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Compensatory and Alternative Regulatory MEasures for Nuclear Power Plant FIRE Protection (CARMEN-FIRE)

Office of Nuclear Regulatory Research

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ABSTRACT

Each commercial nuclear power plant (NPP) operating in the United States has a comprehensive Fire Protection Program (FPP) that the U.S. Nuclear Regulatory Commission (NRC) has reviewed and approved.[1] The purpose of the FPP is to prevent the occurrence of fire, and minimize radioactive releases to the environment in the unlikely event that a significant fire was to occur. To achieve these objectives, the FPP integrates plant design and operating features (i.e., structures, systems, components, personnel- and administrative-controls) that assure defense-in-depth protection of the public's health and safety. This means that the FPP includes measures directed at reducing the likelihood of fires and explosions, rapidly detecting and suppressing those fires that do occur, and ensuring the capability to achieve and maintain safe shutdown conditions should there be a serious fire.

Over the lifetime of a plant, certain elements of the FPP may be found to be in a degraded or otherwise nonconforming condition (i.e., impaired). To maintain conformance to the defense-in-depth safety concept, an adequate level of fire safety must be maintained whenever a fire protection feature is disabled or impaired. Hence, a key element of the approved FPP is ensuring that appropriate actions are taken promptly to mitigate the effects of such impairments until permanent corrective actions can be completed. The objective of these interim fire-safety enhancements, called *"compensatory measures,"* is to provide reasonable assurance that any degradation in fire safety caused by an impairment will be appropriately compensated until permanent corrective actions are completed.

Employing compensatory measures, on a short-term basis, is an integral part of NRC-approved fire protection programs. For most generic impairments, such as a blocked sprinkler head or a damaged fire hose station, the appropriate measures will be specified in the approved FPP. In certain unique, plant-specific cases, however, the measures specified in the FPP may not assure an appropriate level of fire safety. When such unique circumstances are encountered, it is expected that an appropriate alternate measure would be implemented. Depending on the plant-specific circumstances, alternate compensatory measures may be fairly straightforward, such as a procedural enhancement, or more complex, such as installing one or more of the technologically advanced fire protection features described in Appendix B of this report.

This report is intended to serve an information resource related to interim compensatory measures. This report documents the history of compensatory measures, and details the NRC's regulatory framework established to ensure they are appropriately implemented and maintained. This report also explores technologies that did not exist when the current plants were licensed, such as video-based detection systems, temporary penetration seals, and portable suppression systems that, under certain conditions, may offer an effective alternative to the measures specified in a plant's approved fire protection program.

[1] As defined by the NRC in 10 CFR 50.48 and the Generic Letter 81-12, an approved Fire Protection Program includes the fire protection and post-fire safe shutdown systems necessary to satisfy the NRC's guidelines and requirements; administrative and technical controls; the fire brigade and the fire protection-related technical staff; and other related plant features which have been described by the licensee in the FSAR, fire hazards analysis, responses to staff requests for additional information, comparisons of plant designs to applicable NRC fire protection guidelines and requirements, and descriptions of the methodology for assuring safe plant shutdown following a fire.

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EXECUTIVE SUMMARY

During the initial development of the U.S. nuclear reactor program in the early 1970s, fire protection requirements for commercial nuclear power plants were limited to the broad performance objectives of Appendix A to 10 CFR Part 50, *"General Design Criteria for Nuclear Power Plants."* Because of a lack of implementation guidance, the level of fire protection adopted by a facility generally was found to be acceptable if it complied with local and industrial fire codes as evidenced by an acceptable rating from its fire-insurance underwriter. Consequently, the fire protection features at NPPs were very similar to those of conventional, fossil-fueled, power-generating stations. Fire protection continued to be evaluated on this basis until a major fire at the Browns Ferry Nuclear Power Plant on March 22, 1975 prompted significant changes in the NRC's fire-safety regulatory framework.

A key recommendation of a Special Review Group (SRG) tasked by the Commission to investigate the Browns Ferry fire was the need for each operating plant to establish a comprehensive fire protection program (FPP) that integrates the multiple levels of protection established by the time-honored safety concept known as *"defense-in-depth."* Incorporation of this recommendation into the NRC's regulatory framework required each operating plant to establish a FPP that integrates the structures, systems, components, procedures, and personnel needed to do the following: (1) Prevent fires from starting; (2) Rapidly detect, control, and extinguish those fires that occur; and, (3) Ensure that the fire will not prevent the operation of the necessary safe shutdown functions, and will not significantly increase the risk of radioactive releases to the environment. The aim is to achieve a suitable balance between each layer, and echelon of protection. No single layer alone can be perfect or complete by itself. However, strengthening any one layer can compensate in some measure for weaknesses in the others.

Consistent with the defense-in-depth safety concept, the SRG also recommended that an adequate level of fire safety be maintained when a fire protection feature is degraded or disabled. The Commission addressed this recommendation by allowing licensees, through their approved fire protection program[1], to implement temporary corrective actions called *"compensatory measures"* or *"interim compensatory measures"* until the functionality of the degraded or disabled equipment is restored. The objective of these measures is to temporarily offset the reduction in fire safety caused by the impairment. A compensatory measure is not a permanent replacement for a regulatory requirement.

The incorporation of the SRG recommendations into the NRC's regulatory framework ensured that each plant had a comprehensive FPP that integrates plant design and operating features needed to provide an appropriate balance between each element of defense-in-depth and administrative controls (e.g., policies and procedures) to govern all fire protection activities, including the establishment of interim compensatory measures that are appropriate for the specific hazards, compatible with plant operations, and are properly implemented and maintained.

[1] The NRC-approved Fire Protection Program includes the fire protection and post-fire safe shutdown systems necessary to satisfy the NRC's guidelines and requirements; administrative and technical controls; the fire brigade and fire protection related technical staff; and other related plant features which have been described by the licensee in the FSAR, fire hazards analysis, responses to staff requests for additional information, comparisons of plant designs to applicable NRC fire protection guidelines and requirements, and descriptions of the methodology for assuring safe plant shutdown following a fire.

To assure that fire protection systems and features are available and in proper working condition, the Commission initially imposed Technical Specifications (TS) for fire protection systems. At that time, incorporating fire protection systems into the TS was deemed necessary to assure the following:

- Prompt compensatory measures would be taken when needed,
- An appropriate alternate means of protection is available, and,
- Appropriate organizations are notified to counter the effects of systems/equipment being out-of-service.

In 1986, the Commission provided an approach for licensees to remove unnecessary fire protection TS (GL 86-10). Under this guidance, most TS requirements for the operability of the fire protection system (and the associated compensatory measures) were transferred from the TS to documents referred to in the FSAR, such as a technical requirements manual (TRM). The specific FPP elements that remained in the TSs include the following: (a) Specifications associated with safe-shutdown equipment; and, (b) administrative controls ensuring that the NRC-approved FPP is established, implemented, and maintained in accordance with the current license basis (CLB). A review of FPPs implemented by several licensees revealed that relocating fire protection features from the TS to licensee-controlled documents did not significantly change their operability requirements and compensatory measures.

For common impairments, such as a blocked or damaged sprinkler head, the specific compensatory measure is specified in the NRC-approved FPP. The most common compensatory measure is a fire watch; which is a person trained to look for fire hazards, detect early signs of fire, and initiate alarms. For unique impairments not addressed by the FPP, the compensatory measure specified therein may not provide an appropriate level of protection. For example, sole reliance on a fire watch would typically not suffice if the impairment would adversely affect the ability to achieve and maintain safe shutdown conditions in the event of fire. In such cases, the licensee would be expected to implement an alternate measure as a replacement for, or enhancement to, the fire watch. Detailed guidance for implementing an alternate compensatory measure (i.e., measures not specified in the plant's FPP) is provided in Regulatory Information Summary (RIS) 2005-07: "Compensatory Measures To Satisfy The Fire Protection Program Requirements" [RIS 2005-07][2]. As discussed in RIS 2005-07, the evaluation should consider the impact of the proposed alternate compensatory measure to the FPP, and assess its adequacy compared to the FPP-required compensatory measure. In addition, the evaluation must demonstrate that the alternate measure would not compromise the ability to achieve and maintain safe shutdown during a fire.

Depending on the specific circumstances, appropriate alternate compensatory measures may be limited to enhancing the measures specified in the FPP, such as operator briefings, temporary procedures, and interim shutdown strategies; or they may be more comprehensive, such as procedures specifying actions to be taken by operators outside the control room in the event of fire, installing temporary fire-barrier penetration sealing materials, such as intumescent pillows and blocks, and using advanced fire protection technologies.

Compensatory measures are expected to be *temporary*. They are not intended to be in place for extended periods of time or used as a technique to avoid completing activities needed to

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[2] Changes to compensatory measures defined in the plant's TS necessitate a license amendment.

fully comply with regulatory requirements. The NRC staff expects that the corrective action(s) will be completed, and reliance on the compensatory measure eliminated, at the first available opportunity, typically the first refueling outage [RIS 2005-20]. Nevertheless, some NPPs were found to have relied on compensatory measures for extended periods (in some cases years). For the purposes of tracking long-term compensatory measures, the NRC's Office of Nuclear Regulatory Research (RES) and industry (Electric Power Research Institute[3]) agreed to define a *"long term compensatory measure"* as one that has been in place for longer than 18 months. Thus, unless properly justified, the functionality[4] of an impaired fire protection feature is expected to be restored no later than 18 months from the date of its discovery.

This report consolidates several NRC communications and technical documents about using compensatory measures to protect against fire at commercial NPPs. In addition to offering an historical overview of the current regulatory framework, the report illustrates how the adoption of methods different from those specified in a plant's approved fire protection program may afford an effective alternative in unique circumstances. This document is primarily intended as a knowledge base for the NRC's staff. However, NPP operators may also find it serves as a useful reference.

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[3] The Electric Power Research Institute (EPRI) is a nonprofit organization that undertakes research and development for the electric utility industry.

[4] To be considered functional, a fire protection system or component that is not controlled by the plant's TS, does not have to be "fully qualified" in terms of its design and licensing bases provided that the licensee can demonstrate its functionality. This definition does not apply to systems or components controlled by the plant's TS [IM 9900].

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ACRONYMS AND ABBREVIATIONS

AC	Alternating Current
ADAMS	Agencywide Documents Access and Management System
ALARA	As Low As is Reasonably Achievable
AOP	Abnormal Operating Procedure
APCSB	Auxiliary Power Conversion Systems Branch
ASD	Alternate Shutdown or Aspirating Smoke Detection, depending on usage.
BNL	Brookhaven National Laboratory
BTP	Branch Technical Position
BL	Bulletin
CCTV	Closed Circuit Television
CFR	Code of Federal Regulations
CLB	Current Licensing Basis
CM	Compensatory Measures
CO_2	Carbon Dioxide
DID	Defense-In-Depth
EA	Enforcement Action
EGM	Enforcement Guidance Memorandum
ELU	Emergency Lighting Unit
EPRI	Electric Power Research Institute
ERFBS	Electrical Raceway Fire Barrier Systems
FAQ	Frequently Asked Question
FHA	Fire Hazards Analysis
FPP	Fire Protection Program
FR	Federal Register
FSAR	Final Safety Analysis Report
GAO	Government Accountability Office
GDC	General Design Criteria
GL	Generic Letter
HGL	Hot Gas Layer
HVAC	Heating, Ventilation, and Air Conditioning
IEEE	Institute of Electrical and Electronics Engineers
IM	Inspector Manual
IN	Information Notice
IP	Inspection Procedure
LCIE	License Condition Impact Evaluation
LCO	Limiting Condition of Operation

LED	Light-emitting Diode
LER	Licensee Event Report
MCR	Main Control Room
MIC	Microbiological Induced Corrosion
MSO	Multiple Spurious Operations
NEI	Nuclear Energy Institute
NFPA	National Fire Protection Association
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation (at NRC)
NUMARC	Nuclear Management and Resources Council
OE	Office of Enforcement
OMA	Operator Manual Action
PRA	Probabilistic Risk Assessment
QA	Quality Assurance
RES	Office of Nuclear Regulatory Research (at NRC)
RG	Regulatory Guide
RIS	Regulatory Issue Summary
SCBA	Self-contained Breathing Apparatus
SDP	Significance Determination Process
SER	Safety Evaluation Report
SRG	Special Review Group
SRM	Staff Requirements Memorandum
SRP	Standard Review Plan
SSA	Safe Shutdown Analysis
SSD	Safe Shutdown
SSC	Structures, Systems, and Components
STS	Standard Technical Specifications
TIA	Task Interface Agreement
TS	Technical Specification
UFSAR	Updated Final Safety Analysis Report
VEGP	Vogtle Electric Generating Plant
VEWFD	Very Early Warning Fire Detection
VID	Video Image Detection

1. INTRODUCTION

1.1 Background

A fire that occurred at the Browns Ferry Nuclear Power Plant on March 22, 1975 led to significant changes in the regulatory framework for fire protection of commercial nuclear power plants (NPPs). As part of the Commissions immediate response to the fire, the NRC's Executive Director for Operations established a Special Review Group (SRG) to identify lessons learned and to make recommendations for improving the level of fire safety at commercial NPPs. In its report, NUREG-0050, "Recommendations Related to the Browns Ferry Fire: Report by Special Review Group" [NUREG-0050], the SRG noted that when fire protection features are disabled, temporary measures must be established for fire protection in areas covered by the disabled equipment. This recommendation was incorporated into current fire protection programs by requiring licensees to implement temporary actions, called *"interim compensatory measures,"* (or *"compensatory measures")* to offset the reduction in fire safety caused by the impaired[1] fire protection feature until corrective actions are completed. Examples of common impairments include damaged or degraded fire barriers, inoperable smoke detectors, fire protection components taken out-of-service to facilitate maintenance, and broken hardware on fire-rated doors.

Based on recommendations in the SRG's report, in 1976, the NRC issued Branch Technical Position Auxiliary and Power Conversion Systems Branch 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants," [BTP APCSB 9.5-1], describing acceptable methods for implementing General Design Criterion 3, "Fire Protection" of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants" (GDC 3)[2]. A key objective of the BTP APCSB 9.5-1 was for every NPP to establish a fire protection program (FPP) based on a *"defense-in-depth"* safety concept of employing, multiple, independent layers of protection to assure the health and safety of the public.

Integrating the defense-in-depth concept into fire protection resulted in the establishment of comprehensive FPPs at each plant that are designed to achieve an adequate balance among each of the following fire safety objectives:

1. Preventing fires from starting,
2. Quickly detecting, suppressing, and extinguishing fires that may occur and limiting their damage, and,
3. Designing the plant to minimize the effect of fires on essential safety functions so the ability to achieve and maintain safe shutdown conditions will be preserved.

[1] When a fire protection feature or system cannot perform its intended function, it is said to be "impaired" [RG1.189].

[2] BTP APCSB 9.5-1 did not apply to plants already docketed at the time it was issued. Guidance for operating plants was offered later in Appendix A to BTP APCSB 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants Docketed Prior to July 1, 1976," that, to the extent practicable, relies on BTP APCSB 9.5-1.

The BTP APCSB 9.5-1 specifies that normal and abnormal conditions or other anticipated operations such as modifications (e.g. breaking fire stops, impairment of fire detection and suppression systems) and refueling activities should be reviewed by appropriate levels of management and appropriate special action and procedures such as fire watches or temporary fire barriers implemented to assure adequate fire protection and reactor safety. It further specifies that corrective measures should be established to assure that conditions adverse to fire protection (e.g. failures, malfunctions, deficiencies, deviations, defective components, uncontrolled combustible material and non-conformances) are promptly identified, reported and corrected.

Examples of common compensatory measures found in the BTP APCSB 9.5-1 include the following:

- fire watches,
- enhanced controls over combustible materials, and/or ignition sources,
- temporary fire barriers and temporary hose connections,
- administrative procedures,
- staging temporary backup fire suppression equipment

Each licensee is required to evaluate the impact of degraded or nonconforming fire protection features on plant safety. Depending on the nature of the impairment, the licensee may take prompt corrective actions to fully restore operability or implement a compensatory measure to compensate for the impairment until the final corrective actions are completed. As discussed in Regulatory Guide 1.189, “Fire Protection for Nuclear Power Plants” [RG 1.189] and Regulatory Information Summary (RIS) 2005-07: “Compensatory Measures to Satisfy the Fire Protection Program Requirements” [RIS 2005-07], implementing only those measures specified in the approved FPP may not be sufficient to mitigate fire risk in all circumstances. For example, sole reliance on a fire watch may not provide an appropriate level of compensation for impairments that could adversely affect the ability to achieve and maintain safe shutdown conditions in the event of fire. In such cases, a licensee would be expected to implement an alternate measure, or combination of measures to provide an appropriate level of compensation. Depending on the specific circumstances, such alternate compensatory measures may be limited to enhancing the compensatory measures specified in the FPP, such as additional administrative controls, operator briefings, temporary procedures, and interim shutdown strategies; alternatively, they may be more comprehensive, such as procedures specifying actions to be taken by operators outside the control room in during a fire, installing temporary fire-barrier-penetration sealing materials, such as intumescent pillows and blocks or using advanced fire protection technologies, or both. A licensee may implement alternate compensatory measures without the NRC’s prior approval provided they are evaluated in accordance with the discussion provided in the RIS 2005-07. However, changes to compensatory measures defined in the plant’s TS require NRC approval.

The NRC staff has issued several letters to all licensees to address issues that may impact multiple plants, called generic communications, regarding the implementation of compensatory measures. For example, in 1997, Information Notice (IN) 97-48 was issued to alert licensees of inappropriate compensatory measures employed at several facilities. In Regulatory Issue Summary (RIS) 2005-07, the staff described how licensees may use alternate approaches when the measures specified in the approved FPP do not assure an appropriate level of safety for the specific circumstances. Both documents (IN 97-48 and RIS 2005-07) cite cases where the compensatory measures specified in approved FPPs may not be appropriate when unique circumstances are encountered, such as fire protection impairments[3] that may affect the plant's ability to achieve and maintain safe shutdown conditions in the event of a serious fire.

In 2008, the Commission directed the staff to formulate a closure plan for stabilizing the fire protection regulatory infrastructure [SRM-M080171]. In response, the staff identified eight specific tasks for improving the regulatory stability of fire protection [SECY 08-0171]. In a July 2009 Memo [NRC 2009], the Chief of the Fire Protection Branch of NRR identified Task 7 to consolidate regulatory documentation on compensatory measures, and to identify new technologies that potentially could be used in lieu of, or as a supplement to, traditional measures specified in approved FPPs.

To address this issue, the NRC Office of Nuclear Regulatory Research (RES) contracted Brookhaven National Laboratory to assist them in preparing a NUREG-series report that (a) provides a comprehensive reference of regulatory and technical information about compensatory measures for impaired fire protection elements; (b) describes the types of compensatory measures typically included in approved fire protection programs; and, (c) identifies new technologies that may offer a viable alternative to those delineated in the approved programs.

1.2 Objective

The objective of this report primarily is to serve as a reference on the history and use of fire protection compensatory measures. It consolidates the information from several of the NRC's generic communications and technical documents about fire protection compensatory measures at commercial NPPs.

1.3 Purpose and Scope

BNL was requested to assist the NRC staff in developing a NUREG series report which addresses the following:

- Provides an historical background of compensatory measures for fire protection;
- describes the fire protection regulatory framework on compensatory measures, including the relationship between compensatory measures and defense-in-depth;
- consolidates and clarifies existing NRC staff positions, interpretations, and guidance on compensatory measures;
- details the types of compensatory measures typically included in the fire protection programs approved by the staff;

[3] As used in this document, phrases such as *"fire protection impairment," "fire protection element"* or *"fire protection feature"* are intended to include any component or feature identified in NRC approved fire protection program documents (e.g., FSAR, FHA, SSA, and TRM). Thus, the phrases include impairments to both classic fire protection features (e.g., sprinkler systems, hose stations) and features provided to ensure post-fire safe shutdown capability (e.g., electrical raceway fire barrier systems, alternate shutdown panel).

- identifies alternate approaches, such as new fire protection technologies that may be used in lieu of, or as a supplement to, the originally approved compensatory measures; and,
- offer an illustrative example of how the use of new technologies may provide a more appropriate level of compensation than the measures specified in the approved FPP when unique conditions exist.

RES envisioned that this NUREG report would be used by the agency's staff (i.e., inspectors and reviewers), who evaluate the acceptability of alternative compensatory measures after impaired conditions are identified in fire protection features at nuclear power plants. The report would also serve a Knowledge Management role for those wishing to understand the history and implementation of fire protection compensatory measures. Therefore, the report's overall objective is to serve as a consolidated source of regulatory and technical information for the NRC's staff responsible for assessing the appropriateness of fire-safety compensatory measures at commercial NPPs.

As discussed below, the NRC's licensing basis for fire protection is site specific. This document consolidates information from many sources, including regulatory requirements. However, since all the NRC's fire protection regulations are not applicable to all plants, the information contained within this document should not be characterized as requirements for any individual plant. It is the responsibility of the reader to verify the language of applicable regulations and the NRR's positions.

This report provides examples of compensatory measures for hypothetical impairments. The examples discuss the criteria and guidance upon which the approved fire protection program is based, and, to the extent practical, describes unique aspects of compensatory measures, such as the potential for implementing advanced technologies as an alternative to the "traditional" compensatory measures typically specified in approved fire protection programs.

2. HISTORICAL OVERVIEW AND REGULATORY FRAMEWORK

2.1 Historical Overview of Fire Protection Regulations

During the initial development of the U.S. nuclear reactor program in the early 1970s, fire protection requirements for commercial nuclear power plants were limited to the broad performance objectives of Appendix A to 10 CFR Part 50, *"General Design Criteria for Nuclear Power Plants."* Specifically, General Design Criteria 3, (GDC 3) states the following:

> *"…structures, systems, and components important to safety be designed and located to minimize the probability, and adverse effects of fires and explosions, that noncombustible and heat- resistant material be used wherever practical, and that fire detection and suppression systems be provided to minimize the effect of fire on structures, systems, and components important to safety."*

Because of a lack of implementation guidance, the level of fire protection adopted by a facility generally was found to be acceptable if it complied with local and industrial fire codes as evidenced by an acceptable rating from its fire-insurance underwriter. Consequently, the fire protection features of commercial NPPs at that time were very similar to those of conventional, fossil-fueled, generating stations.

A major fire at the Browns Ferry Nuclear Power Plant on March 22, 1975, underscored the need for more detailed criteria and guidance for satisfying GDC 3 [NUREG-0298]. The revised regulatory framework which followed was largely based on recommendations made by a "Special Review Group" (SRG) appointed by the NRC's Executive Director for Operations to identify lessons-learned and make recommendations for improving fire safety. The SRG's main objectives were to (a) review the circumstances, origins, and consequence of the fire; and, (b) propose improvements in NRC's policies, procedures and technical requirements [NUREG-0050].

In its report [NUREG-0050], the SRG recognized the importance of providing *temporary enhancements* when fire protection features are disabled or taken out-of-service. Specifically, in discussing disabling fire protection systems for maintenance, the SRG states: "*Temporary measures" must be established for fire protection in areas covered by the disabled equipment*." This recommendation is reflected in current fire protection programs which require licensees to implement temporary actions, called *"compensatory measures"* [RG 1.189] to offset the reduction in fire safety caused by the impaired systems and features until corrective actions are completed, and the impaired component or system can perform its design functions, as specified in the plant's current license basis (i.e., its functionality[1] is restored).

Based on the SRG's recommendations, the NRC staff developed comprehensive guidelines for satisfying GDC 3; they are documented in the following Branch Technical Positions (BTPs):

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[1] To be considered functional, a non-TS system or component does not have to be "fully qualified" in terms of its design and licensing bases provided that the licensee can demonstrate functionality. This definition does not apply to systems or components controlled by the plant's Technical Specifications. [IM 9900]

1. BTP Auxiliary Power Conversion Systems Branch (APCSB) 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants." BTP 9.5-1 was issued in May 1976 but was applicable only to plants that filed an application for construction after July 1, 1979,and,

2. Appendix A to BTP APCSB 9.5-1. Frequently identified as *"Appendix A to the BTP,"* these guidelines were issued in September 1976 for operating NPPs to offer acceptable alternatives in areas where strictly complying with BTP 9-5-1 would require significant modifications.

At the time these documents were issued, there was a wide variation in the operating status of commercial NPPs. Some plants had been operating for some time, while others were in the early stages of design or construction. Many newer plants were able to incorporate physical separation of safety systems into their designs. However, older plants, like Browns Ferry, had significantly less inherent physical separation. Hence, two documents (BTP 9.5-1 and Appendix A to BTP 9.5-1) were promulgated to offer a balanced approach in applying the SRG recommendations. Licensees then were requested to evaluate their fire protection program against the appropriate guidelines.

Towards the end of 1970's, the NRC found that several fire protection issues remained unresolved, and certain licensees refused to adopt some of the recommendations in the new guidance. Even though only a few plants might contest a given issue, the Commission concluded that rulemaking was the appropriate vehicle for implementing its fire protection policy. Accordingly, in 1980, five years after the Browns Ferry fire, the Commission proposed a new fire protection rule to resolve the contested issues. In a letter dated November 24, 1980 [GL 80-100], the Commission informed all power-reactor licensees with plants licensed before January 1, 1979, of these new regulations in 10 CFR 50.48 ,"Fire Protection," and Appendix R to 10 CFR 50 "Fire Protection Program for Nuclear Power Plants Operating Prior to January 1, 1979". Plants licensed to operate after this date were required to satisfy similar criteria specified in provisions of their operating license.

Because it was not deemed possible at that time (1980) to accurately predict the manner in which a fire would start and propagate, the new fire protection requirements employed a "deterministic" approach that considers a set of challenges to fire safety and then determines how they should be mitigated. The key assumptions of this approach are:

- An exposure fire[2] occurs in any single fire area; and,
- Structures, Systems, and Components (SSCs) not conforming to the specified protection criteria cannot perform their intended function.

One example of a deterministic criterion is the requirement that electrical raceway fire barrier systems (ERFBS), relied upon to protect post-fire safe shutdown-related cables, have a fire rating of either 1- or 3-hours, depending on the availability of other fire protection features [RG 1.189].

General Design Criterion 3 (GDC 3), *Fire Protection*, of Appendix A to 10 CFR Part 50 establishes the fundamental performance objectives for fire protection programs at NPPs. In response to the fire at the Browns Ferry NPP, the NRC codified criteria for satisfying GDC 3 in Title 10 of the *Code of Federal Regulations,* Part 50, Section 48, "Fire Protection" (10 CFR

[2] An *exposure fire* is a fire that involves either in situ or transient combustibles in a given fire area, and is external to any structures, systems, or components located in or adjacent to that same area.

50.48). Paragraph (a) of this document (50.48(a)) requires, in part, that each operating nuclear-power plant have a fire protection plan that describes the overall fire protection program, and specific features necessary to implement the program. In July 2004, the NRC amended 10 CFR Part 50.48 by adding a new subsection, 10 CFR 50.48(c) to allow licensees to voluntarily adopt a risk-informed approach described in the 2001 Edition of National Fire Protection Association (NFPA) Standard 805[3], *"Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants."* Regardless of the approach chosen, all plants must develop and maintain a fire protection program (FPP) that assures, through a defense-in-depth design, that the following fire protection objectives are satisfied:

1. Minimize the potential for fires and explosions to occur;
2. Rapidly detect, control, and extinguish fires that do occur; and,
3. Provide protection for structures, systems and components (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 [NUREG 0800].

The specific features (i.e., personnel, structures, systems, components, analyses, procedures and policies) which collectively form the FPP are described in licensee controlled documents, such as:

- Fire Hazards Analysis (FHA)
- Safe Shutdown Analysis (SSA)
- Plant operating procedures
- Surveillance, maintenance and test procedures
- Fire brigade response procedures and pre-fire plans

The set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with, and operation within, applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect is called the Current Licensing Basis (CLB). As defined in 10 CFR 54.3, the CLB includes the regulations in 10 CFR Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 54, 55, 70, 72, 73, 100, and the appendices thereto; viz., orders; license conditions; exemptions; and technical specifications. It also encompasses the plant-specific design-basis information defined in 10 CFR 50.2 as documented in the most recent final safety analysis report (FSAR) as required by 10 CFR 50.71, and the licensee's commitments remaining in effect that were made in docketed licensing correspondence, such as the licensee's responses to NRC bulletins, generic letters, and enforcement actions, as well as the licensee's commitments documented in NRC safety evaluations or licensee-event reports.

The following sections give a historical overview of the requirements and guidance documents that form the regulatory framework for fire safety compensatory measures.

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[3] Due to the ongoing NRR NFPA 805 Frequently Asked Question Program, the NFPA 805 is discussed here only for historical purposes. Discussions on compensatory measures do not apply to NFPA 805 unless stated otherwise.

2.2 Historical Overview of Fire Protection Technical Specifications

One of the first actions the Commission took in response to the Browns Ferry fire was to impose TSs for fire protection systems. During 1976 to1977, each operating plant was given a sample of the recommended standard TS for fire protection and was requested to do the following:

a) Compare the TS for existing fire protection systems against that sample; and,

b) Provide a proposed fire protection TS for the NRC staff's review.

Technical Specifications (TS) define the limits and conditions necessary to assure that the plant is operated in a manner consistent with the analyses and evaluations in the plant's Safety Analysis Report [10 CFR 50.36]. Specifically, the TS established the following conditions:

- LCOs that constitute the lowest functional capability or performance levels of equipment required to safely operate the facility; and,
- Surveillances (e.g., tests or measurements) needed to confirm the operability of structures, systems, and components (SSCs) identified in the TS.

The incorporation of fire protection systems, including impairments and their associated compensatory measures into the TS, was deemed necessary to assure the following:

- Prompt compensatory measures would be taken,
- Suitable temporary-protection features would be provided, and,
- Appropriate organizations are notified to counter the effects of out-of-service systems/equipment.

FP systems, and features typically included in the scope of the TS include the following:

- Fire Protection Water Supply System
- Fire Detection Systems
- Sprinkler / Spray Systems
- Fire Hose Stations
- Halon Systems
- CO_2 Systems
- Clean-agent Systems
- Fire Barriers and Penetration Seals
- Fire Brigade Staffing
- Rated fire barriers and their components (For example, fire doors, and fire dampers)

This list subsequently was expanded by Generic Letter 81-12 "Fire Protection Rule (45 FR 76602, November 19, 1980) – Generic Letter 81-12" to cover TS for safe- shutdown equipment that was not already included in the plant's existing TSs.

On October 26, 1984, a fire protection policy steering committee (SC) recommended bringing together the existing guidance in one generic letter, and improving the consistency of information given in the Standard Review Plan, TS, and operating licenses [NRC1984]. Specifically, the SC recommended that the staff:

1. Develop and implement a standard fire protection license condition requiring compliance with the provisions of the Fire Protection Program, as described in the FSAR.
2. Revise the Standard Review Plan (SRP) to assure that Appendix R is fully covered.
3. Modify the Standard Technical Specifications (STS) in a manner that assures functioning of the fire protection features but requires only those that are commensurate with other TS items in terms of their importance to safety.

Subsequently, via GL 86-10 "Implementation of Fire Protection Requirements", the Commission recommended that licensees apply for an amendment to their operating licenses to remove fire protection TS that where unnecessarily in their TS. Specific information for preparing a request to amend the license to implement Generic Letter 86-10 was given on August 2, 1988 in Generic Letter 88-12, "Removal of Fire Protection Requirements from Technical Specifications." As discussed in GL 88-12, such an amendment does the following: (1) Institutes the standard license condition for a Fire Protection Program; (2) removes the requirements for fire protection systems from the TS; (3) removes fire-brigade staffing requirements from the TS; and, (4) adds administrative controls to the TS that are consistent with those for other programs implemented by the license condition. GL 88-12 further specified augmenting the Administrative Controls section of the TS to support the Fire Protection Program by adding two specifications:

1. The Unit Review Group (Onsite Review Group) shall be given responsibility for reviewing the Fire Protection Program and implementing procedures, and for submitting recommended changes to the Company Nuclear Review and Audit Group (Offsite or Corporate Review Group).
2. The implementation of the Fire Protection Program implementation shall be added to the list of elements for which written procedures shall be established, implemented, and maintained.

Under the guidelines of GL 86-10 and 88-12, the requirements for fire protection operability and their associated compensatory measures were moved from the TS to documents referred in the FSAR (e.g., administrative procedures and / or technical requirements manual). Consequently, the operability requirements of most fire protection features that formerly were included in the plant's TS are currently governed by licensee-controlled procedures referenced in the NRC-approved fire protection program. FPP elements that remain in the scope of TSs typically include; (a) specifications associated with safe-shutdown equipment; and, (b) administrative controls that ensure that the NRC-approved FPP is appropriately established, implemented, and maintained in accordance with the current license basis (CLB).

In 1999, the Commission determined that the requirement to have the onsite review group (or a similar committee) review all changes to the fire protection program could place an unnecessary burden on licensees. Under the information provided in Regulatory Issue Summary (RIS) 99-002 "Relaxation of the Technical Specification Requirements for PORC Review of Fire Protection Program Changes," licensees were permitted to request a license amendment to remove the TS requirement provided it was demonstrated that adequate controls are in place to ensure that the effectiveness of the fire protection program would be maintained.

A review of a sample of approved FPPs indicates that the relocation of fire protection features from the TS to documents/procedures referenced in the CLB, did not have significant impact on either the operability requirements or their associated compensatory measures. Appendix A of this report summarizes the findings from this review.

2.3 Fire Protection Program

An NRC approved Fire Protection Program includes the fire protection and post-fire safe-shutdown systems necessary to satisfy the NRC's guidelines and requirements; administrative- and technical-controls; the fire-brigade and fire protection-related technical staff; and other related plant features described by the licensee in the FSAR. It also encompasses the fire hazards analysis, responses to NRC's staff requests for additional information, comparisons of plant designs to the NRC's applicable fire protection guidelines and requirements, and descriptions of the methodology for assuring safe plant shutdown following a fire [GL 88-12].

2.3.1 Design Features

Implementing the defense-in-depth safety concept required each NPP to employ a wide array of systems and equipment that are directed at the following: (a) Detecting, containing, and rapidly suppressing fires that may occur (despite fire-prevention efforts), and, (b) preventing fire from damaging SSCs important to safety. Common examples include:

- Structural fire barriers (e.g., fire-rated doors, fire-rated HVAC dampers, fire walls, and cable penetrations)
- Electrical raceway fire barrier systems (ERFBS)
- Fire detection and alarm systems
  - Conventional ionization and photoelectric smoke detectors
  - Heat detectors
- Fire suppression systems and equipment, including the following:
  - Fire-water supply systems
  - Deluge water-spray systems
  - Wet-pipe sprinkler systems
  - Pre-action sprinkler systems
  - Dry-pipe sprinkler systems
  - Carbon-dioxide systems
  - Halon-1301 systems
  - Clean-agent systems
  - Dry-chemical suppression systems
  - Foam suppression systems
  - Manual firefighting equipment
- Post-fire safe shutdown capability, including:
  - SSCs required to perform essential shutdown functions (e.g., reactivity control, reactor-coolant makeup, reactor pressure control, and decay heat removal)

- Alternate Shutdown Panels
- Emergency lighting and communications

Various Professional Organizations such as Institute of Electrical and Electronics Engineers (IEEE), National Fire Protection Association (NFPA), American Society for Testing and Materials (ASTM), and Underwriters Laboratories (UL) have codes and standards that provide information on fire protection systems used at NPPs as compensatory measures. Some of these codes and standards include:

- IEEE Standard 634 -1978 "Standard Cable Penetration Fire Stop Qualification Test"
- NFPA 13 - "Standard for the Installation of Sprinkler Systems", NFPA 14 - "Standard for the Installation of Standpipe and Hose Systems", NFPA 72 - "National Fire Alarm and Signaling Code", NFPA 51 - "Standard for the Design and Installation of Oxygen-Fuel Gas Systems for Welding, Cutting, and Allied Processes", NFPA 251 - "Standard Methods of Test of Fire Endurance of Building Construction and Materials", and NFPA 600 - "Standard on Industrial Fire Brigades"
- ASTM E119-1976 "Fire Test of Building Construction and Materials"
- UL 521, "UL Standard for Safety Heat Detectors for Fire Protective Signaling System", UL 217, "UL Standard for Safety Single and Multiple Station Smoke Alarms", UL 268, "UL Standard for Safety Smoke Detectors for Fire Alarm Systems", UL 268A, "UL Standard for Safety Smoke Detectors for Duct Application", UL 555, "UL Standard for Fire Safety Dampers".

2.3.2 Administrative Controls

In addition to plant design features, the defense-in-depth approach requires the establishment of appropriate administrative controls to ensure that the integrity of the FPP and related equipment is maintained over the plant's lifespan. The Administrative Controls section of the plant's TS typically requires the FPP to be established, implemented, and maintained in accordance with written procedures and administrative policies. For compensatory measures, procedures should be established to identify and control impairments to fire protection systems, and to ensure that appropriate remedial actions are taken. Some additional examples of administratively controlled elements of the FPP include the following:

- The fire protection organization, including staffing requirements and responsibilities.
- Review and control of transient combustibles.
- Review and control of ignition sources.
- Review and control of modifications to ensure that in situ fire-loadings are not increased beyond those accounted for in the fire-hazards analysis, or, if increased, that suitable protection is provided and the analysis is revised accordingly.
- Review and control of temporary modifications and maintenance activities, such as the installation and use of temporary electrical power services.
- Periodic testing and inspection of fire protection features.

Specific guidance on administrative controls for fire protection is provided in section 2 of RG 1.189.

2.3.3 Quality Assurance

The quality assurance (QA) program ensures that inspections, surveillances, and tests that govern the FPP are prescribed by documented instructions, procedures, and drawings. This program also ensures that testing is performed to demonstrate conformance with the design and system readiness requirements. Thus, the QA program assures that fire protection systems and features are designed, fabricated, erected, tested, maintained, and operated so that they function as intended.

Since fire protection systems are not safety-related they are generally not included within the scope of 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” unless the licensee has committed to include them under the plant’s Appendix B program. Licensees that have not done so must provide a description of the fire protection QA program and the measures for implementing it for the NRC’s review. For plants licensed after January 1, 1979, this review is conducted in accordance with the guidance in Regulatory Guide 1.189, “Fire Protection For Nuclear Power Plants,” Revision 2. The QA program for fire protection at plants licensed before January 1, 1979, is reviewed against similar guidance in Appendix A to APCSB 9.5-1 and Generic Letter 77-02, “Nuclear Plant Fire Protection Functional Responsibilities, Administrative Controls and Quality Assurance”.

Examples of features of the fire protection QA program related to compensatory measures include the following:

- Procedures which control plant activities affecting fire protection equipment important to safety.
- Reporting, tracking, and ensuring the restoration of fire protection equipment or features that have become inoperable.
- Ensuring that inspections and tests of fire protection equipment and features are undertaken in accordance with documented instructions, procedures, and drawings.
- Periodic inspections of materials subject to degradation, such as fire barriers, stops, seals, and fire retardant-coatings to ensure these items have not deteriorated or been damaged.

2.4 Guidance Documents Related to Fire Protection and Fire-Safety Compensatory Measures

Specific information related to the use of compensatory measures is contained in the following documents:

1. Appendix A to BTP APCSB 9.5-1, "Guidelines for Fire Protection for Nuclear Power Plants Docketed Prior to July 1, 1976;

   This specifies that licensees should establish administrative controls for the impairment of fire-detection and suppression systems and special actions and procedures, such as fire watches or temporary fire barriers put in place to ensure adequate fire protection and reactor safety.

2. Generic Letter 81-12, “Fire Protection Rule,” February 20, 1981;

Requested licensees to develop TS surveillance requirements and limiting conditions for operation (LCO) for safe shutdown equipment that was not addressed in the plant's existing TS.

3. Generic Letter 86-10, "Implementation of Fire Protection Requirements", April 24, 1986;

   Recommends that each licensee place its fire protection program and major commitments into its FSAR and, encourages licensees to take the following actions:

   - Replace current license conditions on fire protection and adopt the *Standard Fire Protection License Condition* detailed in the GL.
   - Add administrative controls to TS consistent with those for other programs implemented by the license condition.
   - Remove most fire protection requirements from the TS.

   The GL also clarifies that temporary changes to specific fire protection features which may be necessary to accomplish maintenance or modifications are acceptable, provided that appropriate interim compensatory measures are implemented.

4. Generic Letter 88-12, "Removal of Fire Protection Requirements from Technical Specifications," August 2, 1988.

   The GL contains supplemental guidance for licensees preparing a license amendment request that conforms to GL 86-10. It identifies four major areas where the fire protection requirements should be relocated from the TS to those documents approved in the Fire Protection Program (e.g., UFSAR, FHA, and Technical Requirements Manual)[4],, and clarifies that the technical specifications associated with safe shutdown (SSD) equipment, and the administrative controls related to fire protection audits were to be retained. As described in the GL, a conforming amendment would remove the fire protection requirements from the TS in four major areas:

   1. Fire detection systems,
   2. Fire suppression systems,
   3. Fire barriers, and,
   4. Fire brigade staffing requirements.

5. Generic Letter 91-18. Revision 1, "Information to Licensees Regarding NRC Inspection Manual Section On Resolution of Degraded and Nonconforming Conditions," October 8, 1997.

   This Letter addresses licensee's resolutions of degraded- and nonconforming-conditions for plants that are at power, and for those that will resume operations from any shutdown. Attachment 1, Inspection Manual, Part 9900 (IM 9900) Technical Guidance, "Resolution of Degraded and Nonconforming Conditions," identifies compensatory measures as an item to be considered in the licensee's assessments of reasonable assurance of safety for SSCs that are not expressly subject to TSs. In addition,

[4] Current Standard Technical Specifications that resulted from the Final Policy Statement on Technical Specifications Improvement for Nuclear Power Reactors (58 FR 39132) do not include fire protection equipment related to safe shutdown.

IM Part 9900 gave guidance for evaluating compensatory measures as an interim step until final corrective actions were completed.

Note: As indicated in item 9 below, GL 91-18 was replaced by RIS 2005-20 and a September 26, 2005 revision to NRC IM Part 9900, " Technical Guidance: Operability Determinations and Functionality Assessments for Resolution of Degraded and Nonconforming Conditions Adverse to Quality or Safety."

6. Information Notice 97-48, “Inadequate or Inappropriate Interim Fire Protection Compensatory Measures,” July 9, 1997.

   This Notice was issued to alert licensees to potential problems associated with implementing interim compensatory measures for degraded- or inoperable- fire protection features or conditions associated with post-fire safe shutdown capability.

7. Response to Region IV Task Interface Agreement (TIA) [NRC 1998b] - Evaluation of Definition of Continuous Fire Watch, August 17, 1998.

   This Memorandum, documents the staff’s evaluation of a fire protection inspection issue concerning the definition of a continuous fire watch. Specifically, the licensee’s FPP defined a continuous fire watch as a fire watch that patrolled the fire area(s) of concern at least once every 15 minutes. Based on its evaluation, the NRC staff disagreed, and concluded that a continuous fire watch is to remain in the affected fire area at all times.

   The TIA also notes that in addition to a fire watch, enhanced compensatory measures may be warranted to fully address potential safety-issues presented by the nonconformance. Specific examples cited in the staff evaluation include enhancing controls over combustible materials and hot work, briefing operators and members of the fire brigade on a nonconformance condition, implementing temporary operating-procedures, pre-staging manual firefighting equipment, and installing temporary fire protection features.

8. NRC Regulatory Issue Summary (RIS) 2005-07 – “Compensatory Measures to Satisfy the Fire Protection Program Requirements,” April 19, 2005.

   This document informs addressees that, under certain circumstances, measures other than those delineated in the approved fire protection program may be used to compensate for degraded- or inoperable-fire protection features. In addition, it gives specific guidance on how a licensee, with the GL 86-10 standard license condition for fire protection, may change the approved FPP to employ such alternate measures.

9. NRC Inspection Manual Part 9900, "Technical Guidance: Operability Determinations and Functionality Assessments for Resolution of Degraded and Nonconforming Conditions Adverse to Quality or Safety" September 26, 2005.

   This guidance was developed to assist NRC inspectors in reviewing licensee determinations of operability and their resolution of degraded- or nonconforming-conditions. IM Part 9900 covers fire protection systems, structures, and components (SSCs) within the scope of the guidance for reviewing licensee actions for such conditions. This version of the manual supersedes the guidance set out in Revision 1 of GL 91-18, “Information to Licensees Regarding Two NRC Inspection Manual Sections on Resolution of Degraded and Nonconforming Conditions and on Operability," dated October 8, 1997.

10. RIS 2006-10, "Regulatory Expectations with Appendix R Paragraph III.G.2 Operator Manual Actions," June 30, 2006:

    RIS 2006-10 discusses the use of operator manual actions as a means of satisfying Section III.G of Appendix R to 10 CFR 50. Specifically, the RIS notes that some licensees relied on operator manual actions to compensate for degraded or missing fire barriers in lieu of providing one of the protective features specified in paragraph III.G.2 or requesting an exemption under 10 CFR Part 50.12, "Specific Exemptions."[5] Compensatory measures for missing or degraded fire barriers are discussed in section 2.5 of the RIS, "Compensatory Measures and Corrective Actions," which states that for missing or degraded fire barriers, the following should occur:

    - compensatory measures should be implemented, as required, in accordance with the licensees' approved fire protection program,
    - missing or degraded fire barriers should be reported in accordance with the requirements of 10 CFR 50.72(b) (3) (ii) and 50.73(a) (2) (ii), and the guidance in NUREG-1022, "Event Reporting Guidelines 10 CFR 50.72 and 10 CFR 50.73", and,
    - missing or degraded fire barriers should be documented in accordance with their corrective action program including a detailed description of the affected structures, systems, or components (e.g., circuits)
    - Corrective actions should be completed in accord with the guidance in RIS 2005-20, "Revision to Guidance Formerly Contained in NRC Generic Letter 91-18, Information to Licensees Regarding Two NRC Inspection Manual Sections on Resolution of Degraded and Nonconforming Conditions and on Operability."

11. Regulatory Guide 1.189, "Fire Protection For Nuclear Power Plants," Revision 2, October 2009

    This Regulatory Guide contains comprehensive guidance on fire protection and gives specific criteria for defining an acceptable FPP at NPPs. Section 1.5 of the Regulatory Guide details the regulatory position on compensatory measures for degraded and nonconforming conditions.

12. NFPA 805 "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants" 2001

    Compensatory measures are termed "*compensatory actions"* and are defined as:

    > *"Actions taken if an impairment to a required system, feature, or component prevents that system, feature, or component from performing its intended*

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[5] Plants licensed to operate on or after January 1, 1979 (post-1979 licensees), are not required to meet the requirements of paragraph III.G.2. Therefore, for this group of plants, a staff decision in an SER that approves the use of manual operator actions does not require exemption under 10 CFR 50.12. However, Post-1979 licensees may be requested to demonstrate, as part of the NRC Reactor Oversight Process, that the use of an operator manual action would not adversely affect the ability to achieve and maintain safe shutdown in the event of a fire, consistent with their license.

> *function. These actions are a temporary alternative means of providing reasonable assurance that the necessary function will be compensated for during the impairment, or an act to mitigate the consequence of a fire. Compensatory measures include but are not limited to actions such as fire watches, administrative controls, temporary systems, and features of components."*

NFPA 805 requires the development of procedures for compensatory actions to be implemented when fire protection systems and other systems credited by the fire protection program and this standard cannot perform their intended function and limit the duration of impairment. In addition, NFPA 805 specifies that compensatory actions should be appropriate with the level of risk created by the unavailable equipment, and that plant procedures should ensure that compensatory actions are not a substitute for promptly restoring the impaired system.

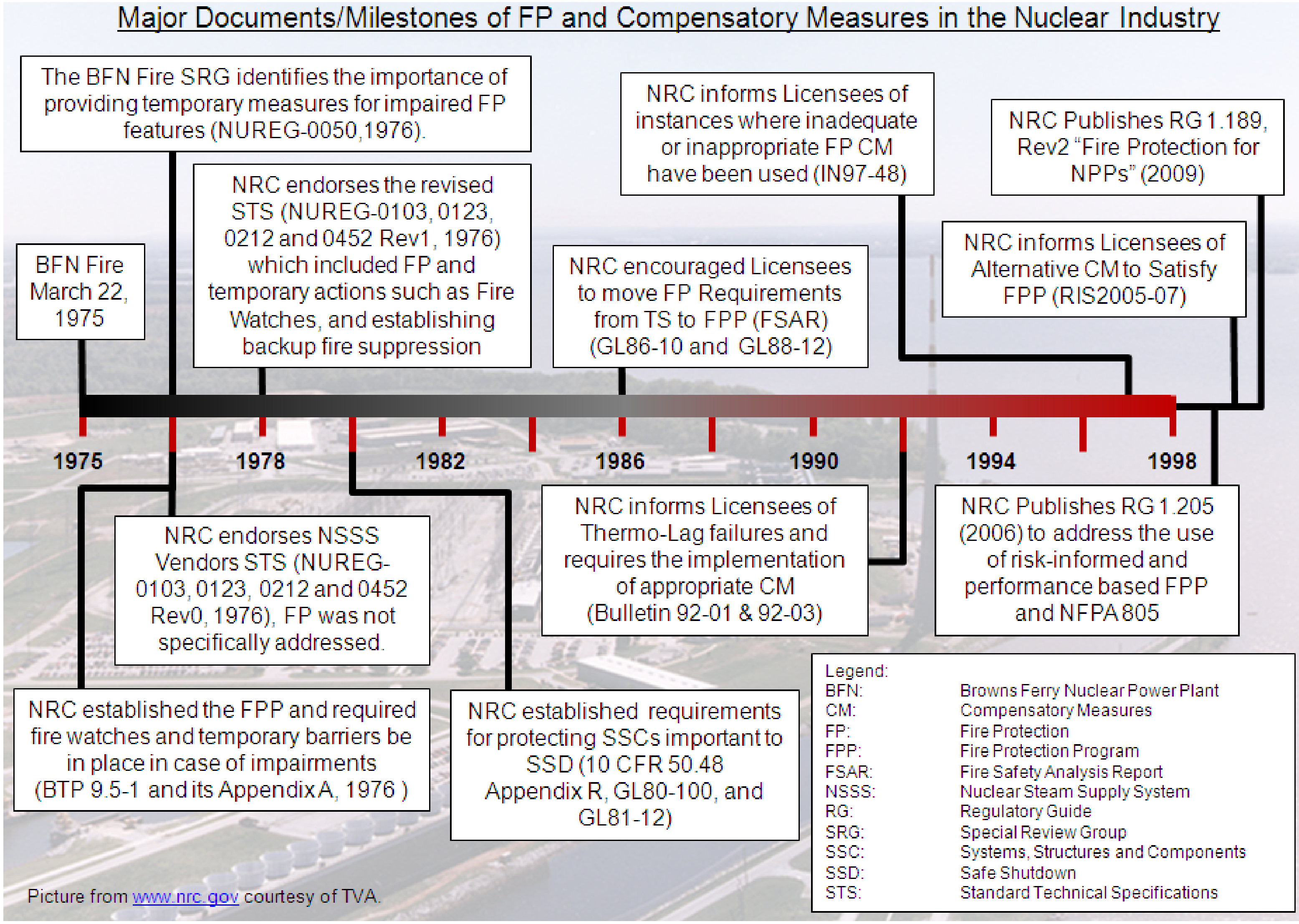

Figure 2-1: Major Documents and Milestones of FP and Compensatory Measures in the Nuclear Industry

3. IMPAIRMENTS AND COMPENSATORY MEASURES

3.1 Fire Protection Impairments

As previously discussed, the fire protection program includes several individual elements (e.g., plant design features, administrative controls, trained personnel, and engineering analyses) that collectively provide defense-in-depth protection of public health and safety. When one element of the FPP cannot perform its intended function, the overall level of defense-in-depth is reduced, thereby causing the potential for loss from fire to increase.

Although FPP features are well designed and highly reliable, the functional performance of certain features may degrade over the plant's lifetime (i.e., become impaired) due to various operational and environmental stressors, such as corrosion and aging. Therefore, when a feature that supports fire prevention, detection and suppression, or the ability to safely shutdown is unable to perform its intended function, it would be considered degraded.

Table 3-1: Examples of Common Fire Protection Impairments

Fire Suppression Water Supply Systems
Inoperable fire pump
Volume of water supply is less than system's requirements.
Inadequate Flow Path (e.g., inoperable valve or pipe necessary to supply fixed suppression systems or hose-station hydrants, automatic valves in the flow path do not actuate to their correct positions on a simulated actuation signal).
Degraded/blocked piping network (e.g. microbiological induced corrosion (MIC), Asiatic clams, etc.)
Sprinkler, Spray, and Deluge Systems
Inoperable or degraded / impaired sprinkler heads.
Inoperable fire-detection actuation system (If fire detection that automatically initiates a fire suppression system is inoperable, the system also is considered to be inoperable).
SSCs that that interfere with the ability of fire suppression systems to perform their intended function (e.g., scaffolds, work platforms, and temporary equipment).
Gaseous Fire-Suppression Systems (CO_2 Halon, and Clean agent)
Unsealed opening in a suppression-system's containment boundary (e.g., fire barrier wall).
Underweight or under-pressure halon cylinder / banks.
Area-ventilation dampers fail to close upon receipt of a simulated actuation signal.
System isolation to support maintenance work.
Fire Hose Stations
One or more of the fire hose-stations inoperable.
SSCs that impede access to a fire hose station, such as scaffolds, work platforms and temporary equipment.
Degraded or missing gaskets in fire-hose couplings.
Failed hose-hydrostatic test.

Table 3-1: Examples of common Fire Protection Impairments (Continued)

Yard Fire Hydrants and Hydrant Hose Houses
One or more of the yard fire hydrants or associated hydrant hose-houses that are the primary means of fire suppression are inoperable.
Fire-rated Assemblies (Electrical Raceway Fire-Barrier Systems, Structural Fire-Barriers and Penetration Seals)
One or more of the barriers are non-functional/missing.
A breach of a fire-rated assembly/barrier that forms the compartmentalization boundary (e.g., fire areas, fire zones).
A breach of a fire-rated assembly/barrier that provides fire proofing for the structural steel supporting the fire barriers.
As-installed fire-barrier penetration seal differs from the as-designed condition (e.g., unsealed penetrations, gaps greater than acceptance criteria).
Fire Detection
The number of operable fire detection instruments is less than the minimum required.
Missing, damaged, severely obstructed or not calibrated detector.
Safe (III.G.2) and Alternative (III.L) Shutdown
A required component is inoperable or has been removed from service
A required support system (e.g., electrical power sources, remote control-circuits, room cooling) is impaired or inoperable.
One or more designated Emergency Lighting Units (ELU) impaired (e.g., lamps fail to illuminate on loss of ac power, ELU not in correct position to illuminate intended target(s)).
Fire Doors
Door's hardware loose or damaged (e.g., loose hinges, missing /damaged door handle, door latch stuck in retracted position).
Door or frame structurally damaged or excessive gaps.
Fire-door propped / blocked open to allow maintenance work or prevented from fully closing by equipment (e.g., by running a temporary cable under the door to facilitate maintenance).
Fire Dampers
Damper or frame structurally damaged.
Operation of damper impaired by rust, corrosion, paint, or dirt.
Damaged or missing parts on damper's release mechanism.
Fire Probabilistic Risk Assessment: Significant Features
Ventilation System becomes inoperable.
ERFBS loses functionality.
Door on electrical cabinets lose functionality (e.g. fails to latch).
Drains near potential source of oil lose functionality.

3.2 Compensatory Measures

When an impairment is identified, either an *operability determination* or *functionality assessment* is performed.[1] In general, a determination of operability is required when an SSC described in the plant's TSs cannot perform the safety function specified in the plant's design basis. For non-TS SSCs that are risk-significant and/or perform functions specified in the plant's current licensing basis (CLB), undertaking a functionality assessment is appropriate. They ensure that the availability and reliability of SSCs are maintained. Implicit in this definition is the assumption of the full capability of all necessary attendant instrumentation, controls, normal- and emergency-electrical power sources, cooling or seal water, lubrication, or other auxiliary equipment required for the performance of the system, subsystem, train, component, or device to complete their related support function(s). Therefore, the majority of fire protection impairments are currently evaluated for functionality, which is normally assessed and documented through the corrective-action process.

Timing of Corrective Actions
The original standard technical specifications for fire protection (circa 1978) established a requirement to implement compensatory measures within 1 hour after discovering the impairment. This timing of implementation was deemed to be a reasonable approach to compensate for the safety of the impaired structure, system, or component after its discovery. Consideration also should be given for extraneous circumstances, such as areas of high radiation, high contamination, and confined spaces all of which warrant extra safety precautions before undertaking the compensatory measure.

The use of compensatory measures, on a short-term basis, is an integral part of the NRC-approved fire protection programs. However, compensatory measures are not expected to be in place for an extended period of time. The NRC has communicated that it expects corrective action(s) to be completed, and reliance on the compensatory measure eliminated, at the first available opportunity, typically within 18 months. For example:

- Generic Letter 91-18, "Informing to Licensees Regarding NRC Inspection Manual Section on Resolution of Degraded and Nonconforming Conditions," notes that NRC expects the licensee explicitly to justify time-frames longer than the next refueling outage after identifying the nonconformance as part of the deficiency documentation.

- Regulatory Guide 1.189 Revision 2, Section 1.5 "Compensatory Measures" states that licensees should address any degraded or nonconforming condition in a time-frame commensurate with the conditions safety significance. Reasonable efforts should be made to complete corrective actions at the first available opportunity, or should appropriately justify a longer completion schedule.
"

- Section 7.2 of NRC Inspection Manual Part 9900, "Operability Determinations & Functionality Assessments For Resolution Of Degraded Or Nonconforming Conditions Adverse To Quality Or Safety," April 16, 2008 (promulgated as Attachment to RIS 2005-

[1] Detailed guidance on the operability, functionality, and resolution of degraded and nonconforming conditions are provided in NRC Regulatory Issue Summary 2005-20, Revision 1, "Revision to NRC Inspection Manual Part 9900 Technical Guidance, Operability Determinations & Functionality Assessments for Resolution of Degraded or Nonconforming Conditions Adverse to Quality or Safety" [RIS 2005-20].

20), states: "*Licensees should address any degraded or nonconforming condition in a time frame commensurate with the safety significance of the condition, even though 10 CFR Part 50, Appendix B, Criterion XVI, "Corrective Action", applies only to activities that affect the safety-related functions of SSCs. If the licensee does not resolve the degraded or nonconforming condition at the first available opportunity or does not appropriately justify a longer completion schedule, the staff would conclude that corrective action has not been timely and would consider taking enforcement action".* The Inspection Manual contains specific guidance for determining whether a licensee is making reasonable efforts to complete corrective actions promptly.

In June 2008, the Government Accountability Office (GAO) issued the results of its review of the NRC's oversight of fire protection programs at U.S. commercial nuclear-power stations [GAO-08-747]. One ensuing recommendation was that the NRC addresses the use of interim compensatory measures (primarily fire watches) to ensure fire safety for extended periods of time rather than making repairs. In October 2012, the GAO published a report "NRC's Oversight and Status of Implementing Risk-Informed Approach to Fire Safety" [GAO-13-8] wherein they noted that the NRC had not yet fully implemented the recommendations its 2008 report about the long-term use of compensatory measures. However, the report acknowledged that in April 2009, the NRC staff was committed to resolving the issues underlying the need for long-term compensatory measures, and was developing metrics to gauge their progress.

More recently, in a March 30, 2012 letter report "Development of Metric Monitoring Methodologies" (ML120900777 and ML120900789), for the purposes of collecting data, the NRC defined a *"long term compensatory measure"* as one that has been in place for more than 18 months. This means that the functionality of impaired fire protection feature(s) is expected to be restored no later than 18 months from the date of discovery. Thus, for the purposes of the program, a "*long-term compensatory measure"* was considered as one that is in place for more than 18 months.

3.2.1 Types of Compensatory Measures

For common fire protection system impairments (e.g., faulty fire detection or suppression systems), the compensatory measure (CM) to be implemented is specified in the plant's procedures or other documents referenced in the approved FPP. Table 3-2 gives examples of common compensatory measures. Occasionally, unique circumstances may arise that were not considered in the approved FPP. When such instances arise, licensees are expected to determine suitable compensatory measures on a case-by-case basis. The selected CM should be appropriate for the equipment or issue for which they were meant to compensate, and consistent with the plant's license basis.

Table 3-2: Common Types of Compensatory Measures

Compensatory Measure	Description
Continuous Fire Watch	A continuous fire watch is an individual that serves as an uninterrupted fire watch in a single fire area (see section below on Fire watch for more details and example in section 3.2.2.1 (B) on "Improper Definition of a Continuous Fire Watch"). If all parts of the single fire area are not in the line of sight from a fixed watch station (e.g., line-of-sight vision is obstructed by equipment), the fire watch is to maintain watch over the entire area by patrolling the assigned fire area.
Hourly Fire Watch	An hourly fire watch is an individual assigned to observe posted area(s) 24 times in 24 hours, at 60 minute intervals. The frequency of the hourly fire watch patrols is defined as intervals of sixty minutes with a margin of fifteen minutes, consistent with the frequencies of other forms of Technical Specification surveillance which allow margins of 25% [NRC 1986]. The repetitive use of a 15-minute margin or 25% grace would not be permitted to allow fewer patrols.
Roving Fire Watch	A roving, once-per-shift, fire watch patrol that is assigned to tour specific fire areas once every eight hours. Unlike the Hourly Fire Watch, this CM is not typically specified in approved FPPs. However, its use has been approved by the staff for certain specific circumstances, such as impairments inside the containment.
Backup Suppression	A backup means of suppression that is provided to compensate for an impaired fire suppression system. Examples include backup pumping capability, supplemental water source(s), or additional lengths of fire hose.
Standard Video Monitoring	Use of standard closed-circuit television (CCTV) systems, such as those used for plant security, to enhance the level of fire protection provided by a fire watch when unique conditions exist.
Temporary Repairs	A short-term, temporary change in the plant to restore the functional capability of an impaired FPP feature. Examples include installing temporary fire barriers, penetration-seal materials, and emergency lighting units.
Temporary Procedure Changes	Revising abnormal operating procedures (AOPs) temporarily to direct operators to use of feasible, reliable manual actions in the event of fire in areas where impaired fire protection features are located (typically, electrical-raceway fire barriers).
Enhanced Combustible Controls	Placing additional limits on the amount and/or type of combustible material materials in the area(s) of concern.
Enhanced Ignition Source Controls	Imposing additional limits on the amount and/or type of ignition sources in the area(s) of concern.
Wireless smoke detectors	Providing wireless smoke detectors as a backup means of detection to compensate for a degraded detection system.

Fire Watch

A fire watch is an individual responsible for providing additional (e.g., during the performance of hot work) or compensatory (e.g., for system impairments) coverage of plant activities or areas for the purposes of detecting fires or for identifying activities and conditions that present a potential fire hazard. (RG 1.189 R2) Fire Watches may be posted continuously in a single fire area or assigned to periodically patrol specific plant areas. Thus, there are two basic types of fire watches; the continuous fire watch, and the hourly fire watch patrol. The type of fire watch needed (continuous or hourly) usually is a function of the level of automatic fire detection capability installed in the fire area with an inoperable, degraded, or nonconforming condition. In most cases, when a fire area is equipped with an operable fixed, automatic fire-detection system, an hourly fire watch patrol is acceptable.

The physical presence of a fire watch enhances fire prevention by promptly recognizing and disposing of fire hazards. A properly trained fire watch strengthens the first element of fire protection defense-in-depth (fire prevention) by looking for fire hazards and other conditions that could lead to a fire. A fire watch also enhances the second element of DID (detection and suppression) by identifying a fire in its early stages (via scent and/or vision) and initiating manual fire-suppression (if permitted by plant-specific protocols[2]), or alerting plant personnel, such as operations or the fire brigade. Should a fire occur, the fire watch helps to assure that it would be detected and extinguished during the early stages of fire development.

The potential benefit of a fire watch was described by the NRC in a issuance of a Director's Decision as follows:

> *A fire watch provides more than simply a detection function. Personnel assigned to fire watches are trained by the licensee to inspect for the control of ignition sources, fire hazards, and combustible materials; to look for signs of incipient fires; to provide prompt notification of fire hazards and fires; and to take appropriate action to begin fire suppression activities. Fire watch personnel are capable of determining the size, the actual location, the source, and the type of fire—valuable information that cannot be provided by an automatic fire detection system.* [NRC 1996a].

In general, fire watches are responsible for the following:

- Knowing the location of the nearest in-plant communications device in relation to the fire watch post.
- Being in the assigned watch area as required.
- Maintaining alertness during the assigned fire watch.
- Ensuring the completeness and accuracy of fire watch records
- Knowing how to properly report a fire to the Main Control Room (MCR).
- Having a clear understanding of the Fire Watch duties and post assignment.

Fire watches typically are assigned when one of the following conditions exists:

[2] Whether or not a fire watch is trained to engage in manual fire-fighting is determined by the individual licensees and the type of fire watch.

1. Fire hazards involving burning, welding, or similar operations that can initiate fires or explosions (hot work).
2. When FPP systems or features are no longer able to perform their intended function, as specified in the plant's fire protection license basis.

Fire watch training should provide appropriate instruction on fire watch duties, responsibilities, and required actions for the different types of fire watches, such as continuous, hourly, hot-work, and roving fire watch patrols. If the fire watch is expected to initiate fire suppression, qualifications should include hands-on training on a practice fire with the extinguishing equipment that will be used while on fire watch. In addition, if fire watches are available as compensatory actions, the training should detail the recordkeeping requirements [RG1.189].

Personnel performing fire watch duties for degraded FPP features typically are trained in the following topics:

- Purpose and responsibilities of a fire watch
- Types and classification of fires
- Selection and use of portable fire extinguishers (if applicable)
- Actions to be taken upon discovering a possible fire
- Types of combustibles and potential ignition sources
- Conduct of plant rounds
- Maintaining complete, accurate logs and records

Fire watches provided for hot-work[3] duties have the authority to stop work activities if unsafe conditions develop. These personnel typically are trained in the following:

- The inherent hazards of the work site, and of the hot work.
- Ensuring that safe conditions are maintained during hot-work operations.
- Using fire-extinguishing equipment (if applicable)
- Procedures for sounding an alarm if there is a fire.

Regardless of the fire-fighting equipment available and the capabilities of the individuals involved, a hot-work fire watch is not a replacement for proper planning to prevent conditions that allow a fire to develop.

An *hourly fire watch patrol* is typically assigned to observe posted area(s) 24 times in 24 hours, at 60-minute intervals. The patrol does not have to begin on the hour, but it must be completed within 60 minutes. A once-per-shift roving patrol that tours assigned areas once every eight hours has been approved by the NRC staff in certain specific circumstances, such as impairments located inside containment.

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[3] Additional information on the use of hot work fire watches is provided in NFPA 51B, "Standard for Fire Prevention during Welding, Cutting, and Other Hot Work."

In most cases, an hourly fire watch can effectively patrol multiple fire areas within the 60 minutes available to complete each fire watch tour. Whether or not a single patrol can cover multiple fire areas varies with plant-specific conditions, such as the size and complexity of the fire areas to be patrolled and their accessibility. Sometimes, the licensee may need to strategically post several fire watches to assure the tours will be successfully completed in the allotted time.

As described by the NRC staff in a 1998 Task Interface Agreement [NRC 1998b], a *continuous fire watch* is defined as follows:

> *A continuous fire watch is an uninterrupted fire watch posted in a single fire area. Where an automatic fire detection system is not installed, the continuous presence of a fire watch is needed to adequately compensate for the degraded, inoperable, or nonconforming condition. In some cases, it may be necessary to strategically post a number of fire watches in order to achieve the required level of fire safety and effectively maintain confidence that potential fire conditions will be promptly detected and reported.*

Thus, as its name implies, a continuous fire watch provides an uninterrupted watch of a single fire area. The 1998 NRR Response to the Region IV TIA, further states that a procedure is not acceptable if it does not require the fire watch to remain within the specified “fire area” at all times. A continuous fire watch may be assigned to monitor several fire zones or rooms located within a single fire area, provided that all of them are readily accessible and easily viewed by a single fire watch at a frequency of about every fifteen minutes, with a margin of five minutes and welding, grinding or burning is not in progress within the area. This approach is acceptable because the “fire area” would be continuously monitored.

A continuous fire watch should have no additional assigned duties that would require leaving the post. In addition, under normal (non-emergency) plant operating conditions, a continuous fire watch should not leave the assigned post unless relieved of his duties by operations (typically the shift supervisor).

An hourly fire watch is the most widely used compensatory measure. However, in certain unique instances, sole reliance on an hourly fire watch may not be appropriate. As discussed in Information Notice 97-48 the sole use of a fire watch for a safe shutdown function that is not adequately protected against fire damage is an inappropriate application of a compensatory measure. In such instances, other measures such as the use of feasible and reliable operator manual actions[4] may afford a more effective compensatory measure than an hourly fire watch for non-compliances involving fire-induced circuit failures.

<u>Temporary Repairs and Modifications</u>

In certain cases, a temporary modification can quickly restore the functional capability of an impaired FPP feature. For example, the functionality of a breached structural fire barrier may be temporarily restored by plugging the gap with intumescent pillows, or blocks such as those shown in Appendix B. Other examples include the following:

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[4] Criteria and associated technical bases for evaluating the feasibility and reliability of post-fire operator manual actions is provided in NUREG-1852, Demonstrating the Feasibility and Reliability of Operator Manual Actions in Response to Fire, October 2007.

- emergency lighting, such as portable lighting units having an 8-hour capacity.
- staging backup suppression equipment, such as fire extinguishers, backup fire pumps, or additional lengths of fire hose.
- procedure changes, such as revising abnormal operating procedures (AOPs) to direct operators to use of feasible and reliable operator manual actions.
- use of portable detection systems or cameras.
- modifications to hardware, such as removing electrical power to preclude fire-induced spurious operations of equipment.

Temporary modifications such as these have been shown to provide an effective method of compensation in many instances. As with all such measures, their selection, preparation, installation, and maintenance should be governed by established procedures that ensure they are appropriate for the particular impairment, and are properly installed and maintained.

3.2.2 Selecting Appropriate Compensatory Measures

The selection of a specific type of compensatory measure for a given impairment should be based on its ability to offset the degradation in defense-in-depth created by the inoperable, degraded, or nonconforming condition [NRC 1998b]. Depending on the plant-specific circumstances, certain impairments may have a greater impact on defense-in-depth than others. For example, because it influences both the detection and mitigation elements of defense-in-depth, impaired fire detectors that actuate fire suppression systems typically represent a more critically important component of a plant's fire protection program than those which provide only early fire warning and notification.

The appropriateness of a proposed compensatory measure should be evaluated by a qualified fire protection engineer. In certain cases, this assessment may determine that additional enhancements are needed to supplement the measure specified in the FPP [NRC 1998b]. The following are some examples:

- Creating temporary "combustible free zones"
- Temporarily prohibiting hot-work in the affected fire area
- Adjusting work planning to minimize the introduction of combustibles or ignition sources that could increase the likelihood and severity of a fire
- Installing closed circuit television (CCTV) capability in high-radiation areas
- Installing temporary detection and alarm systems
- Informing fire-brigade members of nonconforming suppression systems so they can formulate appropriate pre-fire strategies
- Pre-staging manual fire-fighting equipment
- Briefing operators on the potential impacts to safe-shutdown capability

The evaluation also should consider the effects of the compensatory measure on other aspects of the facility. As an example, a licensee may plan to close a valve as a compensatory measure to temporarily isolate a leak. While this action may resolve the degraded condition from a fire-protection perspective, it also may affect flow distribution to other components or systems and so complicate the operator's responses to normal or off-normal conditions, or have other effects that should be reviewed.

3.2.2.1 Examples of Issues and Findings Related to Compensatory Measures

The NRC routinely evaluates compensatory measures as part of its inspection program. The majority of these reviews found that the compensatory measures were appropriate for the impairment. As discussed below, however, certain measures were not found to offer an appropriate level of compensation. These examples are discussed to illustrate the influence ineffective compensatory measures may have on defense-in-depth.

A. Sole Reliance on Fire Watches for Impaired Post-fire Safe Shutdown Functions

In 1996, an NRC inspection found that a licensee relied solely on hourly fire-watches as a compensatory measure for several post-fire safe-shutdown design deficiencies while long-term corrective actions were being evaluated [NRC1996b]. Although the issues identified could reduce the operator's ability to achieve and maintain safe shutdown, the roving fire watches were not supplemented by any additional measures, such as alerting the operators to deficient conditions, or providing them with interim shutdown strategies for successfully dealing with fire damage to safe-shutdown components. Consequently, placing and maintaining the plant in a safe-shutdown condition after a fire in the affected fire areas would have required operators to undertake considerable trouble-shooting, and perform a significant number of repairs to compensate for the design deficiencies. As noted in the Enforcement Action [EA 96 131], reliance on hourly fire patrols as interim compensatory measures for several safety-significant design deficiencies indicated a lack of sensitivity to implementing immediate corrective actions commensurate with their safety significance.

B. Improper Definition of a Continuous Fire Watch

A continuous fire watch is an uninterrupted fire watch that is posted in a single fire area [NRC 1998b]. In areas where an automatic fire detection system is not installed, the continuous presence of a fire watch typically is required to adequately compensate for a degraded, inoperable, or nonconforming condition. Depending on the size of the fire area and the specific hazards involved, it may be necessary to strategically post several continuous fire watches in single fire-area to maintain confidence that potential fire-conditions will be promptly detected and reported.

An inspection conducted by NRC Region IV in 1995, found a licensee had revised the fire watch procedure to allow a single continuous fire watch to patrol multiple fire-areas. The inspectors also noted that a previous version of the procedure specified that a continuous fire watch was restricted to a single fire-area. The licensee stated that it had based its new criteria for a continuous fire watch on an NRC letter to another licensee, and informed the inspector that its revised procedure would not decrease the effectiveness of its own fire protection program. The inspector questioned the adequacy of the licensee's interpretation and concluded that additional NRC review was required. Subsequently, NRC Region IV asked NRR's staff to review the adequacy of the licensee's revised criteria.

In its response [NRC 1998b], the staff concluded the following:

- The licensee did not provide sufficient technical justification for redefining the criteria for a continuous fire watch, or for extending the frequency of the fire watch patrols, and did not establish that the newly defined fire watch is equivalent to the one previously defined.
- The basis cited by the licensee for its revised definition of a continuous fire watch (NRC Letter) was without merit because the letter only approved using a single fire watch to patrol *multiple fire zones within a specific fire area*. Thus, the fire area would be continuously staffed.
- The definition used by the licensee is not consistent with the intent of the continuous fire watch (to remain in the affected fire area at all times).

C. <u>Inappropriate Elimination of a Compensatory Measure (Fire Watch)</u>

In October of 2009, NRC Region IV inspectors observed maintenance personnel undertaking weld preparation work using an abrasive flapper-wheel grinder. Sparks were observed to extend four to five feet from the work area. However, no fire watch was posted. When the inspectors questioned the maintenance personnel about this omission, they stated that since they were using a flapper wheel, a fire watch was not required. From subsequently reviewing applicable procedures, the inspectors determined that a prior (December 2003) procedural revision inappropriately eliminated the need to post a fire watch when using wire brushes, flapper wheels, polishing devices, or buffing pads mounted on power- grinder motor drives or air tools.

The inspectors determined that the revised procedure adversely affected fire safety in the affected area. This decision was based on recognizing that the ability of the fire watch was not limited to identifying fires in a timely manner, but also on mitigation actions that an established fire watch could take in the event of fires. Such actions could include the ability to close doors, limiting fire exposure to adjacent areas, and providing a timely capability of detecting fires in certain cases. The inspectors concluded that the lack of a posted fire watch could adversely affect the ability to achieve and maintain safe shutdown in the event of a severe fire in the affected area [NRC 2010a].

D. Removal of Fire Protection Features without Compensatory Measures

In October 2002, NRC Region II inspectors found that a licensee had reduced the effectiveness of the FPP by changing the approved program [NRC 2003]. Specifically, the licensee inappropriately used the License Condition Impact Evaluation (LCIE) change process to revise the FPP to allow the removal of fire suppression systems and/or fire-rated barrier assemblies installed to satisfy the requirements of 10 CFR 50, Appendix R, Sections III.G.2 and III.G.3, without implementing any compensatory measures (i.e., fire watches). Before making this change, the licensee's NRC-approved FPP required that either a continuous or a one-hour compensatory fire watch patrol (with backup suppression equipment) be posted whenever a required fire suppression system and/or fire-rated barrier assembly was inoperable. The LCIE concluded that the assignment and presence of fire watch personnel for the purpose of detecting and reporting fires with operable fire detection equipment was unnecessary, and provided minimal additional safety margins for fire protection. However, the licensee's evaluation did not include a technical basis for these conclusions.

In this case, the inspectors concluded that the licensee inappropriately used the fire protection program change process to revise the FPP to permit removing fire suppression systems and/or fire-rated barrier assemblies from service without enhancing other defense-in-depth elements with an appropriate compensatory measure. The change adversely affected the ability to achieve and maintain safe shutdown in the event of a fire, in that the licensee went from full compliance with the fire protection safe shutdown system separation and suppression criteria to less than full compliance without implementing temporary measures to compensate for weakness in this defense-in-depth element. This was contrary to the FPP's safety objectives and constituted a change from the approved program that required the NRC's approval prior to implementation. The finding resulted in a Green (non-cited) violation.

E. Untimely corrective actions

Between 1992 and 1995, the plant staff found that the fire protection coatings on most of the structural steel beams in safety-related buildings did not meet the required thickness to achieve a 3-hour fire rating (Condition Report 1997-0595). This condition, which affected more than one-fourth of the beams, had existed since construction and was corrected in most fire areas. In 1997, hourly fire watches were posted as a CM in three areas which remained uncorrected. Seven years later, during a 2004 Triennial Fire Protection Inspection (Inspection Report 05000458/2004007), the inspectors noted that the deficiencies had not been corrected. After reviewing the licensee's documentation and justification, the inspectors noted that the licensee was planning to repair these three fire areas in 2005 and attributed the delay to the fact that the remaining areas were high radiation areas. The finding was greater than minor, but was screened as having very low safety significance because compensatory measures were in place as required, and the remaining defense-in-depth elements remained unaffected. The corrective action deficiency was not considered a violation of the fire protection program. The finding (FIN 05000458/2004007-03) was entered into the corrective action program under Condition Report 2004-000771.

F. Use of Long term Compensatory Measures During the Resolution of Complex Fire Protection Issues

The resolution of certain fire protection impairments may require compensatory measures to remain in place for an extended period of time. For example, in the early 1990s the NRC staff accepted the use of fire watches until comprehensive actions needed to correct Thermo Lag 330-1 fire barrier performance deficiencies were completed. As documented in GL 92-08, corrective actions for this issue were extensive, requiring each affected plant to undertake resource-intensive work, such as base-lining all fire-barrier configurations, designing test assemblies, developing acceptance criteria for requalifying electrical raceway fire barriers (ERFBs), and implementing any needed design changes and plant modifications. Thus, when determining the acceptability of long-term compensatory measures, the staff needed to consider both the extended period of time that would be needed to complete corrective actions, and the significance of the degraded Thermo-Lag barriers on plant safety.

In June 1991, NRR established a Special Review Team to investigate the safety significance and generic applicability of technical issues about Thermo-Lag fire barriers. With regard to their safety significance, the Team determined that the relative safety-significance of the degraded Thermo-Lag fire barriers was low due to a combination of other fire-safety measures already in place and the recognition that the barriers, while degraded, would offer some level of fire protection (IN 92–46)[5].

As documented in Federal Register Notice "All Licensees of Reactors with Installed Thermo-Lag Fire Barrier Material; Issuance of Director's Decision under 10 CFR 2.206", 61FR 70 (April 10, 1996), pages 16005 – 16016, the staff concluded that compensatory measures using fire watches were adequate and acceptable for the degraded Thermo-Lag's fire barrier impairments. Specifically, the Director's Decision states:

> *The goal of the NRC staff's Thermo-Lag Action Plan is directed towards restoring the functional capability of fire barriers as soon as practicable. There is not a time limit associated with the use of fire watches as a compensatory measure. Given the margin of safety a fire watch brings to a fire protection program … the NRC staff has determined that continuing the use of fire watches while barriers are inoperable is acceptable. However, the NRC believes that notwithstanding interim reliance on compensatory measures, appropriate actions must be taken by licensees to restore operability of Thermo-Lag barriers.*

G. Use of Operator Rounds to Compensate for Potential Circuit Vulnerabilities

The 1975 fire at Browns Ferry revealed the ineffectiveness of the electrical separation practices in effect at that time. Failing to adequately identify those circuits required to achieve and maintain safe shutdown and protect them from the effects of fire damage, could result in the following:

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[5] The Special Review Team report was issued with IN 92–46, ''Thermo-Lag Fire Barrier Material Special Review Team Final Report Findings, Current Fire Endurance Testing, and Ampacity Calculation Errors,'' June 23, 1992

1. Fire damaging redundant trains of systems needed to achieve and maintain safe shutdown ; and,
2. The ability to safely shutdown the plant and maintain it in a safe shutdown condition being impaired.

In the mid-1990s, the NRC staff identified a regulatory concern about the potential impact of multiple spurious operations (MSO) that may occur as a result of fire damage to unprotected cables and circuits. These non-compliances were judged to stem, in part, from a misunderstanding of the regulatory requirements and inappropriate reliance on a 1992 recommendation from the Nuclear Management and Resources Council (NUMARC, now NEI) that the NRC did not endorse, and may have caused confusion during licensee evaluations [NUREG/BR-0195].

Based on the apparent widespread misunderstanding of regulatory requirements, enforcement discretion was deemed appropriate until the circuit analysis issue was resolved. On March 2, 1998, the NRC's Office of Enforcement (OE) issued an Enforcement Guidance Memorandum (EGM) 98-002 to temporarily defer formal enforcement actions to allow the industry time to develop positions that the NRC could endorse. During this time, licensees were to implement reasonable compensatory actions for the identified circuit vulnerabilities. This guidance was revised in July 1999 and February 2000.

On September 11, 2006, the staff proposed that the Commission issue a generic letter to clarify the fire-induced circuit failures. However, the staff's proposal was not approved by the Commission. Specifically, in SRM-SECY-06-0196, the Commission did the following:

1. Disapproved the proposed generic letter,

2. Directed the staff to develop a clearly defined method of compliance to resolve fire-induced circuit failures for licensees who choose not to utilize the risk-informed approach in 10 CFR 50.48(c), and,

3. Directed the staff to engage industry stakeholders to discuss clarification of regulatory expectations to ensure a common understanding of the path to closure for this issue.

Subsequently, on June 30, 2008, the staff published SECY-08-0093, "Resolution of Issues Related to Fire Induced Circuit Failures," that proposed a technical path forward to resolve multiple fire-induced circuit faults, including changes to the enforcement guidance. On September 3, 2008, the Commission published SRM-SECY-08-0093 approving the staff's changes to the enforcement discretion for such circuit faults. Accordingly, on May 14, 2009, the NRC issued Enforcement Guidance Memorandum (EGM) 09-002 [EGM 09-002 to provide a period of enforcement discretion for analyzing the effects of multiple fire-induced circuit faults. Specifically, EGM 09-002 gave licensees until November 2, 2012, (3 years from the date of the issuance of Regulatory Guide (RG) 1.189, Revision 2, "Fire Protection for Nuclear Power Plants"[6]) to complete the corrective actions associated with noncompliant multiple fire-induced circuit faults. Under EGM 09-002, licensees were expected to complete the following activities by November 2, 2012:

[6] RG 1.189, Revision 2, issuance date was November 2, 2009 (74 FR 56673)

- Identify noncompliance related to multiple fire-induced circuit faults;
- Implement adequate compensatory measures for each noncompliance,
- Place the noncompliance in the corrective-action program, and,
- Complete all corrective actions or submit a request for exemption or license amendment for the NRC's review [NRC 2010b].

On May 13, 2010, the NRC staff held a public meeting with industry stakeholders to discuss, in part, industry's approach to compensatory measures for the multiple spurious-operation (MSO) non-compliances described in EGM 09-002. During that meeting, industry representatives described the use of existing, once-per-shift, operator rounds as a generic compensatory measure to satisfy these requirements. In a subsequent summary of the meeting, dated June 9, 2010 [NRC 2010c], the staff stated that sole reliance on an operator's rounds of the plant once per shift (i.e., every 8- or 12-hours depending on the shift's duration) is not an appropriate compensatory measure. The staff stated that MSOs that could affect safe shutdown are considered equivalent to a lack of a fire barrier, and licensees should implement appropriate compensatory measures in accordance with their approved fire protection program.

During a subsequent meeting between the NRC Fire Protection Steering Committee and industry stakeholders on August 23, 2010 [NRC 2010e], the staff again discussed the industry's use of operator rounds as a compensatory measure for MSO issues, and reiterated its position that using this approach is considered a noncompliance, and that licensees should implement compensatory measures consistent with the approved fire protection program. NEI staff indicated they would look into the use of enhanced operator rounds.

Certain NRC inspection reports may infer that the NRC accepted the use of once-per-shift operator rounds as a suitable compensatory measure for potential MSOs. However, lacking other mitigating factors, their use is not viewed as providing an acceptable level of compensation for MSOs that may be caused by fire. However, as illustrated in the following two examples, plant-specific factors can influence the suitability of operator rounds as a compensatory measure for MSOs.

- During a Triennial Fire Protection inspection conducted at the Vogtle Electric Generating Plant (VEGP) in 2010 [NRC 2011b], the NRC questioned whether the potential MSOs identified by the licensee constituted non-compliances with its current licensing basis (CLB) and if the compensatory measures implemented (i.e., once per shift operator rounds) were sufficient compensation. The licensee countered that the MSO scenarios did not represent any non-compliances, as considering multiple circuit-faults was outside of the fire protection licensing/design basis for VEGP. The inspection team referred this licensing basis issue to the Office of Nuclear Reactor Regulation for review via Unresolved Item (URI) 05000424; 425/2010006-02, "Licensing Basis for Multiple Spurious Operations and Adequacy of Related Compensatory Measures." The NRC staff's review of this URI is documented in NRC Inspection Report Vogtle Electric Generating Plant - NRC Triennial Fire Protection Inspection Report Nos. 05000424/2012007 and 05000425/2012007 [NRC 2012]. It concludes that compensatory measures are not required in this case because the concern identified by the inspection team (potential MSOs) does not constitute a non-compliance with the Vogtle design and license basis.

- A 2010 inspection at Millstone Power Station Unit 2 and Unit 3 Millstone Power Station,- NRC Triennial Fire Protection Inspection Report 05000336/2010008 and 05000423/2010008) [NRC 2010e] determined that operator rounds, when augmented by additional monitoring of fire detection system operability, provided an adequate level of compensation for potential MSOs.

3.2.3 Alternate Compensatory Measures

In certain instances, a licensee may prefer to implement a method of compensation different from that specified in its approved FPP. For example, properly analyzed Operator Manual Actions[7] (OMAs) may be demonstrated to afford a more effective compensatory measure for a degraded fire barrier than the hourly fire watch typically specified in an approved FPP. In its review of alternate compensatory measures, the RES staff has identified several unique methods of keeping fire watch radiation doses low. In one example, video cameras were placed in areas of high radiation with a video monitor in an area of lower radiation where a fire watch could monitor the video. In another instance, a detection system was designed to send an alarm signal to the Control Room through the phone lines. A fire watch then verified that the phone line was functioning properly. Similarly, a licensee may prefer to use new technologies, such those described in Appendix B, in lieu of, or in conjunction with, the measures specified in the approved FPP. If the plant has adopted the GL 86-10 Standard License Condition, the licensee may modify its FPP to allow the use of measures other than those specifically defined in the approved fire protection program, provided they would not adversely affect the ability to achieve and maintain safe shutdown in the event of a fire. This criterion typically is satisfied if the licensee can demonstrate that the alternate measure adequately offsets the degradation in defense-in-depth created by an inoperable, degraded, or nonconforming condition. In general, the evaluation should incorporate insights regarding the following:

- The location, quantity, and type of combustible material in the fire area,
- The presence of ignition sources and their likelihood of occurrence,
- The capability for automatic fire suppression and fire detection in the fire area,
- The capability for manual fire suppression capability in the fire area, and,
- The probability of human error where applicable.

The NRC staff provided detailed information in RIS 2005-07, “Compensatory Measures to Satisfy the Fire Protection Program Requirements,” on the proper method for changing the approved fire protection program (FPP) to use an alternate compensatory measure.

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[7] In this context, “*properly analyzed*” means that the OMAs are appropriately justified by an evaluation. Criteria acceptable to the staff for undertaking this evaluation is provided in Triennial Fire Protection Inspection Procedure 71111.05T.

3.3 Use of New Technologies

Most compensatory measures specified in approved FPPs remain virtually unchanged from those put in place over 30 years ago following the Browns Ferry fire. Since these “traditional” measures principally were established for common types of impairments, such as blocked sprinkler heads or damaged hardware on a fire door they may not provide an appropriate level of compensation in all cases. For example, issues such as the post-fire safe shutdown deficiencies described in IN 97-48 and the multiple spurious operation concerns described in EGM 09-002, were not considered when the “traditional” compensatory measures were developed. In other instances, a licensee may prefer to implement a compensatory measure that differs from the one specified in its approved FPP. For example, to minimize radiation exposure, a licensee may prefer to install a video imaging detection system in lieu of an hourly fire watch. Depending on the plant-specific circumstances, recent advances in fire technology, such as those illustrated in Appendix B, may offer an appropriate resolution for each of the two scenarios described above. RIS 2005-07 gives specific guidance for implementing these types of compensatory measures.

4. EXAMPLE ASSESSMENTS

As discussed previously, each operating plant has an approved FPP that integrates plant design features, personnel, and administrative controls necessary to achieve an appropriate balance between each of the following elements of the defense-in-depth (DID) safety concept:

1. Prevent fires from starting;
2. Rapidly detect, control, and extinguish those fires that do occur; and
3. Protect structures, systems, and components important to safety so that if a fire is not extinguished promptly, it will not prevent the safe shutdown of the plant.

No single element can be perfect or complete by itself. It is the combination of all three that provide defense-in-depth protection of the public health and safety. As stated in NUREG 0050, "Recommendations Related to the Browns Ferry Fire," the goal is to assure a suitable balance between all three elements. Increased strength, redundancy, performance, or reliability of one echelon can compensate in some measure for deficiencies in the others.

Inherent in the DID safety concept is the need to ensure an appropriate level of fire safety is maintained when a fire protection feature is impaired or disabled. To meet this objective, the FPP is designed to ensure appropriate compensatory measures are implemented when fire protection features are degraded or impaired. The selected CM should be appropriate for the specific hazards, compatible with plant operations, and be properly implemented and maintained.

The selection of a specific type of compensatory measure for a given impairment should be based on its ability to appropriately offset the degradation in DID created by the inoperable, degraded, or nonconforming condition. As shown in Table A-1, compensatory measures to be implemented for common types of impairments are typically specified in the approved FPP. However, as discussed in the NRC's Information Notice (IN) 97-48, "Inadequate or Inappropriate Interim Fire Protection Compensatory Measures," the CMs specified in the FPP may not offer an appropriate level of protection in all cases. When unique, plant-specific, situations are encountered, the licensee should determine appropriate compensatory measures on a case-by-case basis. Specific guidance is given in RIS 2005-07 on how a licensee may change the approved FPP to use compensatory measures other than those specified in the approved FPP.

The example assessments provided in the following sections are intended to illustrate the following:

a. how, under certain unique conditions, an impairment in a single DID element could adversely affect the plant's ability to achieve and maintain safe shutdown conditions;
b. how recent technological advancements may provide an effective alternate CM, and,
c. the potential benefits of using advanced fire detection technologies as alternate CMs.

4.1 Example 1: Degraded Electrical Raceway Fire Barrier System

4.1.1 Scenario

As illustrated in Figure 4-1, Fire Area SW-1A primarily contains equipment and cables associated with Shutdown Train A (shown in green). During a serious fire, Train B systems and equipment would be relied on to achieve and maintain safe shutdown conditions. Cables associated with Train B shutdown systems (shown in red) are protected throughout the area by an ERFBS having a 3-hour rating. In addition, the fire area contains area-wide ionization detectors and partial automatic sprinkler coverage. However, consistent with the plant's fire protection licensing basis, sprinkler coverage is limited to that portion of the fire area that contains a high concentration of combustibles in the form of stacked cable trays.

As Figure 4-1 shows, the automatic suppression system protects all cables trays except a single Train B tray that is routed near the Train A, 480V MCCs. All cables located within this raceway are PVC-insulated and do not meet the flame resistance test of IEEE Standard 383 "Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations." The 480V MCCs are vented at the top.

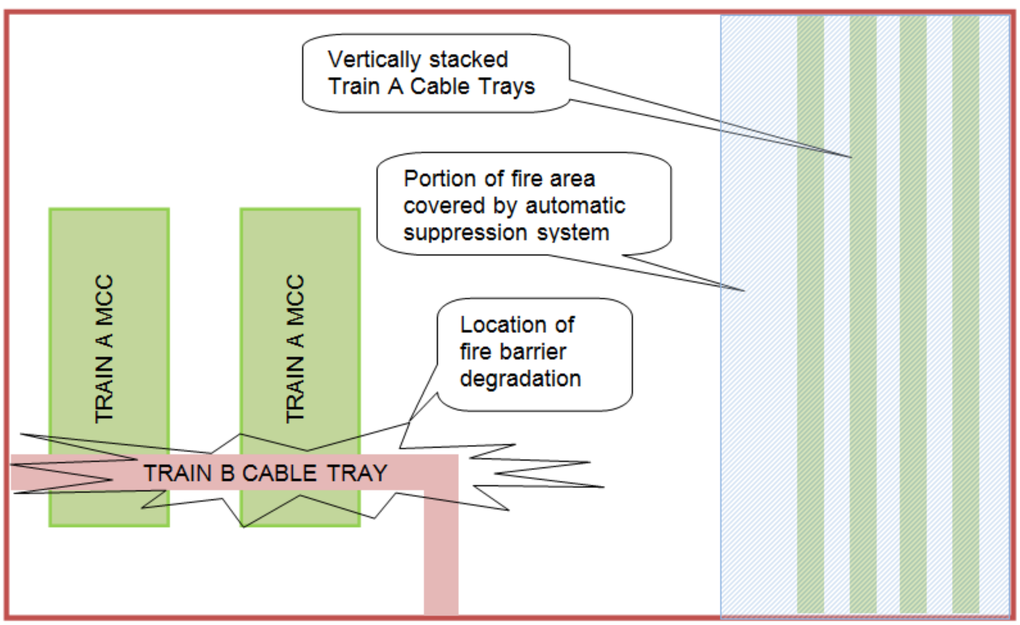

Figure 4-1: Plan View of Fire Area SW-1A

Recently, the 3-hour rated ERFBS protecting the Train B cable tray was found to have several major through-cracks along the underside of the tray. A visual inspection of the barrier found the degradation to be sufficient to allow the cables to be visible in several locations. While not equivalent to a missing fire barrier, the degradation reduces the effectiveness of the barrier and the amount of time for a fire to damage the enclosed cables.

The compensatory measure specified in the approved FPP for a degraded fire barrier is an hourly fire watch. However, as illustrated in the following paragraphs, the unique conditions of fire damage presented in this case are such that sole reliance on a fire watch would clearly be an inappropriate compensatory measure.

Scenario Summary

Degraded / Impaired FPP Feature:	Damage (through-cracks) in an electrical- raceway fire barrier system (ERFBS) that protects the cables of equipment needed to achieve safe shutdown conditions in the event of fire.
DID Element Directly Impacted by the Impairment:	Element 3 – Protect structures, systems and, components important to safety so that if a fire is not extinguished promptly, it will not prevent the safe shutdown of the plant.
FPP-Specified Compensatory Measure:	Hourly Fire Watch
Conditions or Hazards:	• Sources of fire ignition (MCCs) are in close proximity to the cable trays of concern • Affected cable tray contains cables that do not meet IEEE-383 standard. • Target cable is a PVC-insulated, multi-conductor cable. • A single conductor-to-conductor short within the target cable will cause the valve to close. • The target cable tray is outside the area protected by the automatic suppression system • Degree of barrier degradation is fairly extensive – there are a large number of through-cracks on the underside of the cable tray, such that the cables are visible.

4.1.2 Example 1 Assessment

The first step in the assessment process is to qualitatively evaluate the overall level of DID for the fire area, given the impairment. The output of the evaluation is a degradation ranking for each of the three DID elements. From this information, the impact of the impairment on DID can be determined and the effectiveness of potential CMs can be judged with respect to their ability to offset the degradation in DID caused by the impairment.

For this scenario, the following scale will be used to rank degradations:

H = Highly Degraded (e.g., fire protection feature is missing, inoperable, or ineffective),

M = Moderately Degraded, (e.g., fire protection feature does not meet design specifications)

L = Low or no degradation – (Normal Operating State – fire protection feature fully complies with existing regulations and regulatory guidance)

4.1.2.1 Evaluation of Defense-in-Depth (DID) Element 1 – Fire Prevention

The first element of DID is directed at preventing fires from starting. This typically is accomplished by controlling transient combustibles and ignition sources, and preventing, to the extent practical, in situ ignition sources and combustible materials from causing self-sustaining fires. Examples of fire prevention activities include the following:

- Storing, handling, and using flammable materials
- Storage, control, and use of combustible materials relative to locations of flammable materials, and ignition sources
- Use and control of open flames and other ignition sources
- Housekeeping

Evaluation

Combustibles and ignition sources are well controlled by established procedures in accordance with the plant's approved fire protection program. In addition, frequent patrols by plant operators would prevent transients from accumulating in the fire area. Thus, the Fire Prevention element of DID (DID Element 1) is considered to have a low degradation (Normal Operating State).

Fire Prevention Feature	**Degradation Ranking**
Transient Combustible Controls:	L (Normal Operating State)
Transient Ignition Source Controls:	L (Normal Operating State)

4.1.2.2 Evaluation of Defense-in-Depth Element 2 – Detection, Suppression, and Mitigation

The second element of DID is directed at rapidly detecting, controlling, and extinguishing fires that may occur despite of the fire prevention efforts. This DID element is afforded by fire detection and extinguishing systems. Typical examples of these systems include:

- fire detectors (heat or smoke),
- Halon 1301 carbon dioxide (CO_2), clean agent and dry chemical fire suppression systems,
- automatic sprinklers,
- foam and water spray systems,
- portable fire extinguishers,
- hose stations,
- fire hydrants, and water supply systems, and
- Plant's fire brigade.

For the specific scenario under evaluation, DID element 2 is provided by the following systems:

- area-wide ionization detection system,
- partial-area automatic suppression, and
- manual suppression by fire brigade.

Evaluation

Consistent with the plant's fire protection licensing basis, area-wide, ceiling-mounted, spot-type detectors are installed and maintained to meet the NFPA code of record. In addition, the area has partial automatic sprinkler coverage. However, since coverage is limited to a portion of the fire area where there is a high concentration of cable trays, the sprinkler system does not protect the cable tray of concern (i.e. the location of the impaired fire barrier). Therefore, the automatic sprinkler system i may not have the capability to prevent fire damage to the target cable. Therefore, a fire which starts at the MCCs located near the impaired cable tray is expected to damage the cable of concern with no intervention from the installed sprinkler system. In addition, the type of fault needed to cause the pump-suction MOV to spuriously close (i.e., a single conductor-to-conductor short within a multi-conductor cable) is expected to occur fairly quickly. Insights gained from cable fire testing have demonstrated that conductor-to-conductor shorting in a multiconductor cable is one of the most probable causes of spurious actuations.

Based on the nature of the ERFBS impairment, its location with respect to potential fire ignition sources (i.e., directly above the MCCs), the potential for the degraded ERFBS to be exposed to direct flame impingement, and construction features of the target cable (PVC insulation), the time for a fire that starts in the MCC to damage the target cable is estimated to be from 5 to 8 minutes. However, a review of fire drill records indicates that the average fire brigade response time to Fire Area SW-1A is 10 minutes. Therefore, the likelihood of a circuit failure prior to fire extinguishment by the fire brigade is considered to be moderate. Accordingly, the effectiveness of the manual fire-fighting capability, with respect to its ability to prevent damage to the target cable of concern, is considered to be moderately degraded[1].

In summary, the area-wide detection system is expected to provide prompt notification of fire. However, as discussed above, the suppression system is not optimized for a fire in this area, possibly due to the expected reliance on the fire barrier. So although the fire suppression system is not degraded, its capability to provide protection in this case is limited. Therefore, the appropriate credit for the suppression system in determining the compensatory measure may be limited.

4.1.2.3 Evaluation of Defense-in-Depth Element 3 – Protecting SSCs Important to Safety

The purpose of the third and final element of DID is to ensure that in the unlikely event that both DID elements 1 and 2 were to fail (i.e., a fire were to initiate and continue to develop), the capability to achieve and maintain safe shutdown conditions would still be assured. Thus, this element of DID includes SSCs needed to accomplish essential shutdown functions and design features that prevent fire from damaging them[2]. Examples include the following:

- Electrical Raceway Fire Barrier Systems (ERFBS)
- Fire Barriers (e.g., fire-rated walls, floors, and ceilings)
- Electrical Isolation Devices (e.g., Isolation / Transfer Switches)
- Remote / Alternate Shutdown Equipment (e.g., Alternate Shutdown Panels)
- Systems and equipment relied on to perform essential post-fire shutdown functions, such as decay heat removal and reactor coolant inventory control.

In this specific scenario, SSCs which comprise DID element 3 are protected from fire damage by an area wide detection system, 3-hour rated ERFBS and manual fire suppression capability. However, as discussed above, the overall effectiveness of these protective features are considered to be moderately-to-highly degraded. As a result, the target cable of concern will likely be damaged by fire that initiates in nearby 480V MCCs.

Fire damage that causes a short between two conductors of the target cable is sufficient to cause the pump suction MOV to move to an undesired (closed) position. As discussed above, spurious operation is expected to occur fairly quickly, before being extinguished by the plant’s fire brigade. Once the valve closes, permanent damage to the pump is expected due to loss of suction.

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[1] As discussed in NRC IM Part 609 Appendix F, unlike other DID elements manual suppression capability is credited even when it is highly degraded. This credit is based upon the potential for early detection and suppression of fires by personnel using hand-held fire extinguishers

[2] As used in this section, the phrase “safe shutdown” refers to the ability to achieve and maintain hot shutdown conditions (for a BWR), or hot standby conditions (for a PWR).

Summary of DID Element 3

When the degraded ERFBS is considered in conjunction with the other unique circumstances presented in this scenario, a fire that originates in the MCCs could cause a required valve to spuriously close before the fire can be extinguished by the plant's fire brigade. By causing pump damage due to a loss of suction, spurious closure of this valve would significantly affect the operator's ability to achieve and maintain safe shutdown.

Capability to prevent cable damage (given a fire):	H – Highly Degraded – due to location of fire barrier degradation and inability to manually extinguish fire before the cable is damaged
Capability of operators to recover credited SSD flow path:	H – Highly Degraded –If damage occurs, no procedure or training is in place.

Thus, DID element 3 is considered to be highly degraded.

4.1.3 Evaluation of Compensatory Measures

The licensee's FPP specifies implementing an hourly fire watch whenever an ERFBS is impaired, and there is an operable detection system. In this case , however, the ERFBS degradation is significant (through cracks), and other fire protection features normally relied on to prevent fire damage to the cable of concern (the target cable) are also degraded with respect to their ability to prevent postulated fires from adversely affecting the ability to achieve and maintain safe shutdown. When considered in combination with other factors, such as the potential for fire ignition and growth, the limited capability of the fire suppression systems to prevent cable damage, the type of cable, and the relatively simplistic circuit failure mode needed to cause the pump's suction valve to spuriously close, the impaired barrier could significantly affect the plant's ability to achieve and maintain safe shutdown conditions.

As discussed in IN 97-48, sole reliance on a fire watch as a compensatory measure for a safe shutdown function that is not adequately protected against fire damage may not be appropriate. When unique circumstances, such as those presented in this hypothetical example, occur, it is expected that the compensatory measures specified in the approved FPP would be enhanced as needed to restore an appropriate level of DID. For example, in this case a noncombustible blanket such as ceramic fiber could be wrapped around the damaged portion of the cable tray, with appropriate calculations such as ampacity derating, seismic loading, etc., (or an advanced fire-detection system that can detect fire in its incipient stages), along with specific guidance for the operators on actions to take in preventing damage to the required pump would provide an alternative CM than sole reliance on an hourly fire watch.

4.2 Example 2: Inoperable Gaseous Suppression System

Total flooding CO_2 suppression systems are designed to inject and maintain a specified concentration of CO_2 to an enclosed space for a set period of time. The extinguishing mechanism of carbon dioxide is primarily dilution of the oxygen content of the atmosphere to a point where the atmosphere will no longer support combustion. As a result, total flooding CO_2

systems are typically used in normally unoccupied areas where an electrically nonconductive method of extinguishing a fire is desired, such as cable spreading rooms, computer rooms and relay rooms.

Because it extinguishes a fire by reducing the amount of oxygen, the discharge of CO_2 into an enclosed space presents a significant risk of suffocation. For this reason, visual and audible pre-actuation warnings and an actuation time delay are incorporated into the design. Most cable spreading room CO_2 systems are designed to provide a fairly high concentration of CO_2 (typical minimum concentration of 50-percent). Therefore, in addition to the personnel safety hazard, a sufficient concentration of CO_2 may not be maintained if the area is not adequately sealed. To ensure that this minimum concentration is maintained, actuation of the CO_2 system causes selected fire dampers and doors to close and HVAC fans to shut down.

Fire-rated structural barriers (e.g., fire-rated doors, fire-rated HVAC dampers, fire walls and cable penetrations) are a key component of the plant's overall fire safety system. The basic design function of these barriers is to confine a fire to the area in which it started and to protect plant systems and components within an area from a fire outside the area. However, in areas where gaseous suppression systems are used structural fire barriers must also be of sufficient integrity to maintain required concentrations.

4.2.1 Scenario

While at 100% power (Mode 1) a licensee of a PWR is performing a design modification to install a new digital instrumentation system. A portion of the modification requires a large quantity of fiber-optic cables to be installed between the Cable Spreading Room (CSR) and Battery Rooms A and B. To accomplish this, openings must be made in the CSR structural fire barrier wall to accommodate new cables. It is expected that work in the CSR will take approximately six weeks to complete. During this time, the total-flooding CO_2 suppression system in the CSR is locked out to safeguard workers form inadvertent discharge and because the new openings in the fire barrier wall will reduce the available concentration of CO_2 to a value that is less than the minimum concentration required for fire suppression.

As specified in the plants approved fire protection program, compensatory measures for an impaired CO_2 system consist of a continuous fire watch and additional manual firefighting equipment. The specified measures will provide adequate protection on an interim basis. However, they are not as effective as a fully functional automatic suppression system. In addition, although the concern for worker safety only exists for one 8-hour work shift each day the compensatory measures must remain in place continually until the CO_2 system is returned to service.

In this case an alternative compensatory measure may be provided by the use of temporary fire barrier materials, such as intumescent pillows, to seal the open penetrations at the end of each work day. Although the continuous fire watch would still be required while workers are in the area, this approach would permit the automatic CO_2 suppression system to be returned to service during the 16-hour timeframe that personnel are not in the area.

As illustrated in Figure B-11 of Appendix B, intumescent pillows resemble small cushions or soft bricks. The pillows are installed by compressing and stacking into the opening in a brick-like fashion. When exposed to the heat of fire the pillows expand in all directions to form an effective seal around cable trays, conduits or other penetrations. Key advantages include:

- fast installation and removal
- may be reused (as long as they are not exposed to fire)
- pillows can be pushed into openings in any formation, without affecting their fire protection properties
- three-hour rating
- low leakage pillows are available to provide a virtually airtight seal.

Scenario Summary

Degraded / Impaired FPP Features:	Fire Barrier and CO_2 Fire Suppression System
DID Element Directly Impacted by the Impairment:	Element 2 - Detection, Suppression, and Mitigation
FPP-Specified Compensatory Measure:	Continuous Fire Watch and additional manual firefighting equipment

4.2.2 Example 2 Assessment

4.2.2.1 Evaluation of Defense-in-Depth (DID) Element 1 – Fire Prevention

The primary combustibles of concern in the CSR are the large quantity of PVC insulated electrical cables. Fixed sources of fire ignition include transformers, power programmer cabinets, 480V load centers, and DC distribution panels.

The modification will increase the amount of transient combustibles and potential sources of fire ignition. However, the quantity of these additional hazards will be minimal and are well controlled by established procedures. In addition, all personnel working in the area are required to complete training in the control of combustibles and potential transient sources of fire ignition (e.g., hot work). Therefore, the minor increase in transient combustibles and ignition sources is not deemed significantly impact the level of fire prevention normally provided for the area. Thus, the Fire Prevention element of DID (DID Element 1) is considered to have a low degradation (Normal Operating State).

Summary of DID Element 1

Fire Prevention Feature	Degradation Ranking
Transient Combustible Controls:	L (Normal Operating State)
Transient Ignition Source Controls:	L (Normal Operating State)

4.2.2.2 Evaluation of Defense-in-Depth (DID) Element 2 – Detection, Suppression, and Mitigation

During normal operations DID element 2 is provided by the following systems:

- area-wide ionization detection system
- total flooding CO_2 suppression
- manual suppression by fire brigade

Area-wide, spot-type, smoke detectors are installed and maintained to meet the NFPA code of record. In addition, the area is provided with a total flooding, automatic, CO_2 suppression system. However, due to concerns for worker safety and the loss of CO_2 system effectiveness created by the opening being made in the structural fire barrier wall, the suppression system has been locked out until the modification is completed. Consistent with the plants approved fire protection program, a continuous fire watch has been posted in the area and additional manual firefighting equipment has been provided. The continuous fire watch must remain in place until operability of the CO_2 suppression system is fully restored. This approach meets the licensing basis requirements and is, therefore, acceptable. However, it does not necessarily provide the most resolution for this specific case. With the CO_2 system taken out of service, a fire watch must remain in the area at all times, including the 16-hour time period when no workers are in the area. In addition, given the complex geometry of the CSR, and close proximity of in-situ combustibles (cables) and potential ignition sources (electrical equipment), the use of a fire watch does not provide an equivalent level of safety to that afforded by a fully functional automatic suppression system.

<u>Summary of DID Element 2</u>

The combination of area-wide detection system and continuous fire watch is expected to provide prompt notification of fire. However, given the high concentration of cables, the close proximity of cables to potential sources of fire ignition, physical obstacles that impede access (e.g., stacked cable trays), and the CO2 suppression system being locked out the overall degradation ranking of DID Element 2 is to be considered Moderate.

Fire Mitigation Feature	Degradation Ranking
Detection:	L – Normal Operating State
Automatic Suppression:	H – Highly Degraded - The CO_2 system is not operational.
Manual Suppression:	L – Normal Operating State

4.2.2.3 Evaluation of Defense-in-Depth (DID) Element 3 – Protecting SSCs Important to Safety

The purpose of the third and final element of DID is to ensure that in the unlikely event that both DID elements 1 and 2 were to fail (i.e., a fire were to initiate and continue to develop), the capability to achieve and maintain safe shutdown conditions would still be assured. In this specific scenario, prompt detection by the fire watch and manual fire suppression are relied on to protect redundant trains of safety equipment. The CSR is provided with an alternate shutdown capability which requires operators to perform actions needed to mitigate the effect of fire damage outside the MCR.

Summary of DID Element 3

The overall degradation ranking of DID element 3 is considered to have low degradation (Normal Operating State).

4.2.3 Evaluation of Compensatory Measures

The licensee's FPP specifies implementing a continuous fire watch whenever the automatic CO_2 suppression system is impaired. In this case, the suppression system was intentionally removed from service to facilitate the performance of a plant modification and is expected to remain inoperable for approximately six weeks. Based on the other factors, such as the type of ignition sources (electrical distribution equipment), proximity of combustible cables to the ignition sources, and the type of cables involved (PVC insulated), an alternative compensatory measure may be warranted.

Consistent with the plants approved FPP, a continuous fire watch has been posted in the area and additional manual firefighting equipment has been provided. However, for this specific scenario, the use of temporary fire barrier technologies, such as intumescent pillows illustrated in Figure B-11 of Appendix B, may provide an alternate approach than a fire watch. With the CO_2 system taken out of service, a fire watch must remain in the area at all times, including the 16-hour time period when no workers are in the area. Therefore, the use of intumescent pillows may be considered as an alternative to a continuous fire watch for the inoperable CO_2 suppression system.

4.3 Example 3: Use of Alternative Compensatory Measures in High Radiation Areas

Some FPPs allow alternative compensatory measures as determined by a qualified fire protection engineer. In certain circumstances, alternatives to the compensatory measures identified in the approved FPP may be warranted. For example, compensatory measures in areas having high levels of radiation typically warrant different consideration. Various types of alternate compensatory measures have been used to keep fire watch radiation doses as low as reasonably achievable (ALARA). One common approach is the use of a closed circuit television (CCTV) network. Depending on the plant-specific circumstances, standard video cameras, such as those used by plant security, may provide alternative compensatory measures while also minimizing radiation exposures. As illustrated in Figure 4-2, the standard CCTV cameras are placed in the area(s) requiring fire watch surveillance, and the monitor is placed in an area where the fire watch could safely monitor the video.

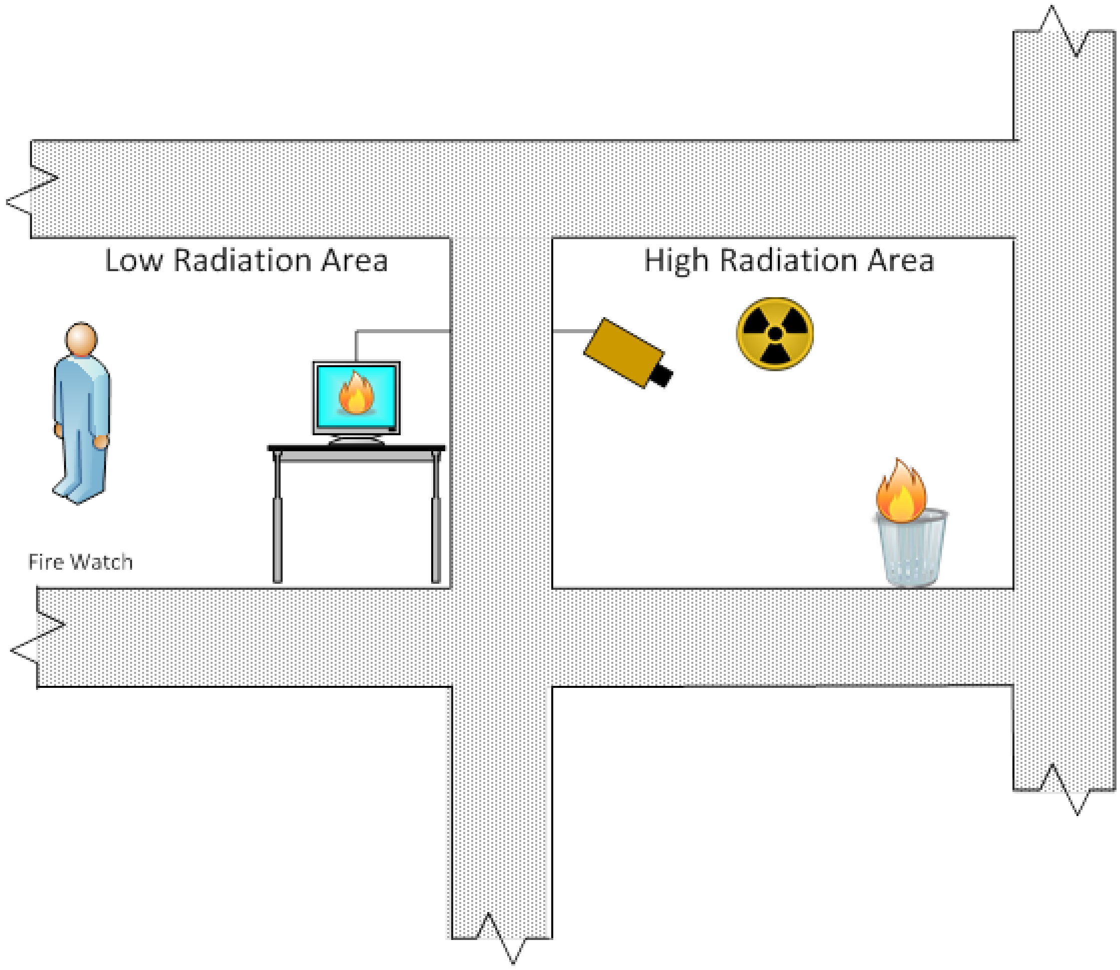

Figure 4-2: Hourly Fire Watch with Standard CCTV Monitoring of High Radiation Areas

In other cases, such as large areas, areas containing equipment that obstructs field of view, and/or areas where prompt fire suppression in the early stages of development is needed or desired, the use of standard video monitoring may not be effective. In such cases, the installation of an advanced video imaging detection (VID) system, such as the example illustrated in Figure 4-3 and Appendix B.1.3 may provide a more effective approach. Advanced VID systems use the same cameras as those used for plant security. However, the camera's video image is processed by several software algorithms to rapidly identify smoke or flame and provide an alarm. Depending on plant specific circumstances, VID may be found to provide an effective alternative to an hourly fire watch.

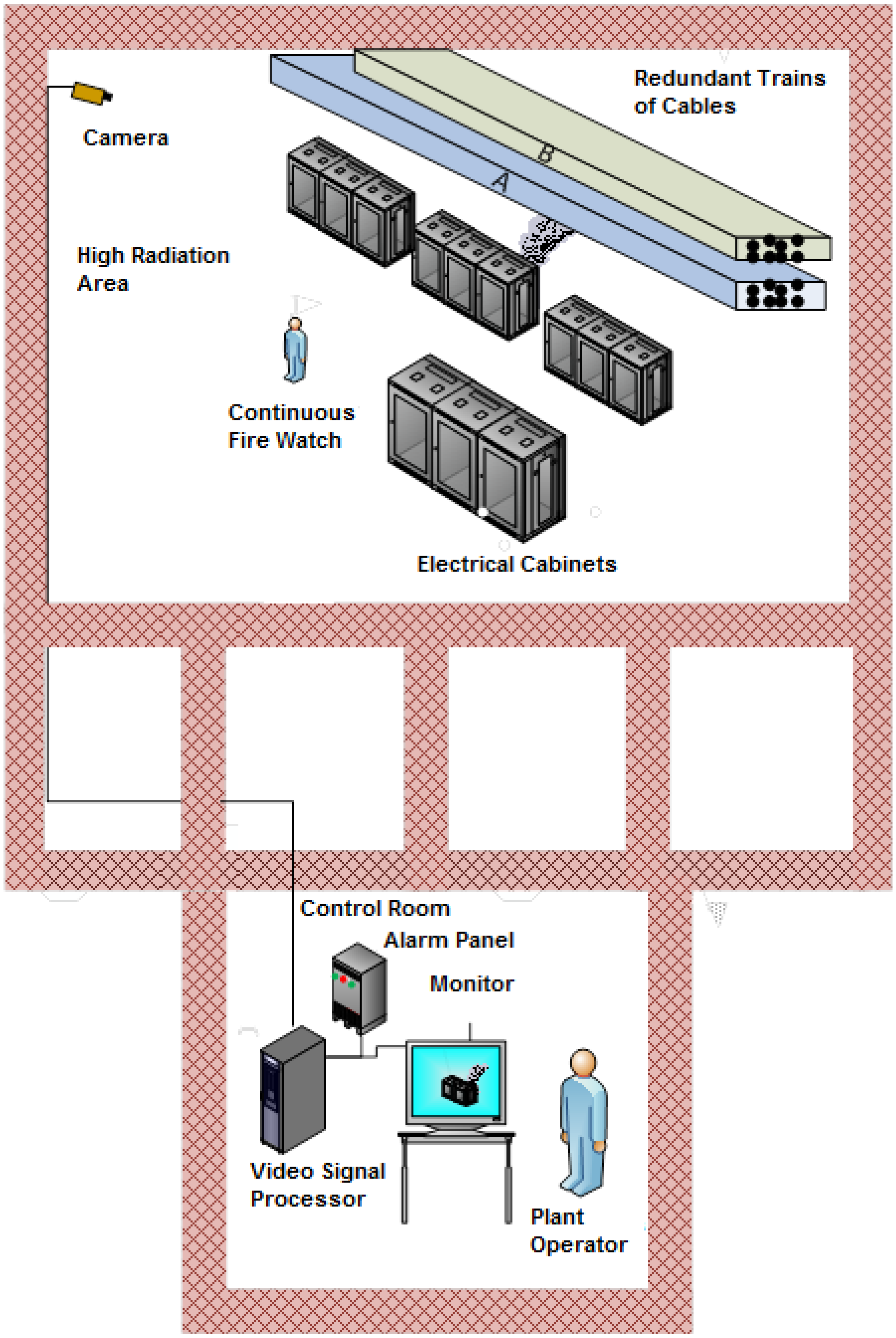

Figure 4-3: Example Use of VID System in High Radiation Large Fire Area

4.3.1 Scenario

A routine inspection and pressure test of the automatic sprinkler system failed to produce enough pressure to meet requirements. The sprinkler system was protecting cables Tray A and B (protected by a 1-hour fire rated ERFBS) associated with the credited shutdown success path. Consistent with the plants CLB, a continuous fire watch was posted as an interim compensatory measure pending investigation and resolution of the degradation. However, as illustrated in Figure 4-3, the fire area of concern is quite large and contains multiple ignition sources in close proximity to the cables of concern. Due to its physical size, the types and location of fire hazards, unique configuration of equipment and high radiation area, an alternative compensatory measure might be warranted.

Scenario Summary

Degraded / Impaired FPP Feature:	Less than adequate fire protection provided for cables of equipment credited for accomplishing required shutdown functions in the event of fire.
DID Element Directly Impacted by the Impairment:	Element 2 – Detection, suppression and mitigation
FPP-Specified Compensatory Measure:	Continuous Fire Watch
Conditions or Hazards	• High Radiation Area • In certain locations, ignition sources (e.g. electrical cabinets) are in close proximity to cable trays containing power cables of safe shutdown success path equipment credited in the SSA. • Equipment in the area hinders both the field of view of the fire watch to the cables trays and switchgear of concern and operator access to those locations. •

4.3.2 Example 3 Assessment

4.3.2.1 Evaluation of Defense-in-Depth (DID) Element 1 – Fire Prevention

The area under consideration is large with high ceilings. The primary combustibles of concern are PVC-insulated electrical cables located in enclosed metal switchgear and cable trays. As illustrated in Figure 4-3, the primary in-situ sources of fire ignition are the electrical cabinets. Transient combustibles and ignition sources are well controlled by established procedures and the area is not frequently traversed by plant personnel. The overall degradation ranking of DID Element 1 is considered to have a low degradation (Normal Operating State).

Summary of DID Element 1

Fire Prevention Feature	Degradation Ranking
Transient Combustible Controls:	L (Normal Operating State)
Transient Ignition Source Controls:	L (Normal Operating State)

4.3.2.2 Evaluation of Defense-in-Depth (DID) Element 2 – Detection, Suppression, and Mitigation

During normal operations DID Element 2 is provided by the following systems:

- automatic sprinkler system
- manual suppression by fire brigade

The automatic sprinkler system failure to meet the required pressure during the routine test would mean the addition of a continuous fire watch in order to meet Appendix R requirements. It is expected that the system be locked out in cases during investigation of the degradation. With the addition of the continuous fire watch, prompt notification of fire would typically be expected. In this case, however, the size of the area and amount of obstructions hinders the capability of the fire watch to determine the fire specific location. In addition, high radiation in the area would result in high doses to the continuous fire watch.

Summary of DID Element 2

As illustrated in Figure 4-3, the cable tray of concern is located in close proximity to a number of electrical cabinets. Because of the close proximity of the electrical cabinets, design of the enclosure (open at the top), and the degraded suppression system, a fire that starts in the electrical cabinets could potentially damage cables required shutdown equipment. However, due to such factors as the field of view of the fire watch, presence of obstructions, and large size of the fire area, confirmation of fire is likely to be delayed. The inability of the automatic suppression systems to prevent damage to equipment required for post-fire safe shutdown causes the overall degradation ranking of DID Element 2 to be considered to have high degradation (Normal Operating State).

Fire Mitigation Feature	Degradation Ranking
Detection:	Not Available
Automatic Suppression:	H – Automatic suppression system failed pressure test
Manual Suppression:	L – Normal Operating State

4.3.2.3 Evaluation of Defense-in-Depth (DID) Element 3 – Protecting SSCs Important to Safety

The during normal operation the 1-hour rated ERFBS along with the automatic sprinkler system would provide adequate protection to meet Appendix R requirements. However, given the degradation of in the DID Element 2, the 1-hour rated ERFBS would not be enough to protect the cable required for SSD from damage in case of a fire.

Summary of DID Element 3

The overall degradation ranking of DID element 3 is considered to have low degradation (Normal Operation).

4.3.3 Evaluation of Compensatory Measures

The licensee's FPP specifies that a continuous fire watch be implemented whenever the automatic suppression system is degraded or impaired. In this case the failed pressure test and possible lockout of the system during the investigation would mean that the suppression system would not have enough water pressure to suppress and extinguish a fire. When considered in combination with other factors, such as proximity of combustible cables to the ignition sources, the type of cables involved (PVC insulated), equipment obstructions and the high radiation in the area, the use of an advanced video detection system such as the one illustrated in Figure 4-3, would likely provide an alternative approach than a continuous fire watch. This system would keep doses to a minimum and provide prompt notification in case of a fire.

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6. GLOSSARY

Below are key terms or phrases whose definitions and associated context, for purposes of this document, are as shown.

Administrative Controls	Policies, procedures, and other elements that relate to the FPP. Administrative controls include, but are not limited to, inspection, testing, and maintenance of fire protection systems and features; compensatory measures for fire protection impairments; review of the impact of plant modifications on the FPP; fire prevention activities; fire protection staffing; control of combustible/flammable materials; and, control of ignition sources. [RG 1.189]
Air Sampling Detector	A detector that consists of a piping or tubing distribution network that runs from the detector to the area(s) to be protected. An aspiration fan in the detector's housing draws air from the protected area back to the detector through air sampling ports, piping, or tubing. At the detector, the air is analyzed for fire products. [NFPA 72, 2007]
Alternate Compensatory Measure	Alternate compensatory measures are those which differ from measures identified in the approved fire protection program. For example, if the approved FPP identifies a fire watch as the only appropriate compensatory measure for a degraded fire barrier, using a video image smoke detection system in lieu of a fire watch would be considered an "alternate compensatory measure." [RIS 2005-07]
Alternate Shutdown	The capability to shut down the reactor that is required when it is not feasible to provide the required protection for redundant safe-shutdown trains in one or more fire areas or where fire suppression activities, including inadvertent operation or rupture of a suppression system, could prevent safe shutdown. Appendix R to 10 CFR Part 50 allows an existing plant system to be rerouted, relocated, or modified (at the time the need for an alternative means of shutdown is identified, but not during or after the fire) such that it can perform the required safe-shutdown function that the redundant system damaged by fire or damaged by suppression system discharge would normally perform. [RG 1.189]
Approved	Tested and accepted for a specific purpose or application by a recognized testing laboratory, or reviewed and specifically approved by the NRC in accordance with the appropriate regulatory process. [RG 1.189 Revision 2]
Automatic	Self-acting, operating by its own mechanism when actuated by some monitored parameter such as a change in current, pressure, temperature, or mechanical configuration. [RG 1.189]
Code of Record	Code edition in force at the time of the design or at the time the commitment is made to the NRC for a fire protection feature. [RG 1.189]

Compensatory Actions	Actions taken if an impairment to a required system, feature, or component prevents that system, feature, or component from performing its intended function. These actions are a temporary alternative means of providing reasonable assurance that the necessary function will be compensated for during the impairment, or an act to mitigate the consequence of a fire. Compensatory measures include but are not limited to actions such as fire watches, administrative controls, temporary systems, and features of components. [NFPA 805] [NFPA Glossary 2008]
Configuration Management	Configuration management is an integrated management process used to ensure that the licensee maintains the plant's physical and functional characteristics in conformance with its design and licensing basis; that operating, training, modification, and maintenance processes are consistent with the conditions prescribed by the design and current licensing basis; and that the licensee operates and maintains the plant within these conditions [NUREG-1913]
Current License Basis	The current licensing basis (CLB) is the set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect. The CLB includes: • NRC regulations contained in 10 CFR Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 54, 55, 70, 72, 73, 100, and appendices thereto; • Commission orders; • License Conditions; • Exemptions; • Technical Specifications. • Plant specific design-basis information defined in 10 CFR 50.2 as documented in the most recent FSAR, as required by 10 CFR 50.71 • Licensee's commitments remaining in effect that were made in docketed licensing correspondence such as licensee responses to NRC bulletins, generic letters, and enforcement actions, • Licensee commitments documented in NRC safety evaluations or licensee event reports (LERs). [10 CFR 54.3(a)]

Defense-in-Depth	Fire protection for nuclear power plants uses the concept of defense-in-depth to achieve the required degree of reactor safety. This concept integrates administrative controls, fire protection systems, and safe-shutdown capability to achieve the following objectives: • Prevent fires from starting. • Rapidly detect, control, and extinguish promptly those fires that do occur. • Protect 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. [10 CFR 50.48] Defense-in-depth is an element of the NRC's Safety Philosophy that employs multiple layers or echelons of protection to prevent accidents or mitigate damage if a malfunction, accident, or naturally-caused event occurs at a nuclear facility. The defense-in-depth philosophy ensures that safety will not be wholly dependent on any single element of the design, construction, maintenance, or operation of a nuclear facility. As stated in NUREG 0050, "Recommendations Related to the Browns Ferry Fire." the goal is to provide a suitable balance of these multiple layers or echelons of protection. Increased strength, redundancy, performance, or reliability of one echelon can compensate in some measure for deficiencies in the others.
Degraded Condition	A condition of an SSC in which there has been any loss of quality or functional capability. [GL 91-18] A degraded condition is one in which the qualification of an SSC or its functional capability is reduced. Examples of degraded conditions are failures, malfunctions, deficiencies, deviations, and defective material and equipment. Examples of conditions that can reduce the capability of a system are aging, erosion, corrosion, improper operation, and maintenance. [NUREG-1913]
Design Basis	*Design bases* means that information which identifies the specific functions to be performed by a structure, system, or component of a facility, and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. These values may be (1) restraints derived from generally accepted "state of the art" practices for achieving functional goals, or (2) requirements derived from analysis (based on calculation and/or experiments) of the effects of a postulated accident for which a structure, system, or component must meet its functional goals [10 CFR 50.2] Design basis is that body of plant-specific design bases information defined by 10 CFR 50.2. [GL 91-18]
Electrical Raceway Fire Barrier System (ERFBS)	Non-load-bearing partition type envelope system installed around electrical components and cabling that are rated by test laboratories in hours of fire resistance and are used to maintain safe-shutdown functions free of fire damage. [RG 1.189]

Fire	A rapid oxidation process, which is a chemical reaction resulting in the evolution of light and heat in varying intensities. [NFPA Glossary 2008]
Fire Alarm System	A system or portion of a combination system that consists of components and circuits arranged to monitor and annunciate the status of fire alarm or supervisory signal-initiating devices and to initiate the appropriate response to those signals. [NFPA 1, 2012]
Fire Area	The portion of a building or plant that is separated from other areas by rated fire barriers adequate for the fire hazard. (RG 1.189) A plant area that is sufficiently bounded to withstand the fire hazards associated with the area and, as necessary, to protect important equipment within the area from a fire outside the area. Redundant post-fire safe shutdown systems located within a fire area are protected to provide reasonable assurance that one train of systems will be free of fire damage and available to achieve and maintain safe shutdown conditions. Licensees establish the post-fire safe shutdown systems and the plant fire areas on the basis of their plant fire hazards and safe shutdown analyses. [96TIA008]
Fire Barrier	Components of construction (walls, floors, and their supports), including beams, joists, columns, penetration seals or closures, fire doors, and fire dampers, that are rated by approving laboratories in hours of resistance to fire that are used to prevent the spread of fire. [RG 1.189 Revision 2] A continuous membrane or a membrane with discontinuities created by protected openings with a specified fire protection rating, where such membrane is designed and constructed with a specified fire resistance rating to limit the spread of fire, that also restricts the movement of smoke. [NFPA 101, 2003] In nuclear facilities, a continuous assembly designed and constructed to limit the spread of heat and fire and to restrict the movement of smoke. [NFPA 805]
Fire Brigade	A team of onsite plant personnel that is qualified and equipped to perform manual fire suppression activities. [RG 1.189]
Fire Damage	The total damage to a building, structure, vehicle, natural vegetation cover, or outside property resulting from a fire and the act of controlling that fire. [NFPA Glossary 2008]
Fire Hazards	Conditions that involve the necessary elements to initiate and support combustion, including in situ or transient combustible materials, ignition sources (e.g., heat, sparks, open flames), and an oxygen environment. [RG 1.189]

Fire Hazards Analysis	An analysis used to evaluate the capability of a nuclear power plant to perform safe-shutdown functions and minimize radioactive releases to the environment in the event of a fire. The analysis includes the following features: • identification of fixed and transient fire hazards • identification and evaluation of fire prevention and protection measures relative to the identified hazards • evaluation of the impact of fire in any plant area on the ability to safely shut down the reactor and maintain shutdown conditions, as well as to minimize and control the release of radioactive material [RG 1.189] An analysis to evaluate potential fire hazards and appropriate fire protection systems and features used to mitigate the effects of fire in any plant location. [NFPA 805]
Fire Protection Feature	Administrative controls, emergency lighting, fire barriers, fire detection and suppression systems, fire brigade personnel, and other features provided for fire protection purposes. [RG 1.189] Administrative controls, fire barriers, means of egress, industrial fire brigade personnel, and other features provided for fire protection purposes. [NFPA 805]
Fire Protection Plan	10 CFR 50.48(a) requires licensees to have a *fire protection plan* that meets General Design Criterion (GDC) 3 of Appendix A to 10 CFR Part 50. In accordance with 10 CFR 50.48, the *fire protection plan* must do the following: • Describe the overall Fire Protection Program for the facility. • Identify the various positions within the licensee's organization that are responsible for the program. • State the authorities that are delegated to each of these positions to implement those responsibilities. • Outline the plans for fire protection, fire detection and suppression, and limitation of fire damage. • Describe the administrative controls and personnel requirements for fire protection and manual fire suppression activities. • Describe the automatic and manually operated fire detection and suppression systems. • Describe the means to limit fire damage to SSCs important to safety to ensure the ability to shut down the plant safely.
Fire Protection Program	The integrated effort involving components, procedures, analyses, and personnel utilized in defining and carrying out all activities of fire protection. It includes system and facility design, fire prevention, fire detection, annunciation, confinement, suppression, administrative controls, fire brigade organization, inspection and maintenance, training, quality assurance, and testing. [RG 1.189]

Fire Protection Program Attribute	*Fire Protection Program Attributes* are characteristics of the fundamental FPP elements and may vary based on the plant licensing basis [SECY-04-0050]
Fire Protection Program Elements	*Fire Protection Program Elements* are the fundamental features or components of the approved fire protection program. [SECY-04-0050]
Fire Protection System	Fire detection, notification, and suppression systems designed, installed, and maintained in accordance with the applicable nationally recognized codes and standards endorsed by the NRC. [RG 1.189 Revision 2] Any fire alarm device or system or fire extinguishing device or system, or combination thereof, that is designed and installed for detecting, controlling, or extinguishing a fire or otherwise alerting occupants, or the fire department, or both, that a fire has occurred. [NFPA 1, 2012] Fire detection, notification, and fire suppression systems designed, installed, and maintained in accordance with the applicable NFPA codes and standards. [NFPA 805]
Fire Scenario	A set of conditions that defines the development of fire, the spread of combustion products throughout a building or portion of a building, the reactions of people to fire, and the effects of combustion products. [NFPA 101, 2012]
Fire Suppression	Control and extinguishing of fires (firefighting). Manual fire suppression is the use of hoses, portable extinguishers, or manually actuated fixed systems by plant personnel. Automatic fire suppression is the use of automatically actuated fixed systems such as water, Halon, clean agent or CO_2 systems. [RG 1.189]
Fire Watch	Individuals responsible for providing additional (e.g., during hot work) or compensatory (e.g., for system impairments) coverage of plant activities or areas for the purposes of detecting fires or for identifying activities and conditions that present a potential fire hazard. The individuals should be trained in identifying conditions or activities that present potential fire hazards, as well as the use of fire extinguishers (if applicable) and the proper fire notification procedures. [RG 1.189] The assignment of a person or persons to an area for the express purpose of notifying the fire department, the building occupants, or both of an emergency; preventing a fire from occurring; extinguishing small fires; or protecting the public from fire or life safety dangers. [NFPA 1, 2012]
Fire Zones	Fire zones are subdivisions of fire areas. [RG 1.189] [NUREG-1805] A subdivision of a fire area not necessarily bounded by fire-rated assemblies. Fire zone can also refer to the area subdivisions of a fire detection or suppression system, which provide alarm indications at the central alarm panel. [NFPA 805] Fire zones are subdivisions of fire areas defined in the context of the fire protection program. A fire zone is not necessarily bounded by fire barriers. Zone divisions are often defined based on the fire suppression and/or detection systems designed to combat particular types of fires. A fire zone may contain one or more rooms. A fire compartment may contain one or more fire zones. [NUREG/CR-6850]

Functional / Functionality	*Functionality* is an attribute of SSCs that is not controlled by TSs. An SSC is functional or has functionality when it is capable of performing its specified function, as set forth in the CLB. Functionality does not apply to specified safety functions, but does apply to the ability of non-TS SSCs to perform other specified functions that have a necessary support function. To be considered operable, a non-TS SSC does not have to be "fully qualified" in terms of its design and licensing bases as long as the licensee can demonstrate functionality. For example, if a fire protection SSC that was removed from the TS in accordance with GL 86-10 is determined to be nonfunctional, a functionality assessment should be performed to determine if it is capable of performing the function specified in the plant's current licensing basis. [IM 9900]
Heat Detector	A fire detector that detects either abnormally high temperature or rate of temperature rise, or both. [NFPA 72, 2010]
Hot Work	Activities that involve the use of heat, sparks, or open flame such as cutting, welding, and grinding. [RG 1.189]
Impairment	The degradation of a fire protection system or feature that adversely affects the ability of the system or feature to perform its intended function. [RG 1.189] Impairment exists if a fire protection feature (both active and passive) is no longer capable of performing the function(s) specified in the current fire protection licensing basis.
Incipient Stage Fire	The incipient stage of a fire is defined as the preheating, gasification and smoldering phases, thus everything occurring prior to flaming combustion. [NFPA Handbook, 2008]
In situ Combustibles	Combustible materials that constitute part of the construction, fabrication, or installation of plant SSCs and as such are fixed in place. [RG 1.189 Revision 2] Combustible materials that are permanently located in a room or an area (e.g., cable insulation, lubricating oil in pumps). [NFPA 805]
Interim Compensatory Measures	Actions taken if an impairment to a required system, feature, or component prevents that system, feature, or component from performing its intended function. These actions are a temporary alternative means of providing reasonable assurance that the necessary function will be compensated for during the impairment, or an act to mitigate the consequence of a fire. Compensatory measures include but are not limited to actions such as fire watches, administrative controls, temporary systems, and features of components. [NFPA 805] [NFPA Glossary 2008]. See Compensatory Measures.
Limiting Condition for Operation	The section of Technical Specifications that identifies the lowest functional capability or performance level of equipment required for safe operation of the facility.

Mitigate	Perform an action that stops the progression of or reduces the severity of an unwanted condition. With respect to nuclear plant fire protection, mitigation generally refers to operator actions inside or outside the main control room to restore the capability to achieve and maintain safe shutdown where a fire has degraded that capability. [RG 1.189] Activities taken to eliminate or reduce the degree of risk to life and property from hazards, either prior to or following a disaster/emergency. [NFPA Glossary 2003]
Noncombustible Material	(a) Material that, in the form in which it is used and under conditions anticipated, will not ignite, burn, support combustion, or release flammable vapors when subjected to fire or heat, or (b) material having a structural base of noncombustible material, with a surfacing not over 3 mm (c inch) thick that has a flame spread rating not higher than 50 when measured in accordance with ASTM E-84, "Standard Test Method for Surface Burning Characteristics of Building Materials" [RG 1.189] A substance that will not ignite and burn when subjected to a fire. [NFPA Glossary 2008]
Nonconforming Condition	A condition of an SSC in which there is failure to meet requirements or licensee commitments [GL 91-18]. Some examples of nonconforming conditions include the following: • There is failure to conform to one or more applicable codes or standards specified in the FSAR. • As-built equipment, or as-modified equipment, does not meet FSAR descriptions. • Operating experience or engineering reviews demonstrate a design inadequacy. • Documentation required by NRC requirements such as 10 CFR 50.49 is not available or deficient.
NRC	*NRC* means the Nuclear Regulatory Commission, the agency established by title II of the Energy Reorganization Act of 1974, as amended, comprising the members of the Commission and all offices, employees, and representatives authorized to act in any case or matter (see also *Commission*).
Onsite	As defined in the site specific UFSAR (usually refers to the owner-controlled area or real estate over which the licensee has the legal right to control access.).
Operable	A system, subsystem, train, component, or device is considered operable or have operability when it is capable of performing its specified safety function(s) This includes adequate performance of any support instrumentation, controls, electrical power, cooling or seal water, lubrication or auxiliary equipment. (NUREG 1913) **Note**: *Operable* applies to SSCs identified in the TS. Existing plant-specific TSs contain several variations on this basic definition. In all cases, a licensee's plant-specific TS definition of Operable/Operability governs. [IM 9900, Operability Determination Process 9/26/05]. *Functionality* applies to non-TS SSCs.

Operator Manual Action (OMA)	Actions performed by operators to manipulate components and equipment from outside the main control room not including "repairs." [RG 1.189] Those actions performed by operators to manipulate components and equipment from outside the main control room to achieve and maintain post fire hot shutdown, but not including "repairs." Operator manual actions comprise an integrated set of actions needed to help ensure that hot shutdown can be accomplished, given that a fire has occurred in a particular plant area. [NUREG-1852]
Passive Fire Protection Feature	A fire protection feature that provides a means of controlling a fire without a distinct change of state. Fire barriers, cable tray fire barrier system, and penetration seals are examples of passive fire protection features. Protection measures that prolong the fire resistance of an installation before an eventual fire occurrence from the effects of smoke, flames, and combustion gases. These can consist of insulation (fireproofing) of a structure, choice of noncombustible materials of construction, use of fire-resistant partitions, and compartmentation to resist the passage of fire. It includes coatings, claddings, or free-standing systems that provide thermal protection in the event of fire and that require no manual, mechanical, or other means of initiation, replenishment, or sustainment for their performance during a fire incident. [NUREG-1805]
Penetration	An opening for penetrations that pass through both sides of a vertical or horizontal fire resistance–rated assembly. [NFPA 5000, 2012]
Performance-Based Approach	A performance-based approach relies upon measurable (or calculable) outcomes (i.e., performance results) to be met but provides more flexibility as to the means of meeting those outcomes. A performance-based approach is one that establishes performance and results as the primary basis for decision-making and incorporates the following attributes: (1) Measurable or calculable parameters exist to monitor the system, including facility performance; (2) Objective criteria to assess performance are established based on risk insights, deterministic analyses, and/ or performance history; (3) Plant operators have the flexibility to determine how to meet established performance criteria in ways that will encourage and reward improved outcomes; and (4) A framework exists in which the failure to meet a performance criteria, while undesirable, will not in and of itself constitute or result in an immediate safety concern. [NFPA 805]
Post-Fire Safe-Shutdown Analysis	A process or method of identifying and evaluating the capability of SSCs necessary to accomplish and maintain safe-shutdown conditions in the event of a fire. [RG 1.189]
Post-Fire Safe-Shutdown System/Equipment	Systems and equipment that perform functions needed to achieve and maintain safe shutdown during and following a fire (regardless of whether the system or equipment is part of the success path for safe shutdown). This includes systems and equipment of which fire-induced spurious actuation could prevent safe shutdown. [RG 1.189]

Pre-Fire (Incident) Plans	Documentation that describes the facility layout, access, contents, construction, hazards, hazardous materials, types and locations of fire protection systems, and other information important to the formulation and planning of emergency fire response. [RG 1.189] A written document resulting from the gathering of general and detailed data to be used by responding personnel for determining the resources and actions necessary to mitigate anticipated emergencies at a specific facility. [NFPA Glossary 2008)
Quality Assurance	"Quality assurance" comprises all those planned and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily in service. Quality assurance includes quality control, which comprises those quality assurance actions related to the physical characteristics of a material, structure, component, or system which provide a means to control the quality of the material, structure, component, or system to predetermined requirements. [10 CFR 50, Appendix B - Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants] Attributes of a QA program include programs that preserve quality through procedures, recordkeeping, inspections, corrective actions, and audits. [NUREG-1913]
Redundancy	Redundancy refers to the provision of multiple independent methods of equivalent capacity to perform a specified function.
Redundant train or system	One of two or more similar trains of equivalent capacity in the same system powered by separate electrical divisions or one of two or more separate systems that each perform the same post-fire safe-shutdown function as its design function. With respect to fire protection regulatory requirements and guidance, a redundant train or system is distinct from an alternative or dedicated shutdown train or system. [RG 1.189]
Risk	The set of probabilities and consequences for all possible accident scenarios associated with a given plant or process. [NFPA 805]
Risk Informed Approach	A philosophy whereby risk insights are considered together with other factors to establish performance requirements that better focus attention on design and operational issues commensurate with their importance to public health and safety. [NFPA 805]
Safe-Shutdown Analysis	A process or method of identifying and evaluating the capability of SSCs necessary to accomplish and maintain safe-shutdown conditions in the event of a fire. [RG 1.189]

Safety-Related Function	A safety-related function applies to the SSCs, procedures, and controls of a facility or process that must remain functional during and following design-basis events to ensure the integrity of the facility's reactor coolant pressure boundary, the facility's capability to shut down the reactor and maintain it in a safe shutdown condition, or the facility's capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to the guidelines in 10 CFR 50.34(a)(1), 10 CFR 50.67(b)(2), or 10 CFR 100.11, "Determination of Exclusion Area, Low Population Zone, and Population Center Distance." An example of a safety related function is a facility's capability to shut down a nuclear reactor and maintain it in a safe shutdown condition. [NUREG-1913]
Smoke Detector	A device that detects visible or invisible particles of combustion. [NFPA 72, 2010]
Spot-Type Detector	A device in which the detecting element is concentrated at a particular location. Typical examples are bimetallic detectors, fusible alloy detectors, certain pneumatic rate-of-rise detectors, certain smoke detectors, and thermoelectric detectors. [NFPA 72, 2010]
Standards (Code) of Record	The specific editions of the nationally recognized codes and standards accepted by the NRC that constitute the licensing and design basis for the plant. (see Code of Record)
Standard Technical Specifications	NRC staff guidance on model technical specifications for an operating license. [NRC Online Glossary] Standard Technical Specifications (STS) are published for each of the five reactor types as a NUREG-series publication. Plants are required to operate within these specifications. [NRC Technical Specifications web page]
Standpipe and Hose Systems	An arrangement of piping, valves, hose connections, and allied equipment installed in a building or structure, with the hose connections located in such a manner that water can be discharged in streams or spray patterns through attached hose and nozzles, for the purpose of extinguishing a fire, thereby protecting a building or structure and its contents in addition to protecting the occupants. [NFPA 14 2010] The provision of piping, riser pipes, valves, firewater hose connections, and associated devices for the purpose of providing or supplying firewater hose applications in a building or structure by the occupants or fire department personnel. [NUREG-1805]
Technical Specification (TS)	Part of an NRC license authorizing the operation of a nuclear production or utilization facility. A Technical Specification establishes requirements for items such as safety limits, limiting safety system settings, limiting control settings, limiting conditions for operation, surveillance requirements, design features, and administrative controls. [NRC Online Glossary]
Transient Combustibles	Combustible materials that are not fixed in place or not an integral part of an operating system or component. [RG 1.189]

APPENDIX A: COMPARISON OF ACTIONS SPECIFIED IN STANDARDIZED TECHNICAL SPECIFICATIONS TO COMPENSATORY MEASURES IDENTIFIED IN APPROVED FIRE PROTECTION PROGRAMS

This section compares the compensatory measures specified in Historical Standardized Technical Specifications (prior to GL 86-10) to those specified in a sample of approved Fire Protection Programs.

Table A-1: Comparison of Technical Specification Compensatory Actions to Current FPP Measures

Affected System or Feature	Impairment	Original STS Action[1]	Current FPP Actions [2]	
			Plant	Action
Fire Suppression Water Supply System	One fire pump and/or one water supply inoperable	Restore to operable status within 7 days	A	Restore the water supply system to operable station within 7 days or provide an alternate backup pump or supply
			B	Restore the inoperable equipment to OPERBLE status within 7 days.
			C	Restore the inoperable equipment to operable status within 7 days.
			D	Establish hourly fire watch in fire areas where design flow requirements for required spray/sprinkler systems are not met using the electric motor-driven pump(s). Provide alternate pumping capability, OR Provide backup pumping capability and maintain fire watch
			E	Restore the inoperable pump and/or water supply to operable status within 7 days, OR provide an alternate backup pump and/or water supply.
			F	Restore on additional pump to operable/functional status OR provide an alternate pump within 7 days.
			G	Restore pump to operable status or provide a backup fire pump in 14 Days

[1] Based on NRC/RES review of the Standard Technical Specifications. Fire Protection was added to the STS in Revision 1 of each of the NSSS Vendor STS (NUREG-0103, 0123, 0212 and 0452).

[2] As specified in available revisions of plant specific TRMs and / or FPP implementing procedures developed in response to GL 86-10

Table A-1: Comparison of Technical Specification Compensatory Actions to Current FPP Measures (Continued)

Affected System or Feature	Impairment	Original STS Action	Current FPP Actions	
			Plant	Action
Fire Suppression Water Supply System	Both fire pumps and/or both water supplies inoperable	Establish backup fire suppression within 24 hours	A	Establish a backup fire protection water system within 24 hours OR within one hour initiate action to place the plant in Hot Shutdown within the following 6 hours, and Cold Shutdown within the subsequent 24 hours.
			B	Establish a backup fire suppression water system within 24 hours, OR Be in at least Hot Shutdown within the next 12 hours and in Cold Shutdown within the following 24 hours.
			C	Establish a backup fire suppression water system within 24 hours or place the reactor in Hot Standby within the next six (6) hours and in Cold Shutdown within the following 30 hours.
			D	Provide a backup supply within 24 hours And Establish hourly fire watch in fire areas where design flow requirements for required / specified spray/sprinkler systems are not met
			E	Establish a backup fire suppression water system within 24 hours.
			F	Restore at least one water supply source OR establish an alternate fire water supply within 24 hours.
			G	Provide a backup fire pump within 24 hours. If completion times are not met Be in Mode 3 within 7 hours AND Be in Mode 4 in 13 hours AND Be in Mode 5 in 37 hours.
Spray and/or Sprinkler Systems	one or more of the required spray/sprinkler systems inoperable in areas containing redundant trains of shutdown	Continuous fire watch with back up fire suppression	A	Continuous fire watch with backup fire suppression equipment
			B	Continuous fire watch with backup fire suppression equipment
			C	Continuous fire watch with backup fire suppression equipment

Table A-1: Comparison of Technical Specification Compensatory Actions to Current FPP Measures (Continued)

Affected System or Feature	Impairment	Original STS Action	Current FPP Actions	
			Plant	Action
	equipment, Outside Containment		D	Continuous fire watch with backup fire suppression equipment
			E	Continuous fire watch with backup fire suppression equipment
			F	Continuous fire watch with backup fire suppression equipment
			G	Continuous fire watch with backup fire suppression equipment
Fire Suppression Sprinkler / Spray Systems	One or more spray / sprinklers inoperable in areas NOT containing redundant trains of shutdown equipment (Outside Containment)	Hourly Fire Watch	A	Hourly fire watch
			B	Hourly fire watch
			C	Hourly fire watch
			D	Hourly fire watch
			E	Hourly fire watch
			F	Hourly fire watch
			G	Hourly fire watch
Fire Suppression CO_2 Systems (TS Rev 2: Combines LP and HP Systems in the same section)	One or more of the required LP CO_2 systems inoperable	Establish a continuous fire watch with back up fire suppression equipment for the unprotected areas within 1 hour STS Rev 2 changed this to fire watch with fire suppression equipment for those areas redundant systems or components	A	(Non-essential): Issue a Fire Protection System Impairment (FPSI) permit. Evaluate the potential impact on the impairment and implement appropriate compensatory actions.
			B	Establish a continuous fire watch and backup fire suppression equipment for the unprotected re(s) within 1 hour AND restore the system to OPERABLE status within 14 days AND Place signs at the backup fire suppression equipment to identify the proper hose to be used.

Table A-1: Comparison of Technical Specification Compensatory Actions to Current FPP Measures (Continued)

Affected System or Feature	Impairment	Original STS Action	Current FPP Actions	
			Plant	Action
		and for other areas an hourly fire watch patrol.	C	Not Applicable.
			D	Not Applicable.
			E	Establish a continuous fire watch with backup fire suppression equipment for those areas in which redundant systems or components could be damaged within 1 hour OR for those areas not having redundant systems or components establish a roving watch.
			F	Not Applicable.
			G	Not Applicable.
Fire Suppression Halon Systems	One or more Halon systems inoperable	With one or more of the required Halon systems inoperable, establish a continuous fire watch with back up fire suppression equipment for the unprotected areas within 1 hour STS Rev 2 changed this to fire watch with fire suppression equipment for those areas redundant systems or components and for other areas an hourly fire watch patrol.	A	Issue a Fire Protection System Impairment (FPSI) permit for the inoperable system. A fire tour is not required in the Min Control Room since it is continually manned.
			B	(DG Building Basement): Establish an hourly fire watch with backup fire suppression within one hour AND restore the system to OPERABLE status within 14 days
			C	Establish a continuous fire watch with backup fire suppression equipment in the area protected within 1 hour AND Restore the system operable status within 14 days or generate a Condition Report to document the event in accordance with SO-R-2.
			D	Not Applicable.

Table A-1: Comparison of Technical Specification Compensatory Actions to Current FPP Measures (Continued)

Affected System or Feature	Impairment	Original STS Action	Current FPP Actions	
			Plant	Action
			E	Establish a continuous fire watch for those areas in which redundant systems or components could be damaged within 1 hour OR for those areas not having redundant systems or components establish roving fire watch patrol within 1 hour.
			F	Establish a continuous fire watch with backup suppression equipment within 1 hour
			G	Establish a continuous fire watch with backup fire suppression capability for those areas containing redundant systems or components within 1 hour; For those areas not having redundant systems or components establish an hourly fire watch patrol within 1 hour. IF Required Action and associated Completion Times not met then initiate a Condition Report immediately.
Fire Hose Stations	One or more of the fire hose stations inoperable	Route additional equivalent capacity to fire hose to the unprotected areas from an OPERABLE hose station within 1 hour. <u>STS Rev 2</u>: route additional equivalent capacity within one hour if the inoperable fire hose is the primary mean of fire suppression; otherwise route additional hose within 24 hours. <u>STS Rev 4</u>: Changed wording to: With one or more of the fire hose stations inoperable, provide gated wye(s) on the nearest operable	A	Issue an Fire Protection System Impairment (FPSI) permit and within one hour: provide gated wye(s) on the nearest operable hose station(s) (one for the hose station and one to sufficient hose for the unprotected area); Post signs to indicate that the station is inoperable and which station is providing coverage; Post signs at the operable station indicating which hose is now providing coverage to the furthest area.
			B	Provide an alternate means of fire suppression for the unprotected areas within one hour, AND/OR Route and additional equivalent capacity fire hose to the unprotected area(s) from an OPERABLE hose station located in another fire zone using a gated wye off that operable station. Place signs at the backup fire suppression equipment to identify the proper hose to be used.

Table A-1: Comparison of Technical Specification Compensatory Actions to Current FPP Measures (Continued)

Affected System or Feature	Impairment	Original STS Action	Current FPP Actions	
			Plant	Action
		hose station. One outlet of the wye shall be connected to the standard length of hose provided at the station. The second outlet shall be connected to a length of hose sufficient to provide coverage for the area left unprotected. Where it can be demonstrated that the physical routing of the fire hose would result in a recognizable hazard to operating technicians, plant equipment, or the hose itself, the fire hose shall be stored in a roll at the outlet of the OPERABLE hose stations. Signs shall be mounted above the gated wye(s) to identify the proper hose to use. The above action shall be accomplished within 1 hour if the inoperable hose is the primary means of fire suppression; otherwise within 24 hours.	C	Stage a hose of equivalent capacity which can service the unprotected areas from an operable hose station within one (1) hour from the time that the hose station is determined to be inoperable, if the inoperable hose station is the primary means of fire suppression; otherwise, stage the additional hose within 24 hours.
			D	Route fire hose to provide equivalent nozzle flow capacity to the unprotected area(s) from the OPERABLE hose station or alternate water supply within 1 hour. (Required to run hose if operable water supply is not within 250' or area protected by the inoperable spray and/or sprinkler system)
			E	(ONE) If identified as being the primary means of fire suppression within one hour: provide gated wye(s) on the nearest operable hose station(s) (one for the hose station and one to sufficient hose for the unprotected area); Post signs to indicate that the station is inoperable and which station is providing coverage; Post signs at the operable and inoperable stations indicating which hose is now providing coverage to the furthest area; If not the primary means then actions to be completed within 24 hours. (ALL) Immediately notify the affected unit CRS/Shift Manager to suspend all hot work within the area affected until adequate compensatory measures have been established.

Table A-1: Comparison of Technical Specification Compensatory Actions to Current FPP Measures (Continued)

Affected System or Feature	Impairment	Original STS Action	Current FPP Actions	
			Plant	Action
			F	Issue an Fire Protection System Impairment (FPSI) permit and within one hour: provide gated wye(s) on the nearest operable hose station(s) (one for the hose station and one to sufficient hose for the unprotected area); Post signs to indicate that the station is inoperable and which station is providing coverage; Post signs at the operable station indicating which hose is now providing coverage to the furthest area.
			G	Provide an alternate means of fire suppression for the unprotected areas within one hour, AND/OR Route and additional equivalent capacity fire hose to the unprotected area(s) from an OPERABLE hose station located in another fire zone using a gated wye off that operable station. Place signs at the backup fire suppression equipment to identify the proper hose to be used.
STS Rev 2: Added the Section: ***Yard Fire Hydrants and Hydrant Hose Houses***	One or more of the yard fire hydrants or associated hydrant hose houses are inoperable and are the primary means of fire suppression	Route sufficient additional lengths of 2.5" diameter hose located in an adjacent operable hydrant hose house to provide service to unprotected area(s) within 1 hours if it is the primary means of fire suppression; otherwise within 24 hours	A	Within 24 hr. attach sufficient additional lengths of 2.5 in. diameter hose located in an adjacent operable hydrant hose house to provide service to the unprotected area(s).
			B	NA - Two fire carts provided in lieu of hydrant hose houses, and contain firefighting equipment necessary to support the fire brigade in response to a fire.
			C	Stage a hose of equivalent capacity which can service the unprotected areas from an operable hose station within one (1) hour from the time that a hose station is determined to be inoperable if the inoperable fire hose station is the primary means of fire suppression; otherwise, stage the additional hose within 24 hours.
			D	Establish backup suppression or verify available backup suppression on fire apparatus.

Table A-1: Comparison of Technical Specification Compensatory Actions to Current FPP Measures (Continued)

Affected System or Feature	Impairment	Original STS Action	Current FPP Actions	
			Plant	**Action**
			E	Within 24 hours, verify sufficient additional lengths of adequate hose is available on an emergency response vehicle to provide service to the Protected Area.
			F	Provide sufficient additional lengths of 2 1/2" fire hose to provide service to the affected structure (Hydrant / Structures identified in the procedure)
			G	Stage adequate fire hose lines at the nearest operable hose station to ensure equivalent capacity backup hose protection to the unprotected area
Fire Rated Assemblies (Fire Barrier)	One or more of the required barriers non-functional	With one or more of the required barriers non-functional, establish a continuous fire watch on at least one side of the affected penetration within 1 hour. STS Rev 2 added: *or verify the operability of fire detectors on at least one side of the non-functional fire barrier and establish an hourly fire watch patrol.*	A	Hourly fire watch patrol –IF detectors or auto suppression on one side of the non-functional fire barrier – Otherwise Continuous Fire Watch
			B	Hourly fire watch patrol –IF detectors or auto suppression on one side of the non-functional fire barrier – Otherwise Continuous Fire Watch
			C	Hourly fire watch patrol –IF detectors or auto suppression on one side of the non-functional fire barrier – Otherwise Continuous Fire Watch
			D	Hourly fire watch patrol –IF detectors or auto suppression on one side of the non-functional fire barrier – Otherwise Continuous Fire Watch
			E	Hourly fire watch patrol –IF detectors or auto suppression on one side of the non-functional fire barrier – Otherwise Continuous Fire Watch
			F	Hourly fire watch patrol –IF detectors or auto suppression on one side of the non-functional fire barrier – Otherwise Continuous Fire Watch
			G	If Detection is operable in the room where the barrier is located establish Hourly Fire Watch, otherwise a Continuous Fire Watch is required

APPENDIX B: ADVANCED TECHNOLOGIES

In recent years, significant advances in fire protection engineering technology have emerged which warrant consideration as possible alternatives or improvements to the compensatory measures typically identified in approved FPPs. Depending on the plant-specific circumstances, these technologies may provide an adequate or improved level of compensation when used alone or in conjunction with the traditional measures specified in the approved FPP. The suitability of any specific alternative needs to be evaluated on a case-by-case basis.

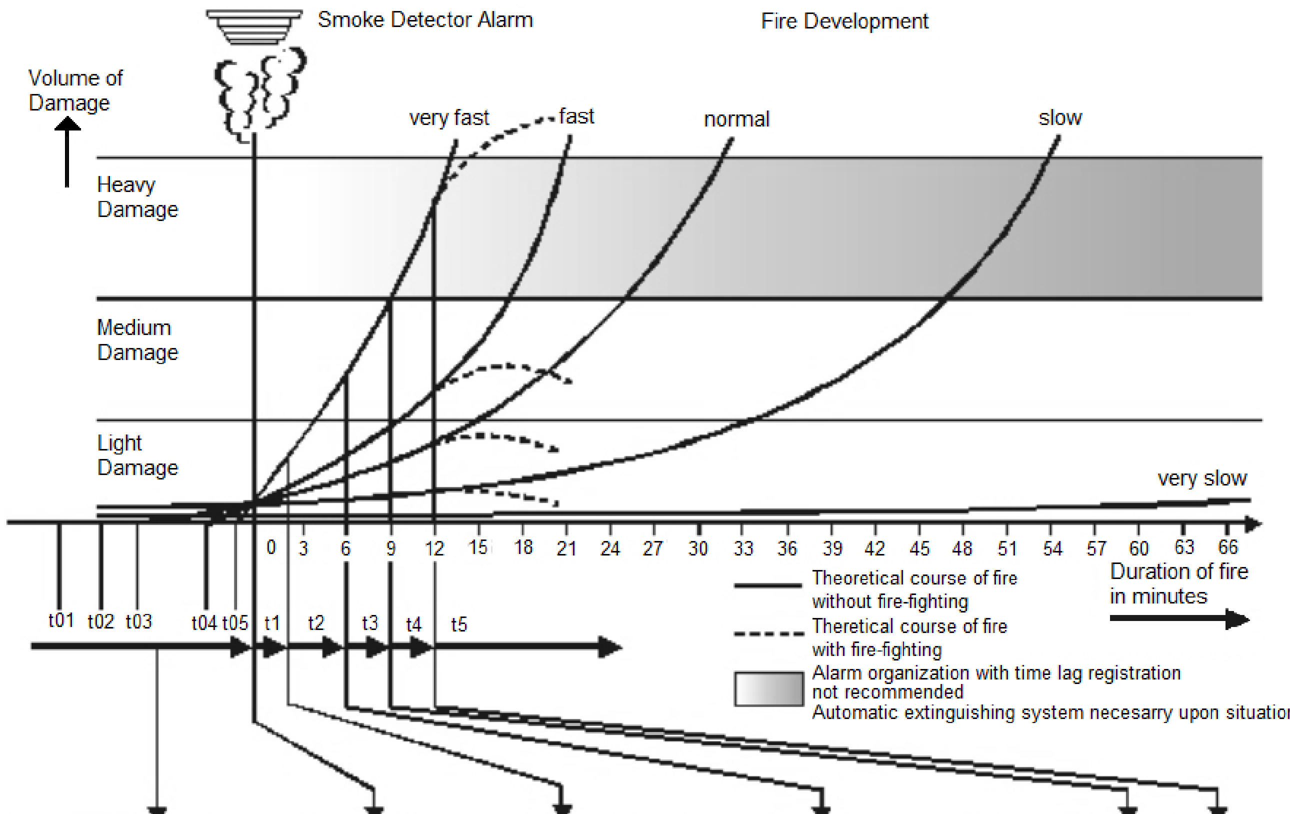
The following examples illustrate the types of advanced detection and suppression technologies that are currently available. Their inclusion in this Appendix does not constitute an endorsement by the NRC. In addition, depending on plant-specific circumstances (e.g., license-basis requirements, fire hazards, physical construction, and operating practices), the technologies may not be cost-effective, may be difficult to implement, or may not provide an appropriate method of compensation.

B.1 Advanced Detection Technologies

Early detection is a key factor in minimizing the likelihood of fire damage to equipment and components important to safety. The earlier a fire is detected, the sooner it can be controlled and extinguished. The initiation of combustion typically requires the conversion of fuel into a gaseous state usually by heating. The chemical decomposition of a solid substance by heat is called pyrolysis. During this phase, microscopic combustion particles are emitted that may be too small concentration to actuate conventional ionization and photoelectric-smoke detectors. While certain standard photoelectric and ionization detectors may be set to very high sensitivities, increasing sensitivity beyond the normal range can result in a high number of nuisance alarms.

Recent advances in sensor types and signal-processing technologies have led to the development of fire detection systems that can detect particles emitted during the pyrolysis or "incipient" [1] stage of fire growth. As shown in Figure B-1 below, detector actuation during the incipient stage may minimize fire damage by allowing early intervention, frequently before suppression is necessary.

[1] The incipient stage of a fire is defined as the preheating, gasification and smoldering phases, thus everything occurring prior to flaming combustion. [NFPA Handbook, 2008]



Incident	Start of Fire	Incipient phase before fire detection by fire alarm	Early warning detector detects fire	Start of RS check 1*	Reaction of operating personnel	Can-celling of RS check 1*	Start of RS check 2*	Investigate source of signal	Decision: - Emergency: Press alarm push button, alerting fire department	Start of initial rescue and fire-fighting operations	Assembly time of fire department	Turn-out time of fire department	Start co-ordinating fire-fighting
Time point	t01 - t05	t01 - t05/t1	t1	t1	t1 - t2	t2	t2	t2 - t3	t3	t3	t3 - t4	t4 - t5	t5
Time require-ment ϕ	—	unknown	—	—	ca. 2 min.	—	—	ca. 4 min.	—	—	ca. 3 min.	ca. 3 min.	—
ϕ Time requi-rement total	—	—	—	—	—	ca. 2 min.	—	—	ca. 6 min.	—	—	ca. 12 min.	—
Detection phase				Reaction, assembly and fire-fighting phase									

* RS Check = Reconnaissance squad check

Figure B-1: Qualitative Relationship between Time and Damage for Different Speeds of Fire Development and Average Detection, Reaction and Fire-Fighting Times [NUREG/CR-2409]

Systems that can detect low-energy fires before fire conditions threaten equipment communication service are referred to as Very Early Warning Fire Detection (VEWFD) Systems. For a fire detection system to be considered a VEWFD system, it must meet the sensitivity criteria specified in NFPA 76, “Standard for the Fire Protection of Telecommunication Facilities”. For example, aspirating smoke detector (ASD) systems typically have multiple alarm thresholds that are determined by the performance objectives of the application and the smooth-bore pipe network design. For an ASD to be classified as a VEWFD system the following minimum sensitivity setting above ambien air borne levels must be achieved:

1. It must be set up to provide Alert thresholds of at least 0.2 percent per foot obscuration (effective sensitivity at each sampling port), and,

2. Alarm thresholds of at least 1.0 percent per foot of obscuration (effective sensitivity at each port).

Additionally, a maximum transport time from the most remote port to the detection unit of an air-sampling system shall not exceed 60 seconds.

Detection technologies capable of satisfying the criteria in NFPA 76 for classification as a VEWFD system are available, and have been used extensively in the telecommunications industry for several years to guard against service disruptions caused by fire. It should be noted, that conventional spot type detectors installed to meet the requirements of NFPA 72 may be described as being able to detect incipient fires. However, to obtain the credit as a VEWFD system, the detection system must be capable of meeting the more stringent requirements in NFPA 76. Currently, the two primary types of VEWFD systems available are aspirated (air sampling) smoke detectors, and laser-based, spot-type, smoke detectors.

B.1.1 Aspirating (Air Sampling) Smoke Detectors

Thermal decomposition (pyrolysis) takes place causing solid materials to generate microscopic particles. Aspirating smoke detectors (ASDs) are capable of detecting the particles that evolve during pyrolysis which typically occurs well before the appearance of visible smoke. As discussed below, there are variations between specific designs. However, all ASD designs operate by actively and continuously sampling the air in a protected space. An aspirator (i.e. fan) draws air through a series of small holes in a piping network to an optical measuring chamber. Inside the chamber a light source (e.g. high energy light source, laser or light-emitting diode [LED]), optical sensor and detector develop a signal that is proportional to concentration of combustion particles in the sampled air. The sensitivity and performance of the ASD system will vary by designs of the piping network and the detector.

Obscuration, or the effect that smoke has on reducing visibility, is a unit of measurement which defines smoke detector sensitivity. A detector that requires higher concentrations of smoke to alarm will have a higher obscuration level (lower sensitivity). Systems used for very early warning of smoke and fire must be capable of sensing low smoke levels, with obscuration values of 0.2% per foot or less. ASDs are capable of providing a much earlier warning of an impending fire than the traditional, spot-type ionization and photoelectric detectors.

Currently, there are two basic ASD sensor technologies: Cloud Chamber and Light Scattering. As illustrated in the following paragraphs, all aspirating smoke detectors use an aspirator (fan) to draw a sample of air from a series of pipes or tubes into a detection chamber. What differs is the technology used to measure the amount of smoke in the sampled air.

B.1.1.1 Cloud Chamber ASD

As shown in Figure B-2, in a cloud chamber smoke detector, a sample of air is drawn into a high humidity chamber. After the air sample is raised to a high humidity, the pressure is slightly reduced. If smoke particles are in the air, the moisture in the air condenses on them, forming a cloud in the chamber. The light obscuration of the cloud is a measure of the number of particles in the air sample (number density). The detector responds when the inferred number density is greater than a preset level. The cloud chamber system typically uses a valve and switching arrangement to sample from several detection zones.

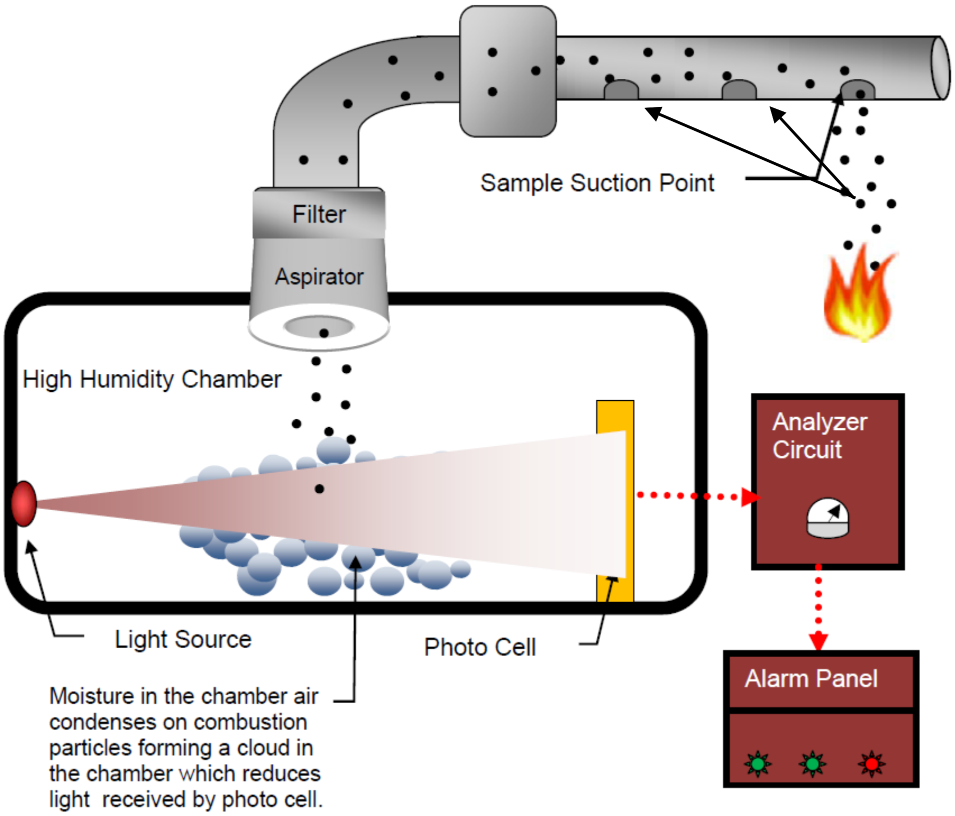


Figure B-2: Cloud Chamber

B.1.1.2 Light Scattering ASD

A stream of sampled air is continually passed through a detection chamber in which a high-energy light source is pulsed. Unlike the cloud chamber that senses light obscuration, the photosensitive device is not in the path of the light beam. As smoke particles enter the sensing chamber, light is reflected (scattered) from the smoke particles on to the photosensitive device causing the detector to respond. As illustrated in Figure B-3, an arrangement of light emitters, screening disk, and receivers inside the measuring chamber prevent emitted light signals from hitting the optical receiver cell during normal (no fire) conditions. Should smoke enter inside the box through the inlet apertures, the floating smoke particles will scatter the light signal. Those scattered light rays will hit the optical cell and be transformed into an electric signal. The intensity of scattered light at a particular angular range is measured by a solid-state light receiver, and is proportional to the smoke's concentration for a fixed size distribution of smoke particles. The analyzer circuit triggers an alarm when a threshold value is exceeded for a predetermined number of consecutive pulses.

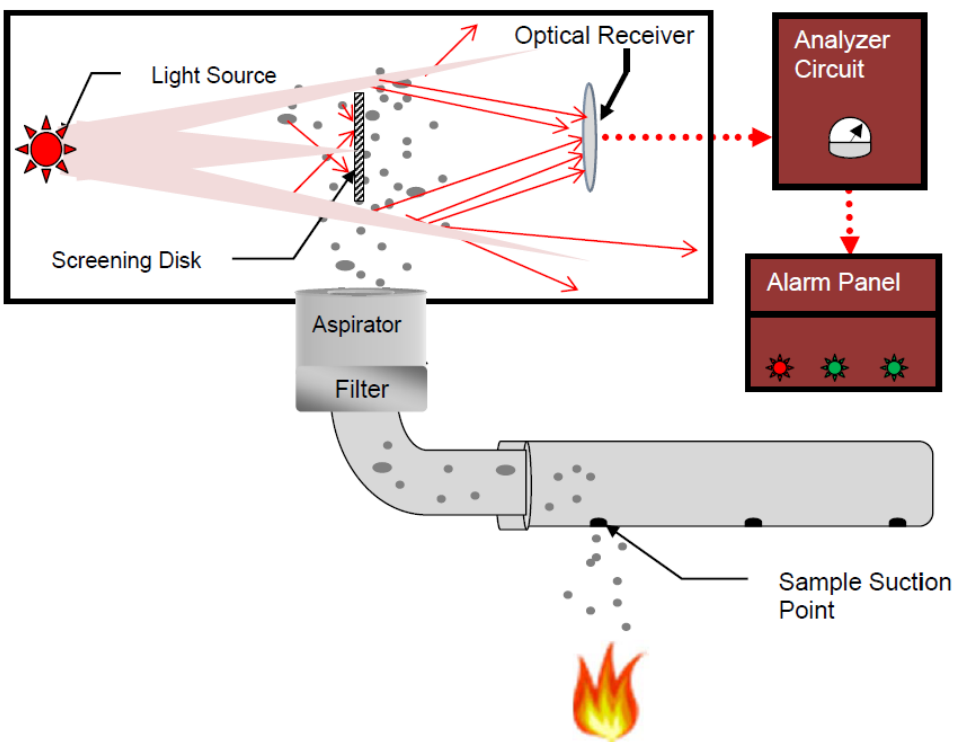


Figure B-3: Light-Scatter Aspirating Smoke Detector

B.1.2 Laser-based Spot-type Smoke Detectors

Spot-type detectors, similar in appearance to traditional ceiling-mounted detectors, are available that meet NFPA 76 criteria for application as a VEWDS. The principles of laser detection are similar to those of light-scattering photoelectric technology. In a photoelectric smoke detector, an LED emits light into a sensing chamber that is designed to keep out ambient light while allowing smoke to enter. Any particles of smoke (or dust) entering the chamber will scatter the light and trigger the photodiode sensor. Rather than a light-emitting diode (LED), laser-spot detectors use a laser diode coupled to a lens, such that it creates a narrow but very intense light-beam which provides greater sensitivity than a standard photoelectric detector. If a particle of smoke enters the chamber, light from the laser is scattered and sensed by a photo detector. Algorithms built into the detector check the nature of the scattered light to determine whether the source is dust or smoke. If a determination of smoke is made, the alarm is signaled.

Laser-based detectors also provide multiple alarm set-points that generally are configurable. In one design, users can select from nine different sensitivities in the range of 0.02–2% per foot obscuration for either pre-alarm or alarm-settings.

Key Benefits

- Laser-based detectors can be mixed with standard photoelectric or ionization detectors on the same loop or system,
- An addressable system allows the exact location of fire to be identified, and,
- They can detect both fast-flaming and slow-smoldering fires.

Potential Limitations

- Because they might generate unwanted alarms, laser-based detectors may not be suitable for use in areas containing large concentrations of dust or in areas where welding or other processes are undertaken that generate combustion particles.

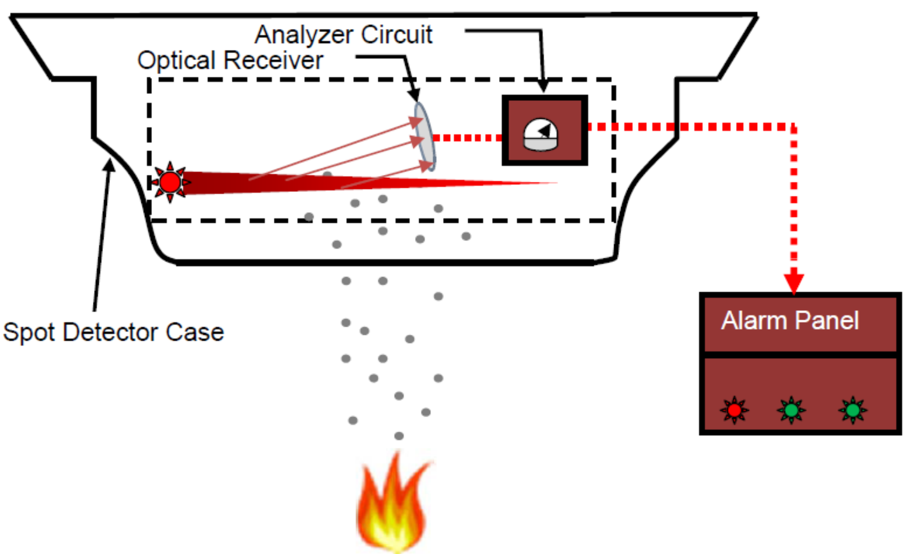


Figure B-5: Spot-Type Laser Detector

B.1.3 Video-Image Detection

Recent improvements in the capabilities of video cameras, computer processing, and image analysis, combined with a desire for real-time monitoring capabilities, have driven the development of advanced video-image detection (VID) systems similar to the one illustrated in Figure B-6.

Advanced VID systems should not be confused with standard closed-circuit television (CCTV) systems, such as those used for plant security. While VID systems may use the same cameras, the video image from the camera is processed by proprietary software to determine if smoke or flame from a fire can be identified in the video image. The detection algorithms identify the flame and smoke characteristics based on spectral, spatial, or time-based properties, such as changes in brightness, contrast, edge content, motion, dynamic frequencies, and pattern and color-matching. Unlike conventional fire detectors, VID is not governed by a single physical principle, such as temperature or optical obscuration. Instead, several software algorithms detect features in the video that correspond to one or more visible characteristics of fire.

The National Fire Alarm and Signaling Code, NFPA 72, covers the application, installation, location, performance, and maintenance of fire alarm systems and their components. The use of VID systems for flame and smoke detection was first recognized in the 2007 edition of the National Fire Alarm Code[2].

Multiple environmental and system variables must be considered in designing and using a VID system, including obstructions, changing light levels, ventilation, lens contamination, and camera settings. Depending on the particulars of an application, the installation goals and performance criteria could vary significantly. Consequently, NFPA 72 specifies a performance-based design approach in the form of an engineering evaluation. This means that VID systems should be designed to achieve a specified goal for a specified use or application.

Key Benefits

- VID systems can protect a large area, while achieving fast detection. They can detect smoke or flame anywhere within the camera's field of view, whereas conventional smoke detectors require smoke to migrate to the detector.
- They can be used in outdoor applications.
- Digitized video and/or audio streams can be sent to any location via a wired and/or wireless Internet Protocol network, enabling video monitoring and recording from anywhere with network access.
- They can use the system's basic hardware (i.e., the cameras and wiring) for multiple purposes (e.g., fire, flood, security, equipment monitoring).
- They improve the operator's response and verification of positive events.
- Video archiving of events supports future investigations of fire.
- They can operate in environments where spot detectors may not be effective.
- Instant situational awareness reduces the operator's and fire brigades' response time.
- They could contribute to the effort to maintain exposures to ionizing radiation "as low as reasonably achievable possible" (ALARA) in areas of high radiation.

[2] As part of the 2010 revision, the title was changed from "National Fire Alarm Code" to "National Fire Alarm and Signaling Code."

- Camera systems may already be installed for NPP requirements (e.g. security)

<u>Potential Limitations</u>

- VID systems require a certain minimum amount of light for effective detection; most will not work in the dark.
- Depending on the software's algorithms, nuisance alarms may be generated by events other than fires, such as steam from vents, or exhaust from vehicles. It should be noted that the potential for nuisance sources highly depends on the specific VID technology. Some systems have the ability to ignore areas of the field of view that may have potential nuisance sources, to adjust sensitivity, and to adjust the persistence time of the event before issuing an alarm signal. Manufacturers also have developed specific alarm algorithms to avoid signaling common nuisance events.
- VID systems should not be expected to perform in the environments outside the normal operating space of general CCTV installations (e.g., pointing a camera where the sun can be in field of view).
- Video images may be degraded by environmental contaminants or hardware adjustments that change the image's focus and brightness. Self-diagnostic capability typically is required to determine quality of the video image quality for proper detection.
- Because VID is a line-of-sight device, it typically requires an unobstructed view of the area to be protected.

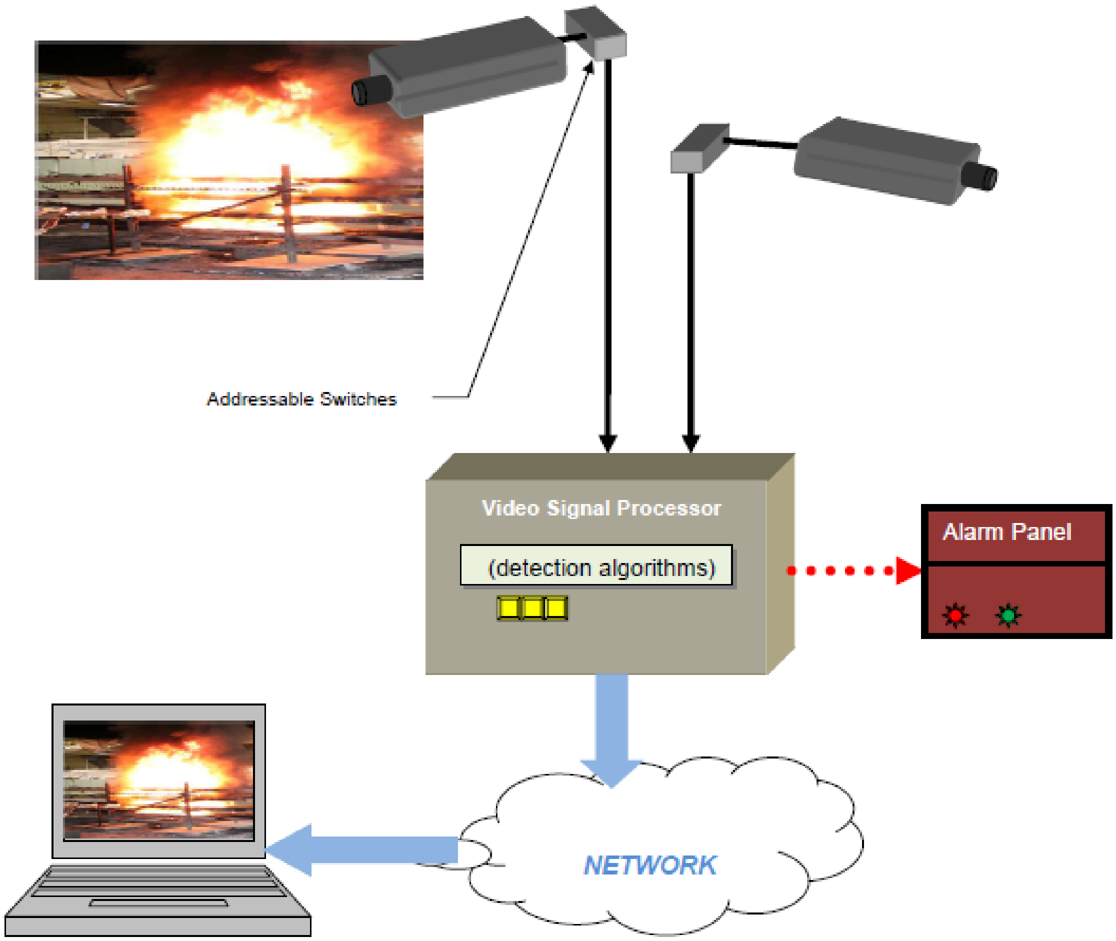


Figure B-6: Video Image Detection

B.1.4 Thermal-Imaging Cameras

One tool currently available to identify possible fire initiators is the thermal-imaging camera. The advantage of this device is its ability to rapidly display areas of varying temperatures without contact. This allows specific elements of equipment that are operating at higher temperatures to be identified.

A thermal-imaging instrument measures radiated infrared (IR) energy and converts the data to corresponding maps of temperatures. With this technology, cameras capture this energy. Thereafter, the camera's video signal processor reads the infrared signals and translates them into an image that we can easily see, providing an early warning of hot spots that are detected. Because thermal-imaging cameras use the heat emitted from an object to produce images, they can work in the dark. Furthermore, it is possible to "see" the surface temperature of any object. A true thermal image is a gray-scale image with the hot items shown in white, and the cold items in black. Temperatures between the two extremes are shown as gradients of gray. Some thermal imagers enhance the operator's performance by adding color that is artificially generated by the camera's electronics in response to the thermal attributes seen by the camera.

Infrared (IR) spot measurements may also be acquired by a simple IR point radiometer (sensor) that measures an object's emitted IR energy and converts it into digital temperature readout. However, a point radiometer does not generate an image of the object and, thus, it is difficult to find what or where the problem is without actually scanning the entire object or its surface.

Thermography may serve as an alternative or complementary approach to conventional fire detection technologies provided the system includes some basic features, such as the ability to

- detect and clearly visualize emerging hot spots,
- measure and indicate temperature, and
- raise an alarm when a temperature threshold is exceeded.

Often, deterioration, such as high contact resistance in a circuit breaker contact, or loose electrical connections, produce warning signs that can be identified by a thermal-imaging device. Using a hand-held infrared camera, potential precursors to fire ignition can be quickly identified for evaluation; in many cases, they can be detected well before an actual failure. Many NPP fire brigades currently use this technology as hand-held thermal imaging cameras (TICs) to aid in locating and evaluating fire conditions. Other applications include locating potential ignition-sources before a fire, such as loose electrical connections, failing/overheated transformers, and overloaded motors or pumps.

Advantages

- These cameras allow monitoring of locations that are difficult to reach due to extreme environmental conditions.
- They provide early identification of potential sources of ignition, such as hot spots in electrical switchgear enclosures or transformers.
- They can significantly enhance the capabilities of a fire watch, and may justify less frequent tours of certain areas.
- They offer a warning before an actual fire occurs.
- They could contribute to the effort to maintain exposures to ionizing radiation "as low as is reasonably achievable" (ALARA) in high-radiation areas.
- Camera systems may already be installed for NPP requirements (e.g. security)

Potential Limitations

- Conditions that cause the camera's thermal detector to become saturated, or in which the range of temperatures detected becomes too wide for the optics and/or electronics to operate at the highest resolution.
- Thermal images may be difficult to interpret. Reflections and low surface-emissivity can produce false indications; training in their usage is required.

B.2 Advanced Suppression Technologies

Research into the development of Halon alternatives has resulted in new fire extinguishing agents that have been incorporated into the design of completely self-contained fire suppression systems and devices. The systems typically use clean agents that are non-conductive and leave no residue. Clean Agents are particularly useful for hazards where:

- An electrically non-conductive agent is required
- Cleanup of other agents presents a problem
- Hazard obstructions require using a gaseous agent
- The hazard is normally occupied and requires a non-toxic agent

Types of hazards typically protected with clean agents include the following:

- Computer rooms
- Control rooms
- Telecommunications facilities
- Electric switchgear

Although clean agents are most common, the systems are generally compatible with most commercially available fire suppression agents. The suppression of fires by clean agents is covered by the NFPA 2001, Standard on Clean Agent Fire Suppression Systems. The self-contained design of the examples illustrated in the following paragraphs enables them to provide a standalone, transportable, fire suppression system. Depending on the plant-specific circumstances, they may provide an effective alternative to compensatory measures specified in the FPP.

B.2.1 Solid Propellant Gas Generators

Based on automotive airbag technology, gas generators have been developed for fire suppression applications. Gas generators can produce a large quantity of gases (mainly N2, CO_2 and water vapor) by the combustion of solid propellants. Solid propellant gas-generators typically consist of solid propellant tablets that rapidly generate a gas when ignited. Two common types of solid propellant gas generators are condensed aerosol extinguisher which produces a powdered aerosol, and a nitrogen generator that produces inert nitrogen gas.

B.2.1.1 Condensed Aerosol Generators
In a condensed system, the aerosols are produced by an exothermic chemical reaction (i.e., pyrotechnically) using a solid compound. When the system is activated, the aerosol is introduced into a space through a delivery system similar to that used for gaseous agents. Condensed aerosol generators are completely self-contained and suitable for dealing with nearly all types of plant fire hazards.

The condensed aerosol generator can be activated manually, thermally (by the fire), or electrically from a suitable detection device. Different sized generators are available to protect different volumes. In addition, several generators can be strung together to provide additional coverage. The design, installation, operation, testing, and maintenance of condensed aerosol fire-extinguishing systems are governed by NFPA 2010, Standard for Fixed Aerosol Fire-Extinguishing Systems.

As illustrated in Figure B-7, a condensed aerosol generator is completely self-contained within a heavy-duty aluminum canister that can be easily installed as needed. Since the extinguishing agent can be stored in a dense solid form until activated, the condensed aerosol generators can be fairly small. Hence, the canisters may be hung from walls, ceilings, or mounted within an enclosure.

Key Benefits

- Compact
- Lightweight
- No pipework required
- Environmentally friendly
- Ease of installation
- Long service-life
- High extinguishing efficiency

Possible Limitations

- Reduced visibility in a protected space following discharge.
- The temperature of the expelled aerosol near the generator surface may be as high as 200 °C (392°F).
- They are effective only in closed spaces, and may not be suitable for ventilated enclosures.
- They should not be used in normally manned enclosures.
- Mounting them within enclosures could increase costs.
- Canisters would need to be placed close to the source.

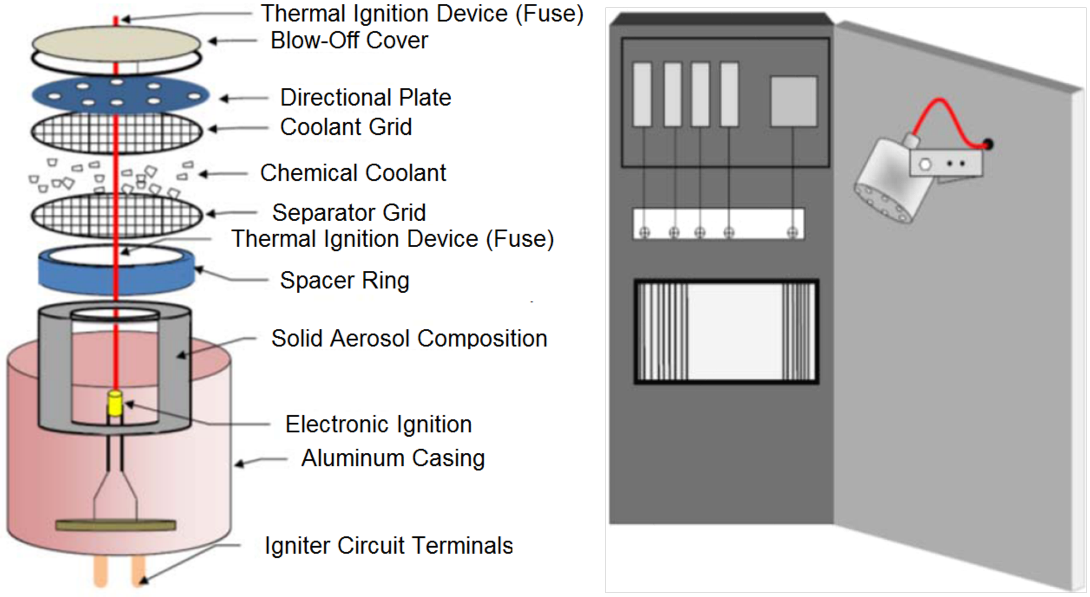


Figure B-7: Condensed Aerosol Generator

B.2.1.2 Nitrogen Gas Generators

As shown in Figure B-8, Nitrogen (N2) generators are physically similar to condensed-aerosol generators. Like the condensed aerosol generator, the N2 generator does not need high-pressure gas-storage cylinders and associated piping networks. Nitrogen generators produce an inert N2 gas, which reduces the concentration of oxygen in a room below the level that will sustain combustion. However, the oxygen concentration is maintained at a sufficient level to meet the requirements of NFPA 2001 for clean agent Halon 1301 alternatives in normally occupied areas.

N2 gas generation is initiated in response to an electrical signal generated by a fire detector, fire control panel, or a manual pull station. The electrical signal actuates a pyrotechnic device (squib) that ignites the solid N2 fuel. Suppression coverage varies with the size of the generator canister. One manufacturer states that a single 6” x 12” generator will cover up to 200 cubic feet. Individual generators can be installed under floors, on ceilings, or inside cabinets and multiple generators can be daisy-chained together to provide capability for total room flooding. N2 systems should conform to NFPA 2010 Standard on Aerosol Fire-Extinguishing Systems - Edition 1 and UL 2775 - Fixed Condensed Aerosol Extinguishing System Units - Edition 1.

<u>Key Benefits</u>

- Long (up to 25 year) service-free shelf life
- Rechargeable on site
- Compact

- No piping or nozzles
- Releases harmless, inert, N_2 gas; maintains oxygen levels that are safe for occupied spaces
- No residue or cleanup

Potential Limitations

- Enclosure must be capable of holding the gas and be able to withstand the pressure produced during discharge
- Could require oxygen monitoring on installed enclosures to ensure habitable conditions

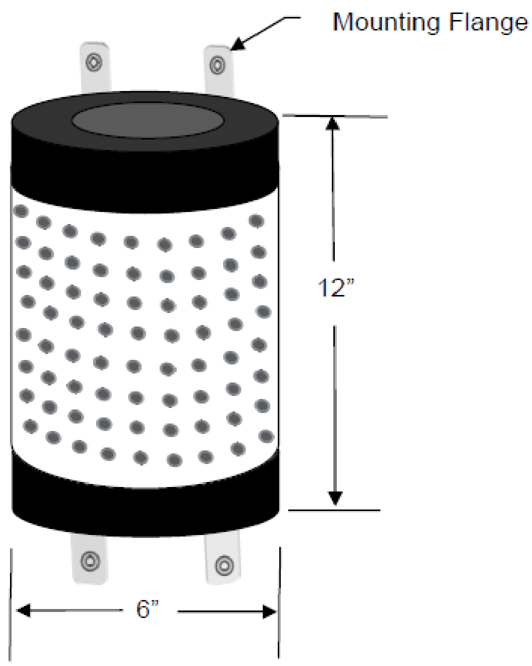


Figure B-8: N2 Gas Generator

B.2.2 Transportable Automatic Suppression Systems

Several self-contained, transportable, fire suppression systems are commercially available that can detect and extinguish fires inside equipment, cabinets, or enclosed spaces up to 250 cu. ft.. As illustrated in Figure B-9, these systems incorporate flexible, polymer tubing that acts as both a fire detector, and suppressant dispersion nozzle. When exposed to the heat of fire (typically 100°C), the tubing ruptures to dispense the suppression agent. A key advantage of these systems is that the flexible polymer tubing can be routed to provide protection in many different types of enclosures, including cable trays. In addition to being highly transportable, these systems do not require any type of outside electrical source or detection system, and remain operational during power outages. Depending on the situation, multiple systems might need to be acquired to provide adequate coverage.

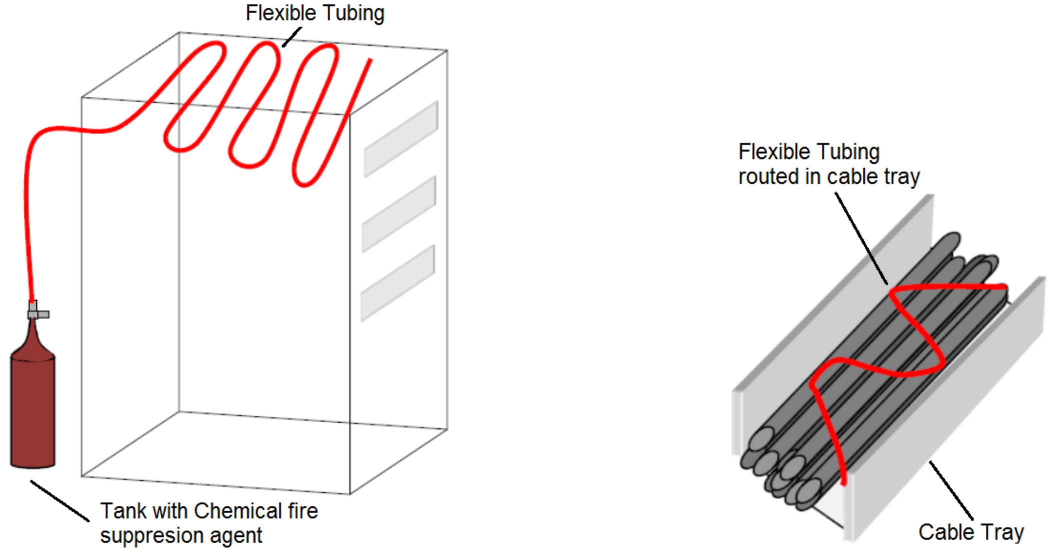


Figure B-9: Transportable Suppression System Applications

B.2.3 Pre-packaged Portable Water-Mist Systems

Water has several favorable properties for fire suppression. When applied in a fine mist, its effectiveness is improved further by the increased surface area of water that is available for heat absorption and evaporation. Water-mist systems have been demonstrated to extinguish a wide variety of fires, including those in electrical and electronic equipment cabinets. In addition, evacuation of the compartment may not be necessary, and the electronic equipment can be continuously operated during the discharge of a water mist, especially if a zoned system is used [Liu 2001].

NFPA 750, Standard on Water Mist Fire Protection Systems, contains the minimum requirements for the design, installation, testing, and maintenance of such systems. Pre-packaged, self-contained, portable water-mist systems are of particular interest for their possible use as an alternate compensatory measure. As illustrated in Figure B-10, a completely self-contained system that is pre-packaged on steel-plate skid is commercially available. The water cylinder is bolted to the skid, and the nitrogen cylinder(s) are mounted to the water cylinder with straps. The skid is designed so it can be easily transported with a fork lift (which may be a limitation at NPPs where accessibility and available space is limited). According to one manufacturer, this system successfully extinguished fires in Factory Mutual's fire tests for machinery spaces[3] up to 9,175 ft^3 (260 m^3). Some systems may require additional sensors or a control panel to actuate.

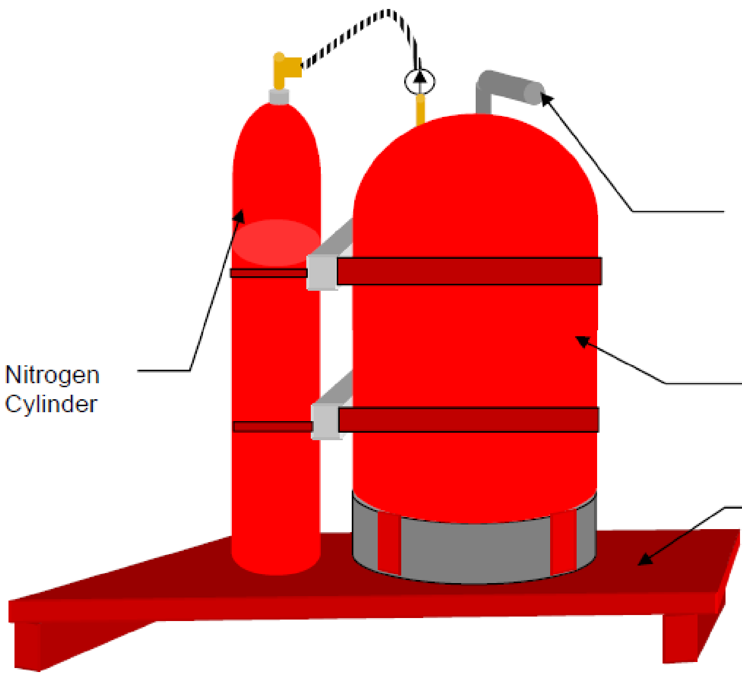


Figure B-10: Skid-mounted Water Mist System

B.3 Temporary Fire Barrier Penetration Seals

To contain fire damage and help prevent the spread of toxic products of combustion (e.g., smoke, hot gases and fumes) NPPs use fire-rated barriers to divide the plant into separate fire areas. The fire-rated walls, floors, and ceiling assemblies (structural fire barriers) have sufficient fire resistance to withstand the fire hazards associated with the area and to protect important equipment located in the area from a fire that occurs outside the area. These structural fire barriers may contain several penetrations or openings to allow such services as piping, electrical conduits, cable trays and ventilation ducts to pass from one fire area to another. To maintain the fire-resistive integrity of the barriers, and provide reasonable assurance that a fire will be confined to the area in which it started, openings and voids in structural fire barriers are closed with penetration seal-assemblies, also known as firestops, that have been tested and qualified to ensure the fire resistance rating of the barrier is maintained.

According to NUREG-1552, each NPP has an average of 3,000 penetration seals. However, a single NPP may have as many as 10,000. The fire at the Browns Ferry NPP in 1975 illustrated

[3] A machinery space is defined as areas that contain flammable liquid processing hazards with Class 1, 2, or 3 flammable liquids as specified in NFPA 325 and incidental Class A combustibles

how improper penetration seal materials can contribute to the spread of fire. Today, penetration seal materials are available that, if properly installed and maintained, will maintain the fire-resistive integrity of the fire barriers in which they are installed. A rated fire barrier penetration seal system includes the fire-rated wall or floor, the opening, the penetrating item cable conduit (e.g. pipe) that passes through the opening, and the material used to seal the opening. The performance of a penetration seal depends upon the specific assembly of materials tested including the attributes such as number, type, and size of penetrating components, the thickness of the seal material and the ceiling/floors or walls in which it is installed. Achieving an effective penetration seal requires taking all of the components present into consideration when selecting the material that is best suited for that application.

Fire barrier penetration seals are intended for use in protecting openings in fire-resistive walls, floors, and ceilings that have been evaluated in accordance with ASTM E119, "Standard Test Methods for Fire Tests of Building Construction and Materials." Conformance to either ASTM E814-11 or IEEE Std. 634-a provides assurance that the penetration seal (firestop) meets its design objective of ensuring that the penetrated fire barrier will be able to withstand the fire hazards located within the area of concern, and will adequately protect important equipment located in the area from a fire that occurs outside it.
Not all fire barriers and fire barrier penetration seals have the same level of safety significance. The importance of a specific fire barrier depends on many factors, such as the importance of the equipment in the fire area (and adjacent areas); the configuration and location of combustible materials and other fire hazards, if any, in the areas; the potential for fire growth in the areas; the other fire protection features installed in the areas; and the accessibility of the areas to the plant's fire brigade. Similarly, the importance of a specific fire barrier penetration seal depends on these factors and on such other factors as its size, location, or position in the fire barrier, and the number and sizes of the other seals in the barrier.

In Generic Letter 86-10, the NRC staff established that certain penetration seals need not have the same fire rating as the barrier in which they are installed, and that certain fire barrier penetrations may not need to be sealed at all provided they are considered by the plant in its evaluation of the overall effectiveness of the barrier. Specifically, Interpretation 4, "Fire Area Boundaries," states, in part:

> *The term "fire area" as used in Appendix R means an area sufficiently bounded to withstand the [fire] hazards associated with the area and, as necessary, to protect important equipment within the area from a fire outside the area. In order to meet the regulation, fire area boundaries need not be completely sealed floor-to-ceiling, wall-to-wall boundaries. However, all unsealed openings should be identified and considered [in] evaluating the effectiveness of the overall barrier. Where fire area boundaries are not wall-to-wall, floor-to-ceiling boundaries with all penetrations sealed to the fire rating required of the boundaries, licensees must perform an evaluation to assess the adequacy of fire boundaries in their plants to determine if the boundaries will withstand all [fire] hazards associated with the area.*

Thus, for penetration seals that cannot be demonstrated to meet ASTM E814-11a, an engineering evaluation may be used to determine the expected fire resistance rating. Licensees evaluate such seals on a case-by-case basis. The engineering evaluations that assess the effectiveness of the penetration seals are based on the seals' expected fire resistive performance and on the fire hazards and fire protection features in the fire area. These analyses may use computer simulations and mathematical fire modeling, thermodynamics, heat-flow analysis, and materials science to predict the performance of the penetration seal assembly. Deviations from the NRC's requirements or accepted industry standards for fire barrier penetration seals should be technically substantiated as part of the review and approval of the fire protection plan, or in other separate formal correspondence.

Like other plant features, it is expected that over the life of the plant, instances of degraded fire barrier penetration seals will be found. It is also expected that penetrations may be periodically opened to allow for plant modifications, maintenance, and upgrades. When such conditions are identified, the NRC's approved fire protection programs typically specify that fire watches are posted to maintain an appropriate level of defense-in-depth to assure the deficiency will not pose an undue risk to the public's health and safety. In general, if fire detection is not available on either side of the barrier, the FPP will specify the establishment of a continuous fire watch. Typically, in cases where automatic detection systems protect the affected components, a roving fire watch patrol is specified. Although posting a fire watch is the most common compensatory measure, depending on the plant-specific conditions and nature of the deficiency, several products are available that may provide a more *effective* compensatory measure. Two specific examples are described below.

B.3.1 Intumescent Pillows and Blocks

An intumescent substance expands or swells when exposed to heat. This phenomenon is the working principle behind many fire-barrier penetration seal products; they expand when exposed to the heat of a fire, thereby closing any small voids or gaps that may remain after installation or form during a fire by melted components.

Intumescent pillows and blocks are two examples of temporary fire-rated materials that are available to seal medium to large openings in structural fire barriers. The pillows and blocks may be used to temporarily fill openings that are entirely blank, or around penetrating items, such as pipes, conduits, cable trays, and HVAC ducts. This capability could be especially useful when a fire barrier is removed or breached during plant modifications. If a fire does not occur, they may be readily removed and stored for reuse. However, should a fire occur, the bags or blocks will expand, tightly closing any small spaces between cables, trays, and masonry to create a fire-rated seal that can withstand mechanical damage caused by falling debris or a hose stream from fire fighters.

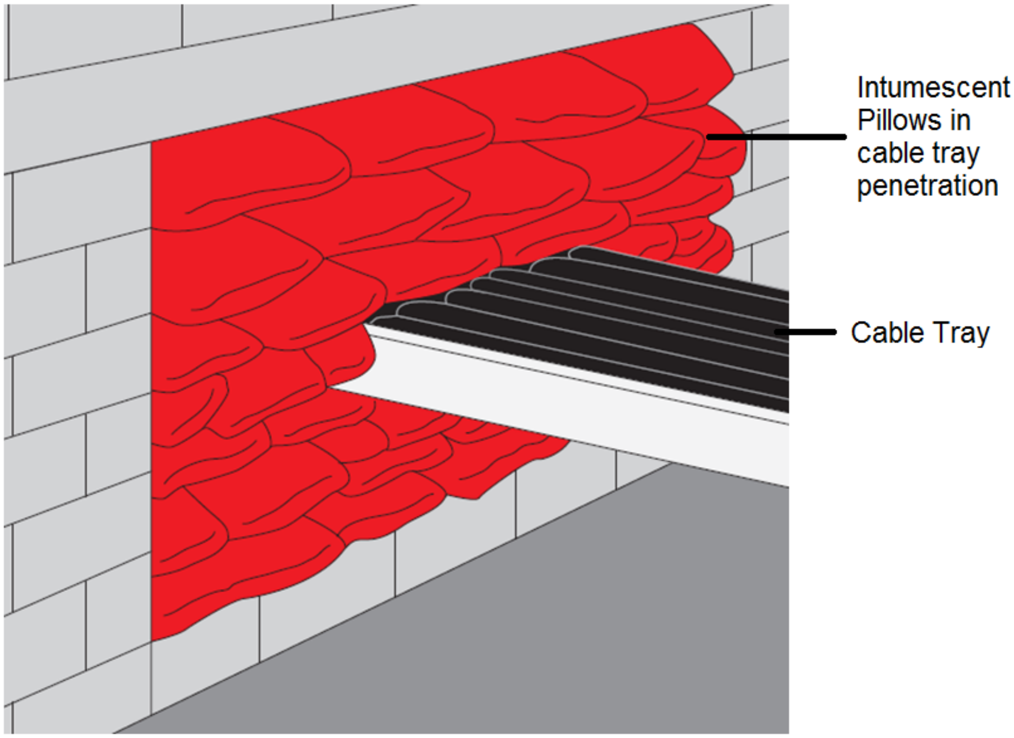


Figure B-11: Diagram of Intumescent Pillows in a Cable Tray Penetration

Key Benefits

- Expand and seal into place when exposed to high temperatures
- Can provide up to 4 hours of fire resistance (F-rating) when tested in accordance with ASTM E 814
- Relatively easy to install, remove, and replace
- Useful for sealing difficult configurations, such as where access is restricted to one side of the assembly
- Can be reused
- Pillows may be used to temporarily protect cable trays during cutting and welding
- Long shelf-life

Potential Limitations

- May be subject to damage during use and unintentional or unauthorized removal; periodic inspection is necessary
- Some configurations may require installing wire mesh.
- Excessive handling or abuse may permanently compress the pillows.

B.3.2 Reusable Fire-stop Plugs and Putty

For small to medium-sized fire barrier penetrations and openings, various plugs and putties are available which may provide an effective temporary seal. Empty conduit penetrations created during plant maintenance or cable routing modifications may be quickly sealed by firestop plugs. Plugs having a three-hour fire rating are available and are easily removed for penetration access. The plugs are typically prefabricated to fit standard conduit /pipe sleeve sizes. However, custom sizes are also available.

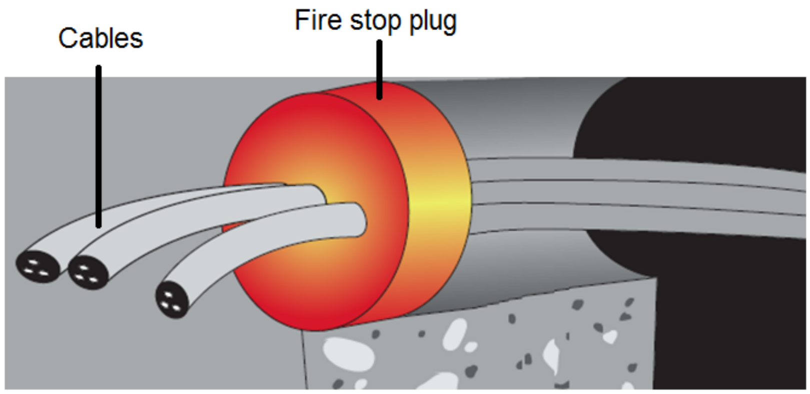


Figure B-12: Diagram of Fire Stop Plug in a Cable Penetration

For sealing small diameter conduits or openings around metallic pipes, fire-stop putty may provide an effective temporary seal. The putty is a ready-to-use fire-stop product that is hand-pressed into place. During normal use, the putty remains soft and pliable. However, in response to high temperatures caused by fire, the putty will expand within the opening, forming a solid char that helps prevent through-penetration of the fire. Since no drying or curing is required, the putty is fully functional as soon as it is installed.

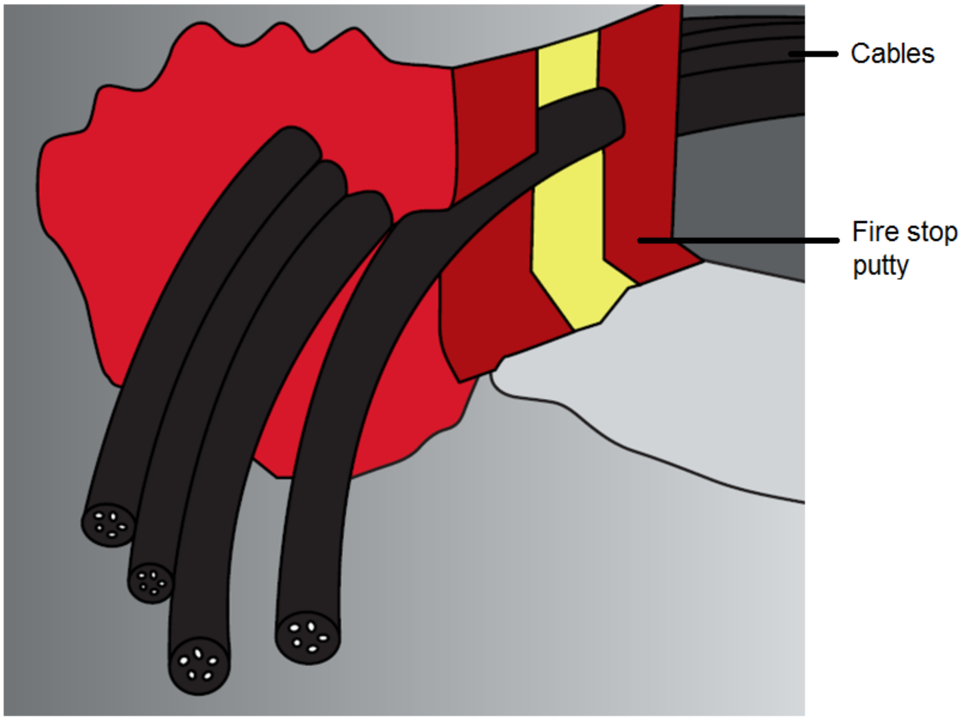


Figure B-13: Diagram of Fire Stop Putty in a Cable Penetration

Key Benefits

- Can provide up to 3-hour F-ratings of fire resistance when tested in accordance with ASTM E 814
- Reusable
- Smoke and gas tight
- Weather resistant
- Long shelf-life
- Quick and easy installation: No special tools required
- Does not require cable de-rating
- No curing or drying time; Provides an immediate fire-stop
- Intumescent
- Easily re-penetrated

Potential Limitations

- May be subject to damage during use and unintentional or unauthorized removal. Therefore, periodic inspection is necessary
- Putties contain oils which may be absorbed into porous surfaces. Sleeves are recommended
- Only high-tack putties should be chosen. Less tacky products may not stay in place

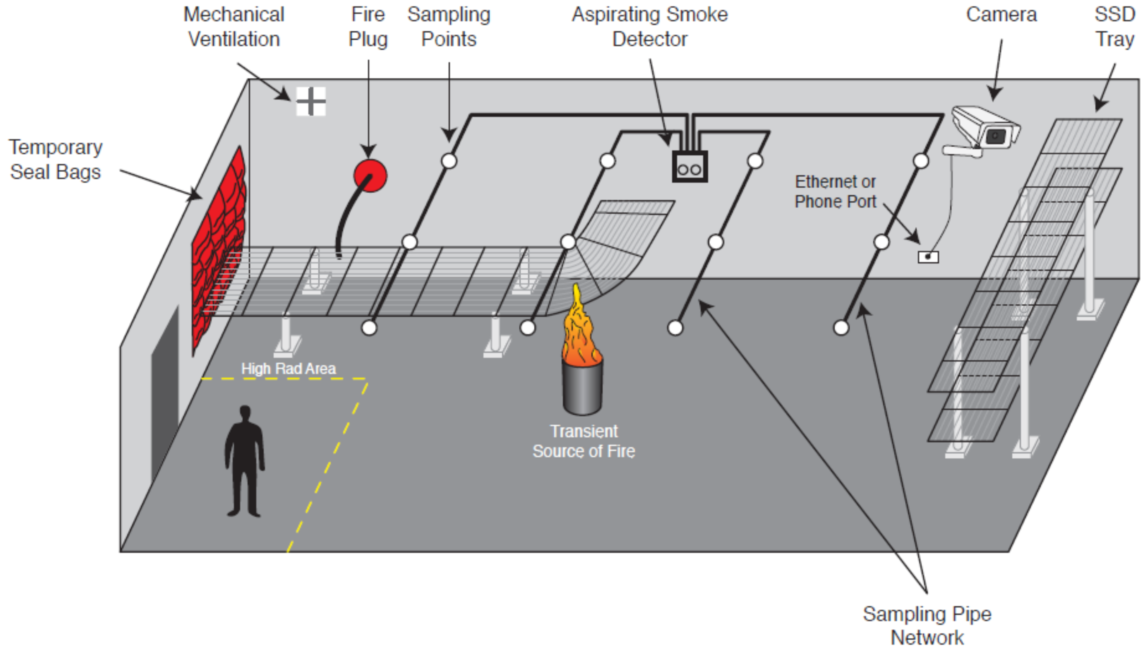


Figure B-14: Possible Applications of Advanced Technologies to Act as, or Enhance Compensatory Measures

NRC FORM 335 (12-2010) NRCMD 3.7 U.S. NUCLEAR REGULATORY COMMISSION **BIBLIOGRAPHIC DATA SHEET** *(See instructions on the reverse)*	1. REPORT NUMBER (Assigned by NRC, Add Vol., Supp., Rev., and Addendum Numbers, if any.) NUREG/CR-7135
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Fire Research Branch
Division of Risk Analysis
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

10. SUPPLEMENTARY NOTES

NRC Project Manager: F. Gonzalez

11. ABSTRACT (200 words or less)

Employing compensatory measures, on a short-term basis, is an integral part of NRC-approved fire protection programs. For most generic impairments, such as a blocked sprinkler head or a damaged fire hose station, the appropriate measures will be specified in the approved FPP. In certain unique, plant-specific cases, however, the measures specified in the FPP may not assure an appropriate level of fire safety. When such unique circumstances are encountered, it is expected that an appropriate alternate measure would be implemented. Depending on the plant-specific circumstances, alternate compensatory measures may be fairly straightforward, such as a procedural enhancement, or more complex, such as installing one or more of the technologically advanced fire protection features.

This report is intended to serve as a reference guide for the agency's staff responsible for evaluating the acceptability of interim compensatory measures provided to offset any degradation in fire safety caused by impaired fire protection features at nuclear power plants. This report documents the history of compensatory measures, and details the NRC's regulatory framework established to ensure they are appropriately implemented and maintained. This report also explores technologies that did not exist when the current plants were licensed, such as video-based detection systems, temporary penetration seals, and portable suppression systems that, under certain conditions, may offer an effective alternative to the measures specified in a plant's approved fire protection program.

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