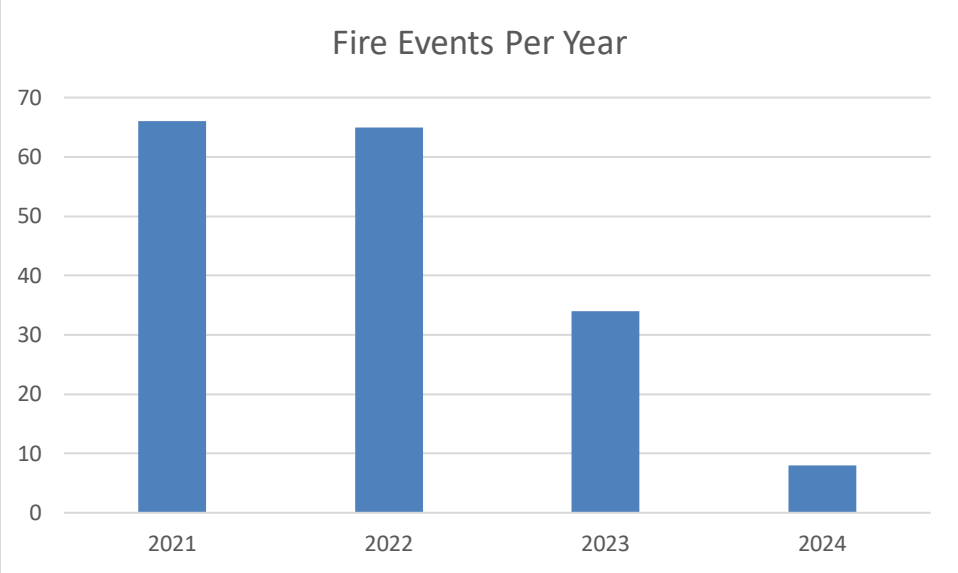

Figure A-4 INPO Fire Events Data (2021 through April 10, 2024)

You can see from Figure A-5 and Figure A-6 that the method of detection/discovery, coupled with the data on fire spread, continues to support the EPRI analysis of the earlier data that most of the fires are discovered and extinguished in the incipient phase. Note that this is only one part of the fire response evaluation and the remaining echelons of defense-in-depth still need to be evaluated to ensure that fires in areas that contain equipment important to safety will not prevent the capability to shut down the plant safely.

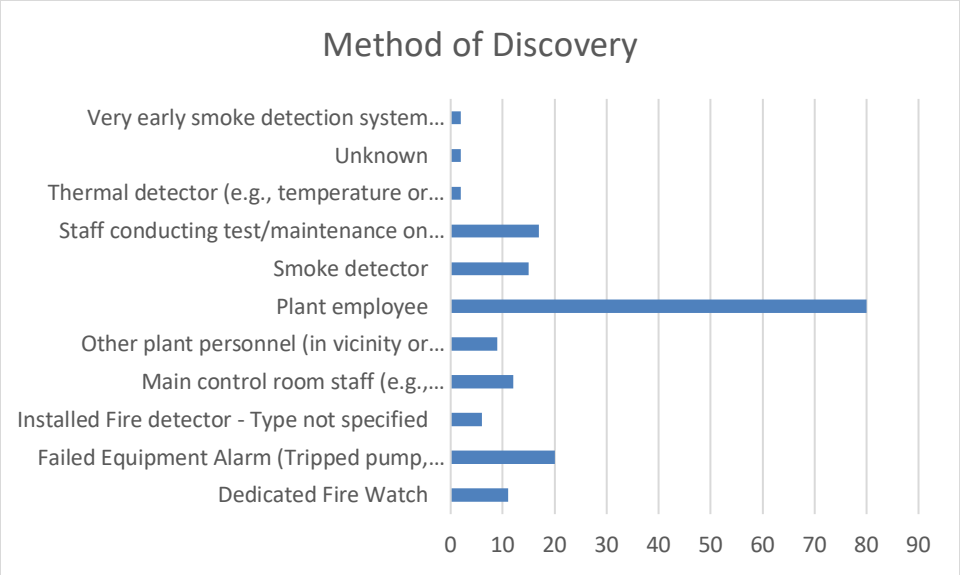

Figure A-5 INPO Fire Events Data (2021 through April 10, 2024) – Method of Discovery

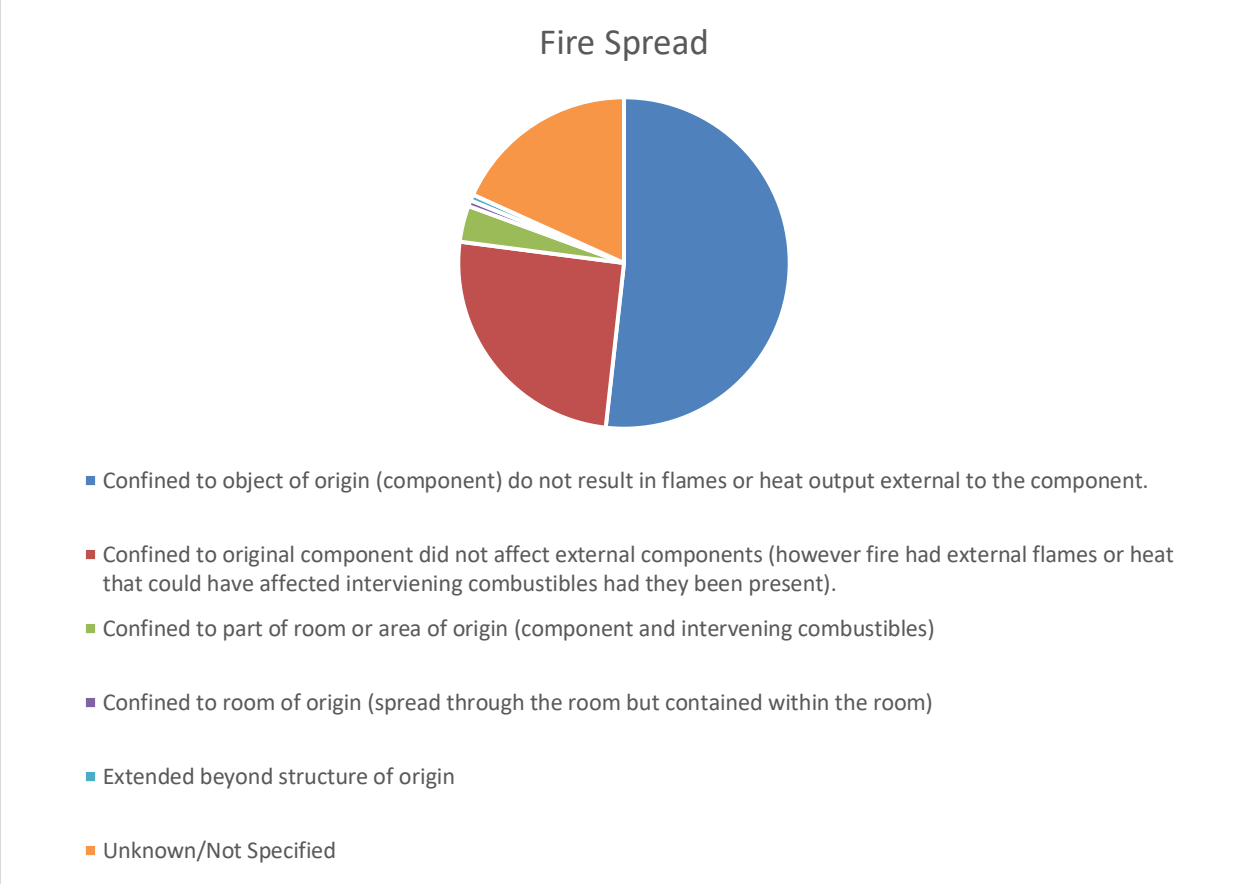

Figure A-6 INPO Fire Events Data (2021 through April 10, 2024) – Fire Spread

APPENDIX B. DEFENSE-IN-DEPTH CONSIDERATIONS

Method of Providing DID	Considerations	Impact on Fire Response
Echelon 1 – Prevent fires from starting		

Design Phase – During this phase, methods include, but are not limited to:
• Use of Noncombustible and fire-resistant materials
• Electrical Design Standards
• Incorporation of Zones of Influence in design to limit fire to ignition source
 	
Operations Phase – During this phase, methods include, but are not limited to:
• Combustible Controls
• Ignition Source Controls
• Hot Work Controls
• Compensatory Measures
  ○ Fire Protection Systems and Features
  ○ Mitigating Systems
	Design Phase
	In addition to the use of non-combustible materials and adherence to electrical design standards, the following should be considered:
	• Insights from the Fire PRA (if performed) for risk significant scenarios
	  ○ Creating a Transient Free Area(s)
	  ○ Creating a Hot Work Restriction Area(s)
	• Using the Zone of Influence concept to minimize the potential for fire propagation outside an ignition source
	
	Operations Phase
	Combustible material, ignition sources, and hot work controls are fundamental elements of a fire protection program and as such should always in place.
	
	Compensatory Programs are developed for:
	• Suppression, detection, barriers and other elements of the fire protection program
	• Mitigating Systems (10 CFR 50.65(a)(4)) to address fire protection program impacts of removing mitigating systems from service
		Although not specifically addressing preventing fires from starting, utilizing the Zone of Influence concept will help ensure that fires remain within the original ignition source, allowing for an incipient brigade response.
		
		Providing ignition source and hot work controls are a primary method of ensuring transient fires do not start.
		
		Providing compensatory measures/risk management actions may entail actions to provide additional assurance that fires will not start when the plant is in a degraded condition.
		
		Review the remaining elements of defense-in-depth to ensure an over-reliance is not placed on programmatic activities to compensate for weaknesses in plant design.

Method of Providing DID	Considerations	Impact on Fire Response
Echelon 2 – Detect rapidly, control, and extinguish promptly those fires that do occur		

Design Phase – During this phase, methods include, but are not limited to:
• Incorporation of Zones of Influence in design to limit fire to ignition source.
• Installation of
  ○ Detection system(s)
  ○ Automatic fire suppression system(s)
  ○ Portable fire extinguishers
  ○ Hose stations
  ○ Fire Hydrants
Operations Phase – During this phase, methods include, but are not limited to:
• Pre-Fire Plans
• Hot Work and Ignition Source Control
• FP Inspection, Testing and Maintenance programs
	Design Phase
	The installation of fire protection systems and features needs to be addressed during the design phase.
	• The fire scenarios should be reviewed to determine the types of fires and reliance on suppression/detection should be evaluated in the area to best determine options for this element of defense-in-depth
	• If the fire area contains potentially risk significant fire scenarios that are of the type that would benefit from automatic suppression/detection, then consideration should be given to installation
	Operations Phase
	During the operations phase of the facility, the following procedures and processes should be considered:
	• Pre-fire plans to provide guidance to both onsite and offsite fire response personnel
	• Management plan identifying responsible individuals on site for the fire protection program and liaison responsibilities for offsite fire response.
	• Drills and drill frequency
	• Hot work procedures
	• Installed fire protection system should be inspected, tested, and maintained in accordance with appropriate NFPA standards
		Establishing criteria to limit fire growth in the design phase will create fire scenarios expected to be discovered and extinguished in its incipient phase.
		The review of the Fire PRA (if performed) and FSSA analyses to determine relative importance of fire areas will also focus on providing suppression and detection, as necessary, to create fire scenarios expected to be discovered and extinguished in the incipient phase.
		The pre-fire plans will play a key role establishing the incident management protocol, the operations liaison for the offsite fire response organization.
		A strong inspection, testing, and maintenance program will ensure the installed fire protection systems and features are functional.

Method of Providing DID	Considerations	Impact on Fire Response
Echelon 3 – Provide protection for SSCs 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.		
Design Phase – During this phase, methods include, but are not limited to: • Separation of SSCs important to safety into distinct fire areas • Provision of independent alternative shutdown capability for the Control Room fire • For design with containments, provision of fire protection systems and features to ensure one shutdown division will be free of fire damage. • Supplemental barriers (e.g., electrical raceway fire barrier systems, cable tray covers, combustible liquid dikes/drains, etc.) • Fire rated cable **Operations Phase** – During this phase, methods include, but are not limited to: • Pre-Fire Plans	The issue to be considered during the design and operation is whether existing separation is adequate and whether additional measures (e.g., supplemental barriers, fire rated cable, or operator actions) are required to offset a weakness in another echelon thereby providing a reasonable balance. The fire scenarios involved should be reviewed to determine the fires evaluated and the consequence in the area to best determine options for this element of defense-in-depth. Considerations include: • If the consequence associated with the potential scenarios is high an operator action, supplemental barriers, or other modification should be considered. • Compensatory Programs are developed for: ○ Suppression, detection, barriers and other elements of the fire protection program ○ Mitigating Systems (10 CFR 50.65(a)(4)) to address fire protection program impacts of removing mitigating systems from service • If the sequence to perform an operator action is particularly challenging, then including the action for defense-in-depth may be considered. An example would be a recovery action that is unique in nature, time critical and/or not included in the emergency response procedures such that the MCR staff may not be able to	The fire response will be dependent not only on the size of the fire, but on the potential consequences should the fire occur and continue to burn in a fire area, prior to response. Unlike the existing nuclear fleet, the advanced reactor fleet has the advantage of including insights gained from the FSSA and Fire PRA (if performed) into the design. This allows the designers to focus on the risk significant scenarios and the factors that are driving that risk. Factors that impact fire response include: • Expectation that the fire will propagate beyond ignition source • Multi-compartment analysis to assess the probability and consequence of fire spread to an adjacent fire area • Risk significance of scenarios and the contributing factors to that risk The impact of removing mitigating systems from service on the fire protection program is factored into the plant's 10 CFR 50.65(a)(4) program. The provision of compensatory measures/risk management actions provides reasonable assurance that fires that do occur

Method of Providing DID	Considerations	Impact on Fire Response
• Operations Procedures	quickly recognize and perform the required action.	will not impact the ability of the plant to safely shutdown, in off-normal conditions.