EXCERPTS FROM A HISTORICAL FIRE PROTECTION LICENSING DOCUMENT DESCRIBING REQUIREMENTS FOR COMMERCIAL NUCLEAR POWER PLANTS OPERATING IN THE UNITED STATES

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ABBREVIATIONS (Cont'd)

IEEE	Institute of Electrical and Electronic Engineers
INPO	Institute of Nuclear Power Operations
IPEEE	Individual Plant Examination of External Events
kPa	Kilopascal
LER	Licensee Event Report
LOCA	Loss of Coolant Accident
LPM	Licensing Project Manager
NEPIA	Nuclear Energy Property Insurance Association
NFPA	National Fire Protection Association
NML	Nuclear Mutual Limited
NRC/U.S. NRC	United States Nuclear Regulatory Commission
NRR	Office of Nuclear Reactor Regulation
NUREG	Nuclear Regulatory (Document)
OSHA	Occupational Safety and Health Administration
OS&Y	Outside Screw and Yoke
pa	Pascal
PSAR	Preliminary Safety Analysis Report
psig	Pounds Per Square Inch Gauge
PWR	Pressurized Water Reactor
OJT	On-the-job Training
QA	Quality Assurance
RegGuides	NRC Regulatory Guides
SER	Safety Evaluation Report
SSA	Safe Shutdown Analysis
SSE	Safe Shutdown Evaluation
TS	Technical Specifications
TSI	Thermal Science Incorporated
TVA	Tennessee Valley Authority
UL	Underwriters Laboratory
U.S.	United States
USNPP	U.S. Nuclear Power Plant

LIST OF ABBREVIATIONS

ac/AC	Air Conditioning or Alternating Current
ACRS	Advisory Committee on Reactor Safeguards
AE	Architect Engineer
AEC	Atomic Energy Commission
AFFF	Aqueous Film-Forming Foam
AID/USAID	United States Agency for International Development
ANI	American National Insurer
ANSI	American National Standard Institute
ASLB	Atomic Safety and Licensing Board
ASTM	American Society for Testing of Materials
AWWA	American Water Works Association
BNL	Brookhaven National Laboratory
BTP	Branch Technical Position
BTP APCSB	Branch Technical Position Auxiliary and Power Conversion Systems Branch
B.T.U.	British Thermal Unit
BWR	Boiling Water Reactor
dc/DC	Direct Current
CFR	Code of Federal Regulations
DOE/U.S.DOE	United States Department of Energy
EEI	Edison Electric Institute
EPRI	Electric Power Research Institute
FHA	Fire Hazards Analysis
FM	Factory Mutual
FSAR	Final Safety Analysis Report
GDC	General Design Criteria
GL	Generic Letter
GPM/gpm	Gallons Per Minute
HELB	High Energy Line Break
IE/OIE	Office of Inspection and Enforcement

1. INTRODUCTION

1.1 Purpose of Document

This document was prepared at the direction of the U.S. Nuclear Regulatory Commission (NRC) as part of the AID-funded, Lisbon Initiative Direct Assistance Program to improve nuclear reactor safety in Russia and Ukraine. In addition to providing a historical perspective on the evolution of fire protection requirements, the document describes salient features of fire protection programs developed by operating U.S. plants in response to NRC regulations, and the licensing and inspection processes established by the NRC to ensure an adequate level of fire safety. The intent of this document is to provide a thorough understanding of the development of fire protection requirements for U.S. nuclear plants to assist regulatory officials in Russia and Ukraine to develop and implement nuclear fire protection policies, requirements, and practices in their respective countries.

1.2 Intended Reader

This document was specifically developed for individuals who may serve in a nuclear power reactor regulatory or oversight role within Russia and Ukraine. However, it may also provide useful background information and insight for anyone involved in establishing and implementing a fire protection program for nuclear power reactor facilities.

1.3 Outline of Document

The evolution of current requirements for fire protection of commercial nuclear power stations operating in the United States has been a long and complex process. This document describes this evolutionary process, along with the actions taken by licensees (authorized and responsible plant operating organizations).

In Section 2, an overview of the general licensing process is presented to familiarize the reader with the various licensing documents and the regulatory relationship between the USNRC and reactor operating organizations (licensees).

Section 3 discusses U.S. fire protection guidance (NRC staff positions, operating guidelines or direction) and requirements (rules or regulations as established in the U.S. Code of Federal Regulations). This section then discusses the lessons learned from the Brown's Ferry reactor plant fire and the influence these lessons had on the development of current fire safety requirements.

The initial USNRC and licensee actions in response to the Brown's Ferry fire are discussed in Section 4.

Section 5 provides a discussion of the development of 10 CFR 50.48 and Appendix R to 10CFR50 (the sections U.S. Code of Federal Regulations pertaining to fire protection of commercial nuclear power plants) and licensee the responses to this new requirement.

The role of the U.S. NRC fire protection inspection program is described in Section 6. Specific examples of the findings and lessons learned from this program are also cited.

Elements of a fire protection program developed by a typical operating organization are outlined in Section 7. This section provides references to the various sections within NRC criteria which address the three key parts of a fire protection program: fire prevention, fire detection & suppression, and post-fire safe shutdown. Insights and examples related to their implementation are included.

Section 8 provides case studies related to the implementation of various aspects of Appendix R. This section provides specific examples which demonstrate the flexibility permitted under the regulations through application of the exemption process.

Section 9 takes a hypothetical plant and walks through the response of plant management to the evolving United States fire protection requirements. While plants responded in a variety of ways, this section attempts to illustrate some of the typical thought processes that plant personnel went through to respond to these requirements.

The following four Appendices to this report provide additional information and references for the reader:

Appendix A	Listing of relevant National Fire Protection Association Codes and Standards
Appendix B	A guide on Appendix R inspection techniques prepared for the USNRC by Brookhaven National Laboratory
Appendix C	Appendix R to 10CFR50
Appendix D	NUREG 0800 Section 9.5.1, Fire Protection (USNRC Standard Review Plan)

1.4 Training Course

This report will be followed by a training course which will go into detail on specific U.S. NRC requirements, associated fire codes and testing standards, and case studies and lessons learned. In preparing this report, thousands of pages of documents were assembled relating to the evolution of U.S. NRC fire regulations as well as complete case histories for four plants. This information, along with supporting codes, standards and other technical publications will be available for review and discussion during the course. Reactor plant site visits and a visit to a nationally recognized fire testing laboratory will be part of the training course activities.

2. NRC LICENSING PROCESS OVERVIEW

This section gives an overview of the process for obtaining and maintaining NRC licenses to construct and operate a commercial nuclear power plant in the United States.

2.1 Background

Obtaining a license to construct and operate a commercial nuclear power plant requires a number of reviews, and hearings. The following is a listing of the typical reviews and hearings included in the (10 CFR Part 50) construction licensing process:

- The licensing process is initiated by the future operating organization's (applicant) submission to the NRC of a Preliminary Safety Analysis Report (PSAR) for the proposed nuclear power plant.
- The PSAR, containing the preliminary design information on the proposed nuclear power facility, is reviewed and evaluated by the NRC.
- Public hearings on the applicant's request are conducted to identify safety concerns and other germane issues.
- Meetings are conducted between the applicant and the NRC staff to identify and resolve questions and issues arising from the various reviews and hearings.
- The applicant revises and resubmits the PSAR for further review and evaluation.
- The NRC staff issues a Safety Evaluation Report (SER).
- The NRC issues a construction permit after the various safety concerns and design issues have been resolved.
- During construction, the design may be refined. The final design of the facility is documented in a Final Safety Analysis Report (FSAR).
- Near the end of construction, additional public hearings and reviews by the Advisory Committee on Reactor Safeguards (ACRS) are held, as are public hearings before the Atomic Safety and Licensing Board.
- Following an acceptable resolution of all safety issues, the NRC issues an operating license for the reactor plant, which includes the plant's Technical Specifications (operating requirements and restrictions).

During the operating life of the facility, the licensee may implement design modifications (design changes) to improve the plant's safety, reliability, efficiency. Whenever such modifications affect the plant's design basis, as documented in the FSAR, additional licensing activities are initiated. Such licensing activities result in an amendment of the facility operating license.

From time to time, industry events may lead to the issuance of new rules (regulations) which then require additional licensing activity. New rules may be developed in response to a series of small individual events at several different facilities, a major event at a single facility (such as the Brown's Ferry fire), or analytical studies (such as the Anticipated Transient Without Scram {ATWS} studies).

Operating organization submittals in response to new rules include designs and proposed methods for achieving compliance with the new requirements. When the method proposed by the operating organization has been previously approved, accepted, or recommended by the NRC to satisfy the rule, the licensing process is simplified. In other instances the operating organization may propose a new or different design or method to achieve compliance with the rule. In this case, the licensing process will require a detailed, in-depth, review of the operating organization's approach to ensure that the proposed alternative approach for satisfying the rule provides an equivalent level of safety.

2.2 Regulatory Documents

To understand the licensing process for U.S. commercial nuclear power plants, it is necessary to identify the different types of regulations and guidance that are applied during the regulatory process. The following are representative examples of the relevant regulatory documents:

2.2.1 Code of Federal Regulations (CFR)

U. S. Regulations, such as 10 CFR Part 50, *Domestic Licensing of Production and Utilization Facilities*, and the Appendices to 10CFR Part 50, carry the force of law. In some instances the NRC may allow an operating organization relief from a specific part of the regulation through the granting of an exemption for the specific item or condition. If an operating organization has no exemption and is found to be in non-compliance with an applicable part of the CFR, then the operating organization would be in "violation" of the regulation.

10CFR50 Appendix A, Criterion 3, *Fire Protection*, provides the basic design requirements for fire protection of commercial nuclear power plants. Appendix A, Criterion 3, reads as follows:

> "*Criterion 3-Fire Protection*. Structures, systems, and components important to safety shall be designed and located to minimize, consistent with other safety requirements, the probability and effect of fires and explosions. Noncombustible and heat resistant materials shall be used wherever practical throughout the unit, particularly in locations such as the containment and control room. Fire detection and fighting systems of appropriate capacity and capability shall be provided and assigned to minimize the adverse effects of fires on structures, systems, and components important to safety. Fire fighting systems shall be designed to assure that their rupture or inadvertent operation does not significantly impair the safety capability of these structures, systems, and components."

10CFR50 Appendix A, Criterion 5, establishes design requirements for the sharing of safety-related systems at multiple-unit sites. This Criterion reads as follows:

> "*Criterion 5-Sharing of structures, systems, and components*. Structures, systems and components important to safety shall not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units."

2.2.2 Regulatory Guidance Documents

Regulatory guidance is provided in various source documents developed by the NRC. These guidance documents include: Generic Letters such as Generic Letter 86-10, *Appendix R Interpretations*; and Information Notices such as Information Notice 85-09, discussing isolation transfer switches and post-fire, safe shutdown capability. During the regulatory process, the operating organization identifies the regulatory guidance documents that the facility has been designed to, constructed to, or will be operated in accordance with. If an operating organization is not in compliance with an applicable guidance document, and the operating organization has not provided an alternative means of achieving or satisfying requirements supported by the guidance document, then the operating organization is said to have "deviated" from a licensing commitment.

The USNRC relies heavily on the fire protection guidance given in a number of documents published by other organizations. The leading organization that develops fire protection standards in the U.S. is the National Fire Protection Association (NFPA). The NRC stated in Generic Letter 86-10, "NRC guidelines reference certain NFPA codes as guidelines to the systems acceptable to the staff, and therefore such codes may be accorded the same status as Regulatory Guides." The NFPA codes and Standards referenced by the USNRC are contained in Section 9.5.1 of the USNRC Standard Review Plan, NUREG-0800 (Appendix D). A more complete listing of NFPA Codes and Standards is provided in Appendix A of this document.

Since NUREG-0800 Revision 3 was published in 1981, a number of the codes and standards it references have been revised substantially or combined with the original reference deleted. However, guidance on all of the above subjects can still be found within NFPA documents. NFPA also is in the process of publishing NFPA 804, Fire Protection for Advanced Light Water Reactors.

Other U.S. organizations also produce standards or guidance documents which are referenced by the USNRC. The American National Standards Institute (ANSI) publishes a number of design standards and standards for personnel qualifications. The American Society for Testing of Materials (ASTM) develops and publishes test methods intended to encourage uniformity in material testing.

Some of the key ASTM tests applicable to nuclear power plant fire protection are:

- ASTM E-84, "Surface Burning Characteristics of Building Materials."

- ASTM E-119, "Fire Test of Building Construction and Materials."

ASTM E-119 is the test standard basis for assigning fire ratings using time designations, i.e. 1 hr., 1 ½ hr., 3 hr., etc. The fire resistance is the time period the material or assembly withstood the fire test without failure when exposed to a standard time varying temperature curve within a test furnace. This temperature profile, known as the standard time-temperature curve, has been the basis of almost all fire resistance testing in the U.S. since 1918. The Standard Time-Temperature Curve is presented in Figure 2.1.

The failure criteria stated in ASTM E-119 include:

- Failure to support load.
- Temperature increases on the unexposed surface to 250°F (121°C) above ambient.
- Passage of heat or flame sufficient to ignite cotton waste.
- Excess temperature on steel members.

- Failure under hose stream.

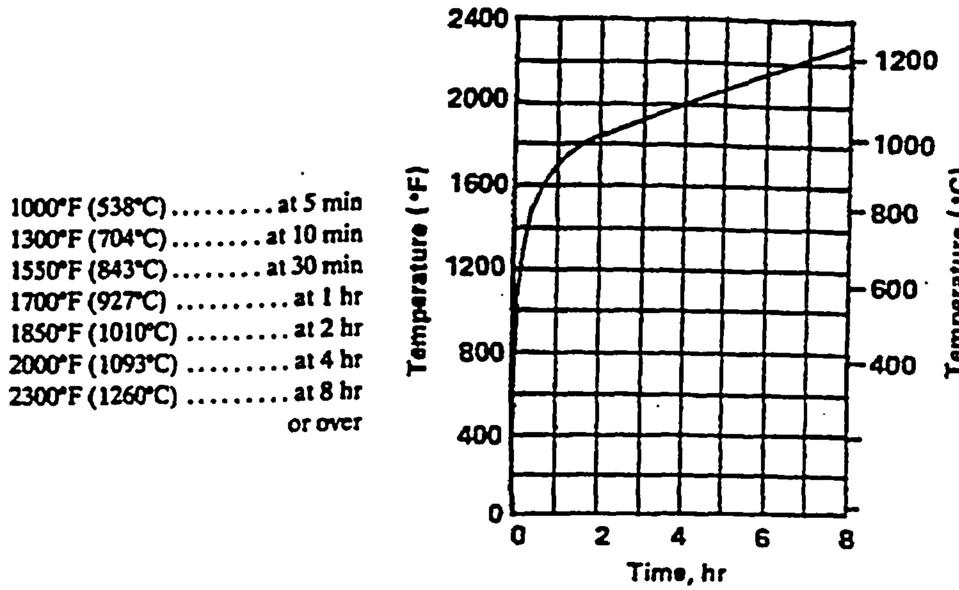


Figure 2.1 Standard Time-Temperature Curve

The Institute of Electrical and Electronic Engineers (IEEE) publishes standards related to electrical equipment. The standard of particular interest for the fire protection program is IEEE 383 "IEEE Standard for Type Test of Class 1E Electrical Cables, Field Splices, and Connections for Nuclear Power Generating Stations." Cables satisfying this standard have reduced flame spread characteristics when compared to non-rated cables.

Factory Mutual (FM) and Underwriters Laboratories (UL) are the two leading U.S. organizations which fire test and rate equipment, components, building materials and construction assemblies. If the test criteria are successfully met, the item receives an approval or listing from the testing organization. The results of fire tests conducted by UL are given in the Fire-Resistance Directory published annually by UL. FM publishes annually The Factory Mutual System Approval Guide which includes equipment and materials which have met the test requirements.

As is commonly practiced in the United States, NFPA, IEEE and ASTM are organizations that develop standards through a voluntary consensus-making process. FM and UL are private organizations which offer independent testing. The USNRC relies on these and other organizations to develop tests and guidance to support a comprehensive fire protection program.

Several private insurance companies provide fire related coverage for U.S. nuclear power plants. The two main companies are American Nuclear Insurer (ANI) and Nuclear Mutual Limited (NML). ANI, in particular, has its own criteria related to fire protection in nuclear power plants.

2.2.3 Licensing Documents

When an operating license is granted to a commercial nuclear power plant, the operating license includes or references a variety of documents including technical specifications, the Final Safety Analysis Report, safety evaluation reports, and licensing commitments. The purpose of each of these documents is briefly described in the following paragraphs.

2.2.3.1 Technical Specifications (TS)

Technical specifications, which define the limits (operating parameters) for operating the plant, are developed by the operating organization and submitted to the NRC for review and approval as part of the initial licensing process. In current practice, the operating organization's Technical Specifications (TS) are evaluated against the NRC developed *Standard Technical Specifications*, to ensure that fundamental fire protection TS criteria are established. After the TS are approved by the NRC, the operating organization must comply with the safety limits, limiting conditions for operation, safety system testing (or surveillance) requirements, minimum staffing requirements, and other operating factors identified in the Technical Specifications.

2.2.3.2 Final Safety Analysis Report (FSAR)

The Final Safety Analysis Report (FSAR) is developed by the operating organization and submitted to the NRC for review as part of the initial licensing process. This document describes such plant-specific features as the system design and configuration, administrative activities, operating organization, and operating organization commitments to industry fire protection standards. FSAR section 9.5, *Auxiliary Systems*, contains information on the facility fire protection program. Any changes to the FSAR must be submitted to the NRC annually by the operating organization.

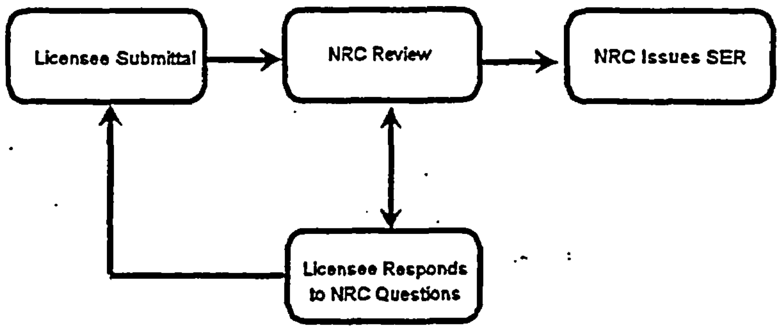
The approved FSAR is a fundamental part of the operating license. Failures to comply with its requirements are identified as deviations from the FSAR commitment.

2.2.3.3 Safety Evaluation Reports (SERs)

Safety Evaluation Reports (SER) document the results of NRC reviews of the operating organization submittals. NRC approval or denial of proposed design changes, shutdown methodologies, and requests for exemption from specific requirements are examples of issues discussed in an SER.

During the construction phase and after the plant has been licensed for power operation, design changes and plant modifications occur. In the case of design changes and/or modifications to safety-related systems, regulatory review may be required. The regulation (10 CFR 50.59) discusses when such modifications require NRC review.

The licensing review process is illustrated in the following figure:



Basic Licensing Process

Section 50.12, *Specific Exemptions,* allows the NRC to grant exemptions from the requirements of the regulations. Exemptions may be granted if they will not present an undue risk to the public health and safety and if special circumstances exist for granting the exemption.

The special circumstances supporting the granting of exemptions include situations in which:

- Application of the regulation conflicts with other rules or requirements of the NRC.
- Application of the regulation would not serve the underlying purpose of the rule or is not necessary to achieve the underlying purpose of the rule.
- Compliance would result in undue hardship or financial costs that are significantly in excess of those contemplated when the regulation was adopted.
- The exemption would result in benefit to the public and safety that compensates for any decrease in safety that may result from granting the exemption.
- The exemption would provide only temporary relief from the applicable regulation, the operating organization or applicant has made good faith efforts to comply with the regulation, and the operating organization or applicant will be in compliance at a specified time in the future.
- There are any other material circumstances not considered when the regulation was adopted for which it would be in the public interest to grant an exemption.

2.2.3.4 <u>Operating Organization Commitments</u>

After an operating license is granted, additional commitments may be made by the operating organization to address specific plant modifications or generic issues. These commitments may be reflected in an amendment to the operating license or may be documented solely in correspondence between the operating organization and the NRC.

3. EARLY HISTORY OF U.S. FIRE PROTECTION

3.1 Background

To encourage research and development of peaceful uses for nuclear technology and to control the licensing of private users of this technology, shortly after the Second World War the United States Government formed the Atomic Energy Commission (AEC). In 1974, the United States Congress enacted legislation which essentially abolished the AEC and created two new agencies in its place - the Energy Research and Development Administration (now the Department of Energy) and the Nuclear Regulatory Commission (NRC). The NRC continued to function with the same regulations and guidance that was developed under the AEC. These criteria, which govern the design, construction, operation and licensing of commercial nuclear power stations operated in the United States are currently codified in Parts 0 - 200 of Title 10 of the U.S. Code of Federal Regulations (CFR).

With regard to fire protection, General Design Criterion 3 (GDC 3) of Appendix A to Title 10 CFR Part 50 requires that 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. Safety Evaluations based on GDC 3 served as the justification for AEC and early NRC acceptance of fire protection programs. However, due to a lack of specific implementation guidance or assessment review criteria, the level of fire protection provided by a plant was typically deemed to be adequate if it complied with National Fire Protection Association (NFPA) standards and received an acceptable rating from a major insurance underwriter. NRC acceptance of this level of fire protection is reflected in the following passage of a Safety Evaluation Report (SER) which was issued in the early 1970's:

> "The fire protection system is designed to provide the capability to detect and extinguish one or more probable combinations of fires that may occur. In accomplishing this purpose, the system:
>
> (1) Complies with the standards of the National Fire Protection Association
>
> (2) Is also based upon the recommendations of the Nuclear Energy Property Insurance Association
>
> (3) Supplies wet-pipe sprinkler systems, deluge systems, carbon dioxide systems, and hand operated (manual) fire fighting devices throughout all potentially hazardous areas of the plant.
>
> ... On the basis of our review we conclude that the fire protection systems conform with the intent and requirements of Criterion No. 3 of the AEC General Design Criteria and are therefore acceptable."

It is evident from this example that early AEC and NRC acceptance of fire safety features was largely based on the plant's compliance with recommendations of the Nuclear Energy Property Insurance Association (NEPIA). As a result, the fire safety requirements imposed on commercial nuclear power stations were very similar to those imposed on conventional, fossil-fueled, electric generating stations. Fire protection features continued to be evaluated on this basis until a major fire occurred at the Browns Ferry plant in 1975. Investigations of the cause and possible consequences of this event clearly demonstrated that the life safety and property protection concerns of the major fire insurance underwriters did not sufficiently encompass nuclear safety issues, particularly with regard to the potential for fire damage to cause the failure of redundant trains of systems and components important to the safe shutdown of the reactor. Consequently, the NRC concluded that fire protection requirements for nuclear facilities must be expanded to include the additional objective of ensuring nuclear safety.

3.2 The Browns Ferry Fire

On March 22, 1975, a severe fire occurred at Unit No. 1 of the Browns Ferry nuclear power station, operated by the Tennessee Valley Authority (TVA). The fire began in a bank of cable trays in an area of the cable spreading room where the trays passed through a penetration in a wall separating the cable spreading room from the reactor building. On the reactor building side of the wall the cable trays connected with a complex system of trays and conduits. Subsequent investigations attributed the cause of the fire to an inspection process which relied on using the smoke from a candle flame to detect air flow through defective penetration seals.

At Browns Ferry, the reactor building functions as the secondary containment for the nuclear steam supply systems. To preclude uncontrolled and unmonitored releases of airborne radioactivity, the reactor building is designed (and required by license condition) to be maintained at a negative pressure (0.25 inches of H_2O / 62.3pa) in relation to the remainder of the plant and the outside environment. The penetration seal inspection process in place at the time of the fire used this differential pressure between the two areas to draw off smoke from a candle. In this manner, a defective seal could be readily detected by the movement of smoke toward and through the penetration. When workers used this method to test a newly installed penetration seal, however, the entire flame of the candle was drawn into the penetration, igniting its polyurethane foam material. The pressure differential between the cable spreading room and the reactor building then served to fan the fire, causing it to rapidly spread to a large number of cable trays located on the opposite side of the fire barrier wall.

Due to the large amount of combustible cable insulation involved in the fire, and operator reluctance to use water to extinguish an electrical fire, the fire continued to burn for several hours. However, it is important to note that once a decision was made to apply water, the fire was quickly brought under control. In the cable spreading room, which was protected by a CO_2 extinguishing system, damage was limited to a 25 square foot (approximately 2.32 square meters) area adjacent to the penetration where the fire started. The major amount of fire damage occurred on the opposite side of the penetration in an area of the Reactor Building approximately 40 feet (12.2 meters) by 20 feet (6.1 meters). Although damage was limited to a relatively small area of the plant, more than 1600 cables routed in 117 conduits and 26 cable trays were affected. Of those, 628 cables were safety related and their damage caused the loss of a significant number of plant safety systems.

While a sufficient quantity of plant equipment remained operational throughout the event to enable operators to shutdown the reactor and maintain it in a safe shutdown condition, this objective was not easily achieved. The extensive damage experienced by electrical power and control systems impeded the functioning of normal and standby reactor cooling systems and degraded the operators' capability to monitor the status of the plant. Due to the loss of multiple safety systems, operators were required to initiate emergency repair actions to restore required systems so that the reactor could be brought to a safe shutdown condition.

4. INITIAL POST-BROWNS FERRY RESPONSE

4.1 Immediate NRC Actions

Immediately following the Browns Ferry fire, the NRC issued Bulletin 75-04. This document required licensees to analyze their existing fire protection capabilities and respond to the NRC. This Bulletin was revised shortly thereafter (75-04A) requiring that licensees evaluate their procedures involving cable penetrations and fire fighting capabilities. Hearings were held before the United States Congress on September 16, 1975 to discuss the implications of the Browns Ferry Fire. On November 3, 1975 the NRC further revised the initial Bulletin (75-04B) requiring licensees to further evaluate their fire protection programs.

4.2 Defense-in-Depth Philosophy for Fire Protection

Shortly after the Browns Ferry fire, on March 26, 1975, the NRC established a Special Review Group to investigate the cause and potential effects of the fire and recommend changes to current NRC fire protection policies and procedures. In its report, "Recommendations Related to the Browns Ferry Fire" (NUREG 0050, February 1976), the Special Review Group noted that reasonable improvements in existing fire protection programs could be achieved and concluded that the NRC should develop specific guidance for implementing the existing fire protection regulations (GDC 3 to 10 CFR 50).

At Browns Ferry a fire started and continued to burn for several hours in spite of efforts to extinguish it. The damage to electrical cables disabled a substantial amount of core cooling equipment, including the pumping capability of the emergency core cooling system for Unit 1. However, the reactors of both units were successfully shutdown and their cores were kept covered with water (the water level remained above the top of active fuel) at all times. In spite of the damage to the plant, the burned cables, and the inoperable equipment, no abnormal release of radioactivity occurred and the health and safety of the public was preserved.

While the final outcome of the Browns Ferry fire was acceptable in terms of its impact on public health and safety, the fire demonstrated significant inadequacies, including the apparent ease with which the fire started, the hours that elapsed before it was fully extinguished, and the unavailability of redundant trains of plant safety equipment.

In recognition of the potential consequences of fire, and to assure that an adequate level of fire safety is incorporated into the overall design and operation of all nuclear power plants operating in the United States, the Special Review Group recommended that the established principles of defense-in-depth be applied in defense against fires.

Section 9.5.1 of the NRC's Standard Review Plan (NUREG-0800) describes the fire protection program of a nuclear power plant as a combination of design features, personnel, equipment, and procedures that provide the defense-in-depth protection of the public health and safety. With respect to fire protection, the defense-in-depth philosophy is aimed at achieving an adequate balance in:

a. Preventing fires from starting;

b. Detecting fires quickly, suppressing those fires that occur, putting them out quickly, and limiting their damage; and

c. Designing plant safety systems so that a fire that starts in spite of the fire prevention program and burns for a considerable time in spite of fire protection activities will not prevent essential plant safety functions from being performed.

The multiple echelons of protection that are embodied in the defense-in-depth philosophy provide a means of assuring fire safety throughout the life of the plant. No one of these echelons can be perfect or complete by itself. Each echelon should meet certain minimum requirements; however, strengthening any one can compensate in some measure for weaknesses, known or unknown, in the others.

4.3 Development of the Branch Technical Position and Appendix A

In May 1976, the NRC issued Branch Technical Position, Auxiliary and Power Conversion Systems Branch 9.5-1 (BTP APCSB 9.5-1) "Guidelines for Fire Protection for Nuclear Power Plants," which applied to plants which filed an application for construction after July 1, 1979. This BTP incorporated recommendations from the Special Review Group. In an effort to establish an acceptable level of fire protection at the older operating plants without significantly affecting the design, construction, or operation of the plant, the NRC modified the guidelines in the original BTP and issued Appendix A to BTP 9.5-1 "Guidelines for Fire Protection for Nuclear Plants Docketed Prior to July 1, 1976" in September of 1976. Regardless of the plant's vintage, the overall intent of the new guidance was to establish a fire protection program that was based on the defense-in-depth philosophy.

The NRC guidance contained in BTP APCSB 9.5-1 requested each licensee to provide an analysis that divides the plant into distinct fire areas and demonstrates that redundant trains of equipment required to achieve and maintain cold shutdown conditions of the reactor were adequately protected from fire damage (post-fire safe shutdown). Additionally, the NRC informed each plant that the guidance in Appendix A to BTP APCSB 9.5-1 would be used to analyze the consequences of a postulated fire within each area of the plant. The NRC then reviewed the analyses submitted by each operating plant against the guidance contained in Appendix A to BTP 9.5-1 and conducted plant visits to examine the relationship of structures, systems and components important to safety with fire hazards, the potential consequences of fire, and the associated fire protection features.

4.4 Plant Responses to the BTP

Under Appendix A, facilities installed fire detection and fire suppression systems in many areas to improve the level of protection for safety related equipment and components. Where possible, fire barriers were installed or existing barriers were evaluated and upgraded as necessary. Additionally, a means of achieving safe shutdown conditions in the reactor in the event of fire in certain critical areas, such as the control room, was provided.

The level of separation attained typically reflected the guidance contained in NRC Regulatory Guide 1.75, Physical Independence of Electrical Systems, and Institute of Electrical and Electronics Engineers Standard No. 384 (IEEE 384), Criteria for Independence of Class 1E Equipment and Circuits. In accordance with this guidance, where appropriate suppression and detection systems were installed, a separation distance of redundant circuit components by 3 feet (0.9 meters) horizontally and/or 5 feet (1.5 meters) vertically was deemed sufficient to assure that one train of equipment was protected.

By the late 1970s, the majority of operating plants had completed their analyses and had implemented most of the fire protection program requirements of Appendix A to the BTP. In most cases, the modifications proposed by licensees as a result of these analyses were found to be acceptable by the NRC. In certain cases, however, technical disagreements developed between certain licensees and the NRC staff, and several plants refused to adopt certain recommendations contained in the BTP. Even though a given issue might be contested by only a few plants, the NRC determined that the issues were a potential generic problem, and rule-making was deemed the appropriate vehicle for resolving these issues and implementing Commission policy with respect to fire protection.. Therefore, to resolve areas of disagreement, the NRC amended its regulations, and in November 1980 issued 10 CFR 50.48, "Fire Protection" and Appendix R, "Fire Protection Program for Nuclear Power Plants Operating Prior to January 1, 1979." Appendix R sets forth Commission policy with respect to fire protection requirements.

5. 10 CFR 50.48 and APPENDIX R

5.1 Rule Development

As discussed in the previous section, when Appendix R was first published for public comment, Appendix A to BTP APCSB 9.5-1 provided the guidance used by the NRC staff in their reviews of fire protection. At this time, features and systems necessary to satisfy the established guidance (Appendix A to BTP APCSB 9.5-1) were already in place or were being installed in many plants. In its original proposal for Appendix R, the NRC staff intended its requirements to be applicable only to settle the unresolved/disputed fire protection features required by Appendix A to the BTP. Thus, the staff had not originally intended the provisions of Appendix R to require additional modification of previously approved features. However, later in the rule making process, the NRC determined that the requirements of three sections of Appendix R (Sections III.G, III.J, and III.O) were of such safety significance that they would be applied to all plants, regardless of previously approved fire protection features. On November 19, 1980, the final rule (10 CFR 50.48 and Appendix R) was published.

5.1.1 10 CFR 50.48 "Fire Protection"

The Fire Protection rule, 10 CFR 50.48, consists of five parts (a through e) which are quoted and described in the following paragraphs. The reader will note that certain parts of the rule, such as parts c and d, contain considerable detail with regard to dates and timing. While these dates were clearly important to licensees, they are not essential for understanding fire protection requirements as they exist today, and have only been included here for completeness.

- *50.48 (a) - "Each operating nuclear power plant must have a fire protection plan that satisfies Criterion 3 of appendix A of this part. This fire protection plan must 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, and outline the plans for fire protection, fire detection and suppression capability, and limitation of fire damage. The plan must also describe specific features necessary to implement the program described above, such as administrative controls and personnel requirements for fire prevention and manual fire suppression activities, automatic and manually operated fire detection and suppression systems, and the means to limit fire damage to structures, systems, or components important to safety so that the capability to safely shut down the plant is ensured. The licensee shall retain the fire protection plan and each change to the plan as a record until the Commission terminates the reactor license and shall retain each superseded revision of the procedures for three years from the date it was superseded."*

- *50.48 (b) - "Appendix R to this part establishes fire protection features required to satisfy Criterion 3 of Appendix A to this part with respect to certain generic issues for nuclear power plants licensed to operate prior to January 1, 1979. Except for the requirements of sections III.G, III J, and III.O, the provisions of appendix R to this part shall not be applicable to nuclear power plants licensed to operate prior to January 1, 1979, to the extent that fire protection features proposed or implemented by the licensee have been accepted by the NRC staff as satisfying the provisions of Appendix A to Branch Technical Position BTP APCSB 9.5-1 reflected in staff fire protection safety evaluation reports issued prior to the effective date of this rule, or to the extent that fire protection features were accepted by the staff in comprehensive fire protection safety evaluation reports issued before Appendix A to Branch Technical Position BTP APCSB 9.5-1 was published in August 1976.*

With respect to all other fire protection features covered by Appendix R, all nuclear power plants licensed to operate prior to January 1, 1979 shall satisfy the applicable requirements of Appendix R to this part, including specifically the requirements of sections III.G, III.J, and III.O."

This part of the rule specified that Appendix R requirements of Sections III.G, III.J, and III.O, were applicable to all nuclear power plants licensed prior to January 1, 1979. Additionally, the previous resolutions reached regarding the other issues addressed by Appendix R during the BTP APCSB 9.5-1 review process were allowed to stand.

Section 50.48(b) required significant action on the part of all licensee's:

(a) To demonstrate that the provisions of section III.G were satisfied, the licensees conducted an analysis of the plant's post-fire safe shutdown capability. Extensive modifications typically were required to comply with section III.G.

(b) Demonstration of compliance with provisions of section III.J required analysis and further plant modifications to install additional emergency lighting capability.

(c) Plant modifications were required to install the oil collection system for the reactor coolant pumps required by section III.O.

- *50.48 (c)* - This part of the rule contained scheduler information for rule implementation by the licensees, and included guidance regarding the requirement for prior NRC review and approval, which was required for modifications needed to provide alternative or dedicated shutdown capability (per Section III.G.3 of Appendix R). Licensees requested numerous exemptions from the scheduler requirements of this part. The exemptions usually were requested to allow additional time to complete analyses and install plant modifications necessary to comply with the rule.

- *50.48 (d)* - This part of the rule contained scheduler information for completing the installation of fire protection features that were previously evaluated by the NRC staff and found to satisfy the provisions of Appendix A to Branch Technical Position BTP APCSB 9.5-1, as documented in Fire Protection Safety Evaluation reports. Numerous exemptions from the scheduler requirements of this section were granted.

- *50.48 (e) - "Nuclear power plants licensed to operate after January 1, 1979, shall complete all fire protection modifications needed to satisfy Criterion 3 of Appendix A to this part in accordance with the provisions of their licenses."*

This part of the rule directed nuclear power plants licensed to operate after January 1, 1979, to complete all fire protection modifications needed to satisfy Criterion 3 of Appendix A in accordance with their licenses. The details of the fire protection program for these later plants is typically in accordance with the NRC staff's Standard Review Plan, NUREG 0800, Section 9.5.1, a document which closely parallels Appendix R.

5.1.2 10 CFR 50 Appendix R

Appendix R, entitled "Fire Protection Program For Nuclear Power Facilities Operating Prior to January 1, 1979", sets forth fire protection features required to satisfy Criterion 3 of Appendix A to 10 CFR

50. Appendix R contains three sections:

It should be noted that for the purposes of this training document certain sections of Appendix R are paraphrased in the following paragraphs.

Section I. Introduction and Scope

This section applied Appendix R to plants operating prior to January 1, 1979 and defined the following fire damage limits for hot shutdown, cold shutdown, and design basis accidents:

- "Hot Shutdown - One train of equipment necessary to achieve hot shutdown from either the control room or emergency control stations must be maintained free of fire damage by a single fire including an exposure fire."

- "Cold shutdown - Both trains of equipment necessary to achieve cold shutdown may be damaged by a single fire, including an exposure fire, but damage must be limited so that at least one train can be repaired or made operable within 72 hours using onsite capability."

- "Design Basis Accidents - Both trains of equipment necessary for mitigation of consequences following design basis accidents may be damaged by a single exposure fire."

An exposure fire is defined as: "A fire in a given area that involves either in situ (fixed/permanent) or transient (movable/temporary) combustibles and is external to any structures, systems, or components located in or adjacent to that same area. The effects of such fire (e.g., smoke, heat, or ignition) can adversely affect those structures, systems, or components important to safety. Thus, a fire involving one train of safe shutdown equipment may constitute an exposure fire for the redundant train located in the same area, and a fire involving combustibles other than either redundant train may constitute an exposure fire to both redundant trains in the same area."

Section II. General Requirements

This section established the following requirements:

- Section II.A. Fire protection program - This section extends the defense-in-depth concept to fire protection for fire areas important to safety. Fire protection program objectives must include fire prevention and assure the rapid detection and prompt extinguishment of fires that may occur. Additionally, the program must provide protection for structures, systems, and components important to safety so that a fire that is not promptly extinguished by the fire suppression activities will not prevent the safe shutdown of the plant.

- Section II.B. Fire hazards analysis - This section discusses the important features of a fire hazards analysis, namely it must: consider potential in situ (permanent) and transient fire hazards; determine the consequences of fire in any location in the plant on the ability to safely shut down the reactor or on the ability to minimize and control the release of radioactivity to the environment; and specify measures for preventing, detecting, suppressing and containing a fire, and alternative shutdown capability that may be required for fire areas containing structures, systems, and components important to safety.

a. Separation of cables and equipment and associated non-safety circuits of redundant trains by a fire barrier having a 3-hour rating. Structural steel forming a part of or supporting such fire barriers shall be protected to provide fire resistance equivalent to that required of the barrier;
b. Separation of cables and equipment and associated non-safety circuits of redundant trains by a horizontal distance of more than 20 feet (6.1 meters) with no intervening combustible or fire hazards. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area; or
c. Enclosure of cable and equipment and associated non-safety circuits of one redundant train in a fire barrier having a 1-hour rating. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area;

Inside non-inerted containments (a containment that is not filled with an inert gas during normal power operation of the plant) *one of the fire protection means specified above or one of the following fire protection means shall be provided:*
d. Separation of cables and equipment and associated non-safety circuits of redundant trains by a horizontal distance of more than 20 feet (6.1 meters) with no intervening combustibles or fire hazards;
e. Installation of fire detectors and an automatic fire suppression system in the fire area; or
f. Separation of cables and equipment and associated non-safety circuits of redundant trains by a noncombustible radiant energy shield."

<u>Section III.G.3</u>

"Alternative or dedicated shutdown capability and its associated circuits, independent of cables, systems, or components in the area, room or zone under consideration, shall be provided:
a. Where the protection of systems whose function is required for hot shutdown does not satisfy the requirement of paragraph G.2 of this section; or
b. Where redundant trains of systems required for hot shutdown located in the same fire area may be subject to damage from fire suppression activities or from the rupture or inadvertent operation of fire suppression systems.
In addition, fire detection and a fixed fire suppression system shall be installed in the area, room, or zone under consideration."

- Section III.H. Fire brigade.

This section requires the fire brigade to consist of five members on each shift, of which the fire brigade leader and at least two members shall have sufficient training in or knowledge of plant safety-related systems to understand the effects of fire and fire suppressants on safe shutdown capability.

- Section III.I. Fire brigade training.

This section describes specific features of an acceptable fire brigade training program and requires the program to consist of classroom instruction, practice sessions and periodic drills.

- Section III.J. Emergency lighting.

This section requires emergency lighting units having at least an 8-hour battery power supply to be provided in all areas where the operation of safe shutdown equipment may be required, and in the access and egress routes to that equipment.

- Section III.K. Administrative controls.

This section describes the requirements for administrative controls for combustible material and actions to be taken when discovering and fighting a fire.

The fire protection program uses administrative controls for fire prevention and pre-fire planning. The minimum requirements for effective administration of the fire protection program are specified. Controls are placed on the storage and use of combustible materials to reduce the fire loading in safety-related areas and on all potential sources of fire ignition. Procedures are used to control the actions to be taken by individuals who discover a fire, and by the fire brigade (preplanned fire fighting strategies and actual fire fighting techniques).

- Section III.L. Alternative and dedicated shutdown capability.

Section III.L specifies the following requirements for the alternative or dedicated shutdown capability: (a) achieve and maintain subcritical reactivity conditions in the reactor; (b) maintain reactor coolant inventory; (c) achieve and maintain hot standby conditions for a PWR (hot shutdown for a BWR); (d) achieve cold shutdown conditions within 72 hours; and (e) maintain cold shutdown conditions thereafter. During the post-fire shutdown, the reactor coolant system process variables must be maintained within those limits predicted for a loss of normal ac power, and the fission product boundary integrity must not be affected (i.e. there shall be no fuel clad damage, rupture of any primary coolant boundary, or rupture of the containment boundary).

- Section III.M. Fire barrier cable penetration seal qualification.

This section specifies that penetration seal designs must use only noncombustible material and must be qualified by tests that are comparable to tests used to rate fire barriers. The specific test acceptance criteria are also established.

- Section III.N. Fire doors.

The best fire protection for redundant trains of safe shutdown systems is separation by unpierced fire barriers - walls and ceiling-floor assemblies. Because these barriers are passive fire protection features, they are inherently reliable, provided they are properly installed and maintained. Even fire barriers with openings have successfully interrupted the progress of many fires provided the openings were properly protected by fire doors or other acceptable means.

- Section III.O. Oil collection system for reactor coolant pump

If the containment is not inerted during normal operation, this section requires the reactor coolant pump to be provided with an oil collection system.

5.1.3 Fire Barrier Guidance

Three-hour rated barriers are considered adequate to account for transient combustibles, to allow time for suppression activities to control the fire, and to provide time for safe shutdown activities to occur.

The NRC stated in its statement of considerations to the final rule that the presence of automatic suppression and detection in areas that had 1 hour barriers between redundant trains was considered an equivalent level of protection to that provided by a 3 hour barrier without suppression or detection. The basis for this determination is that the 1 hour barrier will ensure that fire damage is limited to one train until the fire is extinguished by the automatic suppression and the fire brigade. Allowing plants to use 1 hour rated barriers for separation along with automatic suppression and detection was intended to give already constructed plants the ability to meet the rule without having to install 3 hour barriers. Thus, the barrier guidance in the rule was considered by the NRC to be sufficiently flexible to accommodate specific plant differences.

5.1.4 Associated Circuits

Fire areas are designed and constructed to provide the maximum level of separation possible between redundant trains of equipment required to achieve safe shutdown. The three-hour rated fire barrier walls, floors, and ceilings which define these areas provide assurance that a fire in one fire area will not damage equipment located in unaffected areas. The layout and configuration of specific plant fire areas is based on an evaluation of plant construction, materials, layout, and the location of major components (e.g., pumps, cable raceways, motor-operated valves and electrical distribution cabinets) of redundant systems that are capable of performing the required shutdown functions.

Containing required components in separate fire areas however, does not, by itself, provide sufficient assurance that a fire will not affect the shutdown capability. While the fire may be contained within a single fire area, fire damage to certain configurations of non-essential circuits (i.e., cables and circuits that are not required to perform safe shutdown functions) may present a threat to the proper operation of required safe shutdown equipment. Therefore, the safe shutdown analysis must also include an evaluation of the potential effect of fire-initiated circuit faults on nonessential or "associated" circuits. Based on the results of this evaluation, corrective actions must then be implemented to ensure that such faults will not result in the loss of essential shutdown functions or cause the plant to enter an unrecoverable condition.

Associated circuits are described in Appendix R to 10 CFR 50 as non-safety circuits that could prevent operation or cause maloperation due to fire-induced hot shorts, open circuits, or shorts to ground. Associated circuits of concern, include any circuit (safety-related, non-safety related) that is not provided with a level of fire protection (e.g., rated fire barriers) equivalent to that required by Section III.G.2 of Appendix R and whose fire initiated failure may prevent the proper operation of equipment and systems relied on to achieve post-fire safe shutdown conditions. Such circuits may be found to be associated with circuits of required systems through any of the following configurations:

- Circuits which share a **common power supply** (e.g., switchgear, Motor Control Center, Fuse Panel) with circuits of equipment required to achieve safe shutdown; or,

- Circuits which share a **common enclosure**, (e.g., raceway, conduit, junction box, etc.) with cables of equipment required to achieve safe shutdown; or,

- Circuits of equipment whose **spurious operation** or mal-operation may adversely affect the successful accomplishment of safe shutdown functions.

The following paragraphs discuss methods of providing an acceptable level of protection for each type of associated circuit defined above, as described by the NRC in Generic Letter 81-12 and Generic Letter 86-10.

5.1.4.1 <u>Circuits Associated By Common Power Supply</u>

Electrical power supplies (e.g., switchgear, motor-control centers, fuse and circuit breaker panels) required to accomplish safe shutdown are identified by the plant's Safe Shutdown Analysis (SSA). Once identified, the analysis must assure that a fire in one fire area will not affect the operability of redundant trains of equipment located in that area or in other fire areas.

In most cases, only a few circuits of a required power supply are necessary to accomplish safe shutdown. While providing power to the remaining circuits may not be necessary to accomplish safe shutdown, it must be assured that fire initiated faults on cabling associated with these circuits will not affect the shutdown capability by causing a trip of a protective device (e.g., circuit breaker, fuse, or relay) located upstream of the required supply.

Therefore, the SSA must be extended to consider the effects of fire-induced faults on non-essential circuits of a required power supply. This analysis must ensure that: (1) non-essential circuits which share a common power supply with circuits of required equipment are adequately protected from the affects of fire, or (2) fire-induced faults on these circuits will not affect the capability of achieving safe shutdown conditions.

Figure 5.1 is a simplified diagram demonstrating the common power supply associated circuit concern.

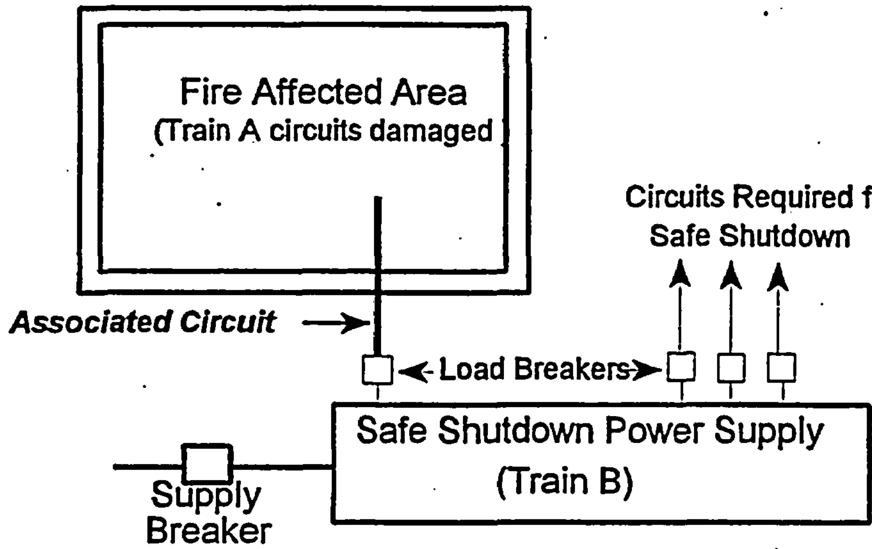


Figure 5.1 Common Power Supply Associated Circuit

For the example shown in Figure 5.1, a fire is assumed to occur in the illustrated fire area which damages Train A safe shutdown equipment. In this case, Train B safe shutdown equipment, powered by safe shutdown Bus B, is relied on to accomplish safe shutdown. Note, however, that a Train B associated circuit cable (a cable not required for safe shutdown) is also routed through the fire area of concern. If a fire initiated fault on this cable is not rapidly isolated by an individual branch circuit protection device (e.g., circuit breaker, fuse, or relay) located at Bus B, the resulting fault current may propagate to cause a protective device located upstream of the required supply to trip. This would result in a loss of electrical power to all equipment powered from safe shutdown Bus B.

Protection for circuits associated by a common power supply is typically provided by the following means:

1. Re-routing of cables whose fire initiated failure could cause a loss of a required power supply, or

2. Providing fire protection (e.g., 1-hour rated fire barrier wrap) for cables whose fire initiated failure could cause a loss of a required power supply, or

3. Ensuring proper coordination (selective tripping) of all circuit protection devices (e.g., circuit breakers or fuses) associated with a required power source. In a properly coordinated circuit, fire-initiated faults are rapidly isolated by the protective device located nearest the fault before the fault current can propagate to cause a trip of the protective device located upstream of a required power supply.

5.1.4.2 Associated Circuits By Common Enclosure

Cables of non-essential equipment and circuits may share a common enclosure (e.g., raceway, conduit, or panel) with cables of equipment required for safe shutdown. In the absence of adequate electrical protection, the heat generated by fire-induced faults on the non-essential cables may damage the required circuits which share the common enclosure. Additionally, the routing of certain non-essential cables may allow a fire to propagate beyond the initial fire area and ultimately affect fire safe shutdown equipment or cables in another area.

Figure 5.2 is a simplified diagram demonstrating the common enclosure concern. The associated circuit is routed through both the Train A and Train B fire areas. In this example Train B safe shutdown equipment is providing the fire safe shutdown capability for the Train A fire area. If the associated circuit cable is electrically faulted by fire, the resulting overheating condition within the common enclosure may also damage the Train B safe shutdown cable. Another failure method occurs by the direct transmission of the fire into the common enclosure along the associated circuit cable.

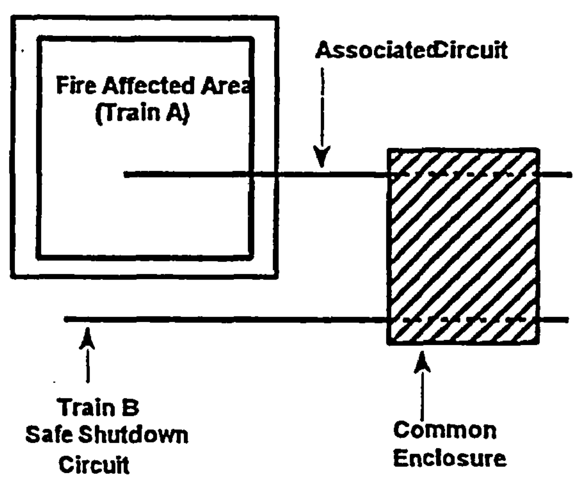


Figure 5.2 Common Enclosure Associated Circuit

The postulated failures described above may be prevented by providing suitable overcurrent electrical protection for the associated circuit cable <u>and</u> installing fire stops (barrier seals) to prevent fire propagation along the associated circuit cable.

5.1.4.3 <u>Circuits Associated By Spurious Signals</u>

Fire-induced cable damage (e.g., hot shorts, open circuits or shorts to ground) may cause connected equipment to operate in an undesirable manner. For example, a fire-induced short circuit on control wiring of a normally open motor-operated valve (MOV), could cause the valve to spuriously close, thereby blocking a previously open flow path. Conversely, the spurious opening of a normally closed valve could divert flow from a required flow path. Additional examples include false instrument indications, the spurious starting or stopping of electrically powered equipment such as pumps and motors, and the initiation of false control and interlock signals.

Figure 5.3 is a simplified diagram demonstrating the spurious signal associated circuit concern.

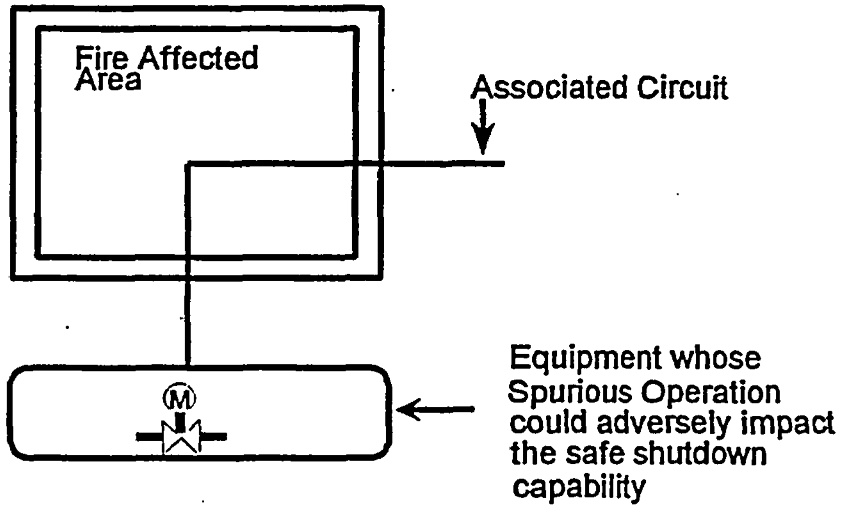


Figure 5.3 Spurious Signal Associated Circuit Concern

Circuits that could cause undesirable spurious equipment operations must be identified and evaluated for their effect on safe shutdown capability. Wherever necessary, appropriate methods of control are then implemented. The specific method of control must be consistent with the potential severity of the spurious actuation. For example, the spurious opening of valves which form a high/low pressure interface may place the plant in a potentially unrecoverable condition. Therefore, the spurious actuation of these valves must be precluded. Preventing spurious actuations of these valves may be accomplished through the implementation of plant modifications to install additional fire barrier material (fire wrap) on potentially affected cabling, or the adoption of plant operating procedures which require at least one of the redundant valves to be locked closed, with its associated power circuit breaker racked open, during normal plant operation.

Other potential spurious equipment operations may not require this level of protection, provided it can be demonstrated that the spurious actuation would not have an immediate adverse affect on the safe shutdown capability of the plant. A specific example of this case is a spurious actuation which causes the loss of ventilation in an area containing safe shutdown equipment. If it can be demonstrated through analysis that the required equipment will remain operable (i.e., capable of performing its intended function) for a sufficient length of time without ventilation, expensive plant modifications necessary to preclude the spurious operation may not be necessary. In this case, additional procedural guidance which directs operators to perform timely actions necessary to recover ventilation, may be sufficient to ensure the operability of required equipment. In certain cases, analyses have demonstrated that simply opening the doors of the affected area will provide an adequate level of ventilation.

Spurious actuations of equipment may have a significant effect on the post-fire safe shutdown capability of the plant. Once identified, appropriate methods of control can then be planned. However, it is imperative that the safe shutdown analysis include a thorough evaluation of all plant systems so that potential spurious equipment operations of concern can be properly identified for each fire area. The following assumptions are typically applied during this analysis:

1. The plant is operating with a 100% power history (approximately 3 continuous months at 100% power) at the time of the fire

2. All components are in their normal operating condition when the fire-induced spurious signal occurs.

3. Unless cables are protected by acceptable methods, fire-induced damage will occur at the inception of fire.

4. The fire-induced cable damage may cause either one or a combination of the following possible cable failure modes:

   Short Circuits - An individual conductor within a cable comes in electrical contact with another conductor, cable, circuit, etc.

   Shorts To Ground - An individual conductor comes in electrical contact with a grounded conducting device such as a cable tray (raceway), conduit, grounded conductor, grounded equipment, etc.

   Hot Shorts - An energized conductor within a cable comes in electrical contact with unenergized conductor(s) located within the same cable or in another cable.

   Open Circuits - An individual conductor within a cable loses electrical continuity.

5. All possible functional failure modes must be considered for components subject to spurious operation. For example:

   - Valves may spuriously open or close.
   - Valves may fail to reposition on automatic actuation signals or by normal remote operations.
   - Circuit breakers may close or trip open.
   - Pumps and motors may start or stop.
   - Process instrumentation and control signals may initiate unacceptable automatic operations.
   - Process instrumentation may provide erratic or incorrect indications

Additional, more conservative, assumptions are required to be applied in the evaluation of equipment whose spurious operation may place the plant in an unrecoverable condition. An example includes redundant valves which form the boundary between high and low pressure reactor coolant systems (High/Low pressure interface valves). The spurious opening of both valves could lead to an uncontrollable loss of reactor coolant inventory. Specifically, unlike other analyses, the analysis of this equipment must consider multiple, simultaneous, hot shorts of the required polarity and sequence as a credible event. Unenergized conductors of a three-phase cable which powers a high/low pressure interface valve should be assumed to become energized as a result of fire damage.

5.1.5 Interpretations of Appendix R

Following the implementation of 10 CFR 50.48 and Appendix R, questions were posed to the NRC staff by operating organizations and other industry representatives on carrying out its requirements. Additionally, during inspections the NRC identified instances where the licensee's interpretations, established procedures, installations and equipment configurations which did not appear to satisfy the provisions of Appendix R.

The NRC staff addressed the issue by conducting public meetings with representatives of the various operating organizations and through the issuance of the following generic letters and information notices:

- Generic Letter 81-12 forwarded two documents, which, if used by the plant engineering staffs and operating organization contractors, would expedite the staff's review process and reduce the number of NRC requests for additional information with regard to the review.

- Generic Letter 83-33 provided "NRC Positions On Certain Requirements Of Appendix R to 10 CFR 50". This letter was issued following several meetings with representatives of the Nuclear Utility Fire Protection Group (NUFPG), other industry representatives, and individual licensees to discuss clarification of certain requirements. The following staff positions (interpretations) were provided:

  (a) Detection and Automatic Suppression;
  (b) Fire Areas;
  (c) Structural Steel Related To Fire Barriers;
  (d) Fixed Suppression System;
  (e) Intervening combustibles;
  (f) Transient Fire Hazards.

- IE Information Notice 84-09, "Lessons Learned From NRC Inspections Of Fire Protection Safe Shutdown Systems (10 CFR 50, Appendix R)", was provided as guidance for power reactor facilities conducting analyses and/or making modifications to implement requirements of 10 CFR 50, Appendix R. Enclosure (1) to IN 84-09, "Supplemental Guidance On 10 CFR Appendix R Fire Protection Safe Shutdown Requirements", provided guidance on the following:

  (a) Fire areas;
  (b) Fire Barrier Testing and Configuration;
  (c) Protection of Equipment Necessary To Achieve Hot Shutdown;
  (d) Licensee's Reassessment for Conformance with Appendix R;
  (e) Identification of Safe Shutdown Systems and Components;
  (f) Combustibility of Electrical Cable Insulation;
  (g) Detection and Automatic Suppression;
  (h) Applicability of 10 CFR 50, Appendix R, Section III.L;

(i) Instrumentation Necessary for Alternative shutdown;
(j) Procedures for Alternative Shutdown Capability;
(k) Fire Protection Features for Cold Shutdown Systems;
(l) RCP Oil Collection Systems.

- Generic Letter 86-10, "Implementation of Fire Protection Requirements", provides the most current guidance on acceptable methods of satisfying NRC regulatory requirements. This document addresses the following issues:

(a) Process Monitoring Instrumentation
(b) Repair of Cold Shutdown Equipment
(c) Fire Damage
(d) Fire Area Boundaries
(e) Automatic Detection and Suppression
(f) Alternative or Dedicated Shutdown Capability

5.2 Plant Responses

As the operating organizations performed the fire hazards and safe shutdown analyses, many innovative solutions for implementing specific fire protection requirements were developed. Because many different designs were used in constructing U.S. nuclear power plants, several different approaches were employed, including:

1. Total wrapping of one train of equipment required to achieve post-fire safe shutdown conditions
2. Manual operations
3. Dedicated post-fire shutdown equipment
4. Administrative controls
5. Shared equipment at multiple unit sites

As discussed below, the NRC reviewed and approved many (but not all) of the various proposed approaches for satisfying Appendix R requirements.

5.2.1 Total Wrapping Of One Train

The "as-built" configuration of many older plants did not provide adequate fire protection for redundant trains of safe shutdown circuits and cables. To achieve the required level of separation, some plants installed a fire barrier material (i.e., 1-hour fire barrier) around all cables associated with one train of safe shutdown systems. Additionally, fire detection and automatic fire suppression capabilities where installed where required. While this configuration clearly satisfies the separation requirements of Appendix R, attention must be paid to the ampacity rating of cables located within the wrapped enclosure to ensure that the increased thermal (heating) effects of the wrapping material will not degrade their electrical current capacity below acceptable limits.

5.2.2 Manual Operations

As discussed previously, the fire-induced failure of power, control and instrument cables may cause equipment to spuriously operate in an undesired manner. Preventing the occurrence of unacceptable equipment actuations due to fire may require plant modifications such as wrapping the affected cables in a rated fire barrier material, or re-routing the cables out of the fire area of concern. In certain cases, however, the performance of manual operator actions may provide an acceptable alternative. For example, post-fire operating procedures which direct operators to take manual, local, control of a motor-operated valve may provide a suitable alternative to the installation of additional plant modifications.

Manual operator actions are commonly used to mitigate spurious equipment operations that may be caused by fire. However, their use must be based on the following considerations:

- The time-critical consequences of the spurious operation - does the spurious operation have the potential to cause the plant to enter an unrecoverable condition?
- Assuming the spurious actuation occurs at the time the reactor is tripped, how much time is available to perform the action, and how much time is required for an operator to travel to the remote location and complete required tasks (i.e., time-line study)?
- Manpower availability - are there a sufficient number of operators available to perform required actions?
- Feasibility of required actions - are the components accessible and are they capable of being manually operated? Is there sufficient emergency lighting in the area? Will the products of the fire (smoke, hot gasses) and fire suppression activities (sprinkler actuation, manual fire fighting hose streams) affect the operator's ability to perform required actions?

5.2.3 Dedicated Shutdown

In some cases, neither modification of existing equipment nor procedural solutions provide an acceptable post-fire safe shutdown capability. In these instances, a dedicated post-fire shutdown capability may be provided. The installed capabilities range from the relatively simple installation of dedicated equipment capable of performing a required shutdown function (e.g., a dedicated auxiliary feedwater pump, or diesel generator); to the very complex, such as bunkered facilities located in separate structures that are capable of performing all shutdown functions completely independent of existing plant systems.

Alternative shutdown capability is distinct from dedicated shutdown capability in that it is provided by modifying existing plant systems (e.g., the installation of isolation/transfer switches to electrically isolate existing equipment from the affected fire area). A dedicated shutdown capability consists of new equipment that is installed to perform specified shutdown functions. Hybrid approaches are also common. For example, a plant may have developed an alternative shutdown capability that includes the use of dedicated equipment, such as a pump, to perform a specified shutdown function.

5.2.4 Special Administrative Controls

Administrative controls consist of a set of documented procedures used to govern plant activities. With regard to fire protection, administrative controls include general housekeeping procedures and procedures used to control specific tasks such as cutting and welding activities within the plant. At some plants, special administrative controls are used to control the effects of fire and support safe shutdown capability. Examples of these additional or special administrative controls include:

- Pre-fire actions to prevent spurious operations such as shutting the RHR isolation valves and removing power to the valves prior to normal power operation. This action, included in the operating procedures, is performed during plant startup.

- Controlling access to spaces containing safe shutdown equipment or cabling to avoid the introduction of transient combustible material.

- Some plants were unable to demonstrate an acceptable level of selective coordination for certain power supplies required for safe shutdown. In these cases, post-fire shutdown procedures direct operators to promptly trip open all non-essential loads of the affected power supply at the inception of the fire.

- Pre-positioning of tools and equipment that may be required to perform local operator actions necessary to support safe shutdown. For example, it may be necessary to position a ladder near a valve to provide access. Since the ladder provides an important shutdown function it would be administratively controlled to prevent its removal from the area. Frequently such ladders are chain-locked in a designated location.

5.2.5 Shared Equipment At Multiple Unit Sites

Some multiple unit facilities use equipment of the non-affected unit to provide a redundant safe shutdown capability. When equipment is shared among units, the shared equipment must satisfy General Design Criterion 5 (GDC 5) of Appendix A of 10 CFR 50. Specifically, the plant must demonstrate that such sharing will not significantly impair their ability to perform their safety functions, including, in the event of an accident in one unit, an orderly shutdown and cooldown of the remaining units.

Examples demonstrating use of shared equipment or equipment from another unit include:

- Non-affected unit emergency diesel generators are used to provide safe shutdown power for the affected unit.

- Service water, component cooling water, and auxiliary feedwater may be cross-connected to supply the affected unit from the non-affected unit.

- Water supplies such as refueling water storage tanks and condensate storage tanks may be cross-connected to permit use of the non-affected unit's water inventory to supply the affected unit.

5.3 Review Process

Appendix R to 10 CFR 50 requires plants to demonstrate that one train of equipment necessary to achieve and maintain hot shutdown conditions will remain free of fire damage and also provides several optional approaches for assuring this capability. Although compliance with Appendix R is clearly evident when methods of protection prescribed by the rule are adopted, alternative approaches may also be acceptable, provided the proposed alternative will provide an equivalent level of protection to that afforded by the rule. As the plants identified innovative and unique methods for achieving a safe shutdown capability, documents describing the proposed methods were forwarded to the NRC staff for review. Examples of alternative approaches proposed by licensees and the subsequent NRC review results are provided below.

5.3.1 Total wrapping of trains

The total wrapping of trains was found to be acceptable by the NRC staff because this approach can satisfy the fire protection requirements of Appendix R Section III.G.2 (i.e., separation by a 1 hour fire barrier with fire detection and automatic fire suppression). Additionally, in some instances where this method was proposed, licensee requests for exemption from the requirement to provide automatic fire suppression were granted for the following reasons:

- Low combustible loading in the fire area of concern.
- No intervening combustibles present.
- Transient combustibles administratively controlled.
- Area wide fire suppression capability would not significantly improve safety.

5.3.2 Bunkered Dedicated Shutdown System

A bunkered type of dedicated shutdown system consists of a single train of equipment that is housed in a reinforced concrete structure independent of the operating units, and capable of accomplishing required shutdown functions. A typical bunkered system for a pressurized water reactor (PWR) may include the following major subsystems:

- A high volume auxiliary feedwater (AFW) system capable of removing decay heat from the reactor.
- A reactor coolant makeup system of sufficient capacity to compensate for normal reactor coolant system losses and volume reduction which result from going from power operation to hot shutdown.
- Independent AC and DC electrical power supplies and associated distribution equipment.
- Instrumentation and monitoring capability of essential plant parameters including reactor coolant temperature and pressure, pressurizer level, steam generator level and pressure, and source range neutron flux.

The use of dedicated shutdown facilities was found to be acceptable by the NRC staff because they satisfy the alternate shutdown requirements of Appendix R. However, due to several factors including the high initial cost of construction, their use has not been widely adopted at U.S. reactor plants.

5.3.3 Extensive manual operations

Some licensees employed extensive manual operations to assist in achieving alternate shutdown capability. The licensee submissions to the NRC staff included the manual operation procedures for performing alternate shutdown. During the NRC staff reviews, particular attention was directed toward verifying that the manual operation procedures achieved each of the safe shutdown functions, that they accurately reflected the information in the licensee's safe shutdown analysis (SSA), and that they could be performed within required time limits as established by the SSA.

The following issues were identified during NRC staff reviews of licensee submittals describing this approach:

- Performance of manual operations in the fire area of concern;
- Operator actions described as manual operations were actually hot shutdown repairs (not permitted by Appendix R);
- Failure to pre-position and administratively control tools and repair parts required for cold shutdown repairs;
- Manual operation procedures did not assure the achievement of safe shutdown functions;
- Manual operation procedures could not be satisfactorily performed within the times specified in the safe shutdown analysis.

Some NRC staff reviews accepted the following innovative methods that were incorporated into the manual operation procedures:

- As stated previously, Appendix R requires each operating U.S. plant to demonstrate the achievement of stable hot-shutdown conditions in the event of fire without reliance on repairs. The removal of fuses is considered by the NRC to be a repair activity and, therefore, not generally permitted under the regulation. However, under certain conditions, and on a case by case basis, NRC reviews have found the removal of fuses to be no more difficult than many manual operator actions (such as the tripping of circuit breakers or) already allowed under the rule. Factors influencing NRC staff acceptance of post-fire safe shutdown methodologies requiring the removal of fuses include:

    (a) The fuse removal is a normal manual operation performed by operators during routine plant operation;

    (b) The operator does not require special tools to gain access to the fuse;

    (c) The fuse removal will not unnecessarily jeopardize operator safety.

    (d) The operators are trained in performing the removal of the fuse;

    (e) The fuse will not need to be replaced in the circuit;

    (f) Emergency lighting is available and sufficient to illuminate the area where the fuse is to be removed

    (g) All required operator actions are governed by a written procedure.

- An alternative method for achieving a safe shutdown function was employed. As an example some plants verified that the plant was shutdown by determining the reactor coolant system (RCS) boron concentration by evaluating an RCS sample. The use of a boron analysis was used in lieu of using an indication of source range neutron level. The sample process was accepted because:

(a) The boron sample and analysis can be completed within the time limits identified in the safe shutdown analysis;

(b) If the reactor coolant system boron concentration is greater than an established level, then the reactor plant is shutdown.

- Manual operations within the fire affected area were determined to be acceptable based on:

(a) The required action is not an immediate operator response necessary to achieve safe shutdown conditions - based on an evaluation which considers such factors as the combustible loading in the area, availability of suppression and detection systems, fire brigade response times and shutdown system performance requirements, it is determined that a postulated fire will be extinguished before the action is required to be performed;

(b) Large size of fire area;

(c) Combustible loading was low in the location where the manual operation is performed;

(d) Access to the location where the manual operation is performed could be gained without passing through the fire-affected area or areas of high combustible loading;

(e) Fire damage would not preclude the manual operation;

(f) The manual operation could be completed within the time limits specified in the safe shutdown analysis.

6. APPENDIX R INSPECTION PROGRAM

This section provides an overview of the inspection program established by the NRC to validate the post-fire safe shutdown capability of commercial nuclear power plants operating in the U.S.. For additional guidance on specific aspects of fire protection inspections, the reader is referred to "Inspection Techniques for Post-Fire Safe Shutdown of Nuclear Generating Stations," included as Appendix 2 of this report, and to the following NRC Inspection and Enforcement Manual Procedures: Inspection Procedure 64100, "Post-Fire Safe Shutdown, Emergency Lighting and Oil Collection Capability at Operating and Near-Term Operating Reactor Facilities" and Inspection Procedure No. 64704, "Fire Protection/Prevention Program". Copies of these procedures will be distributed during the training course.

6.1 Inspection Objectives

- Verify that the approved fire protection program, as described in the NRC's plant specific Safety Evaluation Report, has been adequately implemented; and,

- Validate the reactor plant's capability to achieve and maintain safe shutdown conditions in the event of fire.

6.2 Inspection Process

To achieve the inspection objectives a broad range of technically complex issues must be evaluated. The capability of systems, equipment and operator actions necessary to accomplish safe shutdown conditions must be verified and the adequacy of fire protection features must be validated. A well planned, organized approach is necessary to ensure that inspection issues are properly evaluated. The following are the key elements of the inspection process:

- Formation of the inspection team
- Preparation and planning for the inspection
- On-site evaluation
- Documenting the results of the inspection

6.2.1 Inspection Team

Due to the technical diversity of issues which must be evaluated, inspections of post-fire safe shutdown capability are performed by multi-disciplined teams of specialists. As a minimum, the inspection team includes a team leader, a fire protection engineer, a specialist in mechanical/nuclear plant systems, and an electrical specialist experienced in the area of associated circuits and post-fire safe shutdown requirements. Typical areas of responsibility assigned to each of these individuals include:

- **Inspection Team Leader**

    - Appropriateness of inspection team activities
    - Accomplishment of inspection objectives
    - Ensuring NRC and plant management are appraised of inspection activities
    - Assisting other members of the inspection team

- **Fire Protection Engineer**

    - Quality assurance
    - Fire brigade training
    - Automatic suppression and detection systems
    - Fire barriers and penetration seals
    - Adequacy of protection provided for redundant trains of shutdown equipment
    - Control of ignition sources and combustible material
    - Emergency lighting
    - General plant housekeeping
    - Assist other members of the inspection team as needed

- **Mechanical/Nuclear Plant Systems Engineer**

    - Availability and capability of systems and equipment required to achieve and maintain post-fire safe shutdown conditions
    - Adequacy of procedures and equipment provided to accomplish alternate or dedicated shutdown independent of the main control room
    - Feasibility and appropriateness of manual operator actions specified in post-fire shutdown procedures
    - Assist other members of the inspection team as needed

- **Electrical Engineer**

    - Availability and capability of the on-site electrical distribution system
    - Adequacy of separation provided for redundant trains of cabling and equipment
    - Adequacy of protection provided for associated circuits of concern
    - Assist other members of the inspection team as needed

6.2.2 Inspection Preparation and Planning

Variations between operating organizations in the method of demonstrating the capability of achieving post-fire safe shutdown, and plant-specific features such as system configuration and reactor operating characteristics require the team to conduct detailed preparation activities in advance of each inspection. Typical preparations include:

- Retrieval and review of applicable design basis information, supporting analyses, and licensing documents. (e.g., the plant's Final Safety Analysis Report, NRC Safety Evaluation Reports on fire protection, fire hazard analysis, and safe shutdown analysis);

- Selection of an "inspection sample" of systems, components, cables, and procedures to be evaluated during the inspection;

- Preparation of a documented inspection plan which defines the objectives of the inspection and delineates the major topics to be addressed.

6.2.3 On-site Review Activities

Upon arrival at the plant site, the inspection team holds a formal entrance meeting with senior members of the operating organization. During this meeting the inspection team leader states the scope and purpose of the inspection, outlines the planned inspection activities and their expected time-frame of accomplishment, confirms the pre-agreed level of inspection support from plant personnel, introduces members of the inspection team, and discusses the scheduling of team leader/plant management briefings.

Fire protection inspections are performed on an "inspection sample" basis, where a selected systems, equipment and procedures are reviewed in detail. Based on the results of this detailed review, an overall assessment of the plant's compliance with the established requirements can be made. In performing its assessment, the inspection team considers all sources of available information including discussions with the plant-staff, documents, records and drawings, and observations noted during field walk-down of the plant.

The principal tasks performed when evaluating post-fire safe shutdown capability are outlined below. For more detailed information, the reader is referred to "Inspection Techniques for Post-Fire Safe Shutdown of Nuclear Generating Stations," included as Appendix 2 of this report.

- Identify the systems that will be relied on by the operating organization to accomplish required shutdown functions in the event of fire in each fire area.
- Identify redundant equipment and components required for shutdown function accomplishment. This list should include equipment of required support systems (e.g., electrical distribution, and equipment cooling water systems) and components whose spurious operation, could adversely affect system operation (e.g., motor-operated valves).
- Identify a sample of power, control and instrument cabling associated with the selected equipment.
- Verify the capability of the selected equipment to accomplish the desired shutdown functions.
- Verify the adequacy of separation provided for redundant trains of required equipment and cabling.
- Evaluate the effects of fire damage on Associated Circuits of concern.
- Evaluate the adequacy of electrical isolation provided for required equipment in the event of fire in areas requiring plant shutdown from outside the main control room (alternate shutdown).
- Verify that local operator actions, including any repair activities necessary to achieve cold shutdown conditions, are governed by written procedures, are feasible under post-fire conditions, and may be completed within required time limits.
- Verify that the results of the safe shutdown analysis are adequately incorporated into post-fire safe shutdown procedures, that the shutdown procedures are available, and that they provide sufficient direction to accomplish safe shutdown tasks.

At the conclusion of the inspection, the inspection team presents a oral summary of its activities and findings to members of the plant management and staff (exit meeting). At this time plant management is provided an opportunity to comment, provide additional data, and request additional clarification of the specific issues identified by the inspection team.

6.2.4 Documentation of Inspection Results

Each member of the inspection team provides the inspection team leader with a detailed summary of inspection activities performed and results obtained. The inspection team leader then combines these individual inputs into a formal NRC inspection report. Following review and approval by NRC management, copies of the final report are distributed to the operating organization and within the NRC. Additionally, in accordance with the NRC's "Rules of Practice" (10 CFR 2.790) a copy of the inspection report is placed in NRC public document rooms located in Washington D.C. and near the plant site.

6.3 Illustrative Inspection Findings

The NRC performed its first Appendix R inspection at the D.C. Cook plant in 1982. This plant was chosen because the operating organization had notified the NRC in writing immediately after Appendix R was issued that it was in compliance with the new rule. Although the plant later withdrew this declaration, the NRC continued with its planned inspection. The inspection identified a number of discrepancies, including certain configurations which did not meet the requirements of Appendix R to 10CFR50.

As a result of evaluating requests for exemptions and after inspecting four plants (all of which had stated that Appendix R modifications were complete) the NRC issued Generic Letter 83-33 in October, 1983. This Generic Letter was issued because the evaluations and inspections identified a number of instances where licensees did not properly request or justify certain exemptions. Examples of problems described in this Generic Letter include:

- Lack of fire suppression or detection throughout the fire area.
- Designated fire areas which were not bounded by rated barriers.
- Unprotected structural steel.
- Hose stations designated as fixed fire suppression.
- Lack of proper accounting for intervening combustibles.
- Non-conservative analysis of transient combustibles.

In February 1984, after performing inspections at four additional plants that had stated that Appendix R modifications were complete, the NRC issued IE Information Notice 84-09, Lessons Learned From NRC Inspections Of Fire Protection Safe Shutdown Systems (10 CFR 50, Appendix R). Problems discussed in this Information Notice include:

- A fire hazards analysis had not established fire areas.
- Fire barriers could not be validated by testing documentation.
- Inadequate separation of redundant components.
- Lack of a comprehensive analysis of associated circuits for all fire areas.
- Use of analyses made before the issuance of Appendix R.
- Failure to identify safe shutdown components within a fire area.
- Failure to account for cable insulation as an intervening combustible.
- Automatic fire suppression system not installed throughout the fire area.
- Sprinkler systems installed in such a way that obstructions could prevent their effectiveness.
- Failure to fully consider the alternative shutdown requirements of Appendix R, Section III.L.
- Failure to provide instrumentation necessary to verify reactor process system variables (system operating parameters) when using the alternative shutdown capability.
- Inadequate, incomplete, or ineffective shutdown procedures.
- Failure to provide an acceptable repair capability for cold shutdown equipment that may

be damaged by fire.

- Inadequate capacity of the reactor coolant pump oil collection system.

Inspections for compliance with the post-fire safe shutdown requirements of Appendix R identified a wide range of deficiencies. Specific examples of issues identified as a result of the NRC inspection effort include:

- Inadequate analysis of potential fire-induced spurious operation of equipment.
- Incomplete identification of required cold shutdown repairs.
- Shutdown methodology that differed from that described in the SER issued by the NRC.
- Incomplete analysis of the effects of fire in fire areas containing safety related equipment.
- Incomplete analysis of the effects of fire damage to non-safety grade cables which share a common enclosure (raceway, junction box, etc.) with cables of equipment required for post-fire safe shutdown.
- Inadequate isolation of shutdown equipment from the effects of fire in the control room.
- Insufficient instrumentation on the Remote (Alternative) Shutdown Panel.
- Fire areas which do not satisfy the separation and protection requirements of Section III.G.2 of Appendix R.
- Lack of emergency lighting in areas traversed by operators during implementation of alternative shutdown procedures.
- Inadequate coordination of electrical overcurrent protection devices (relays, circuit breakers and fuses).
- Lack of a suitable communication system to support alternative shutdown activities outside of the main control room.

6.4 Follow-up Actions

Based on its assessment the number and type of findings identified during the inspection, NRC management determines the nature and extent of follow-up activities. In certain cases involving violations of Appendix R, NRC may impose a civil penalty (fine) against the plant operating organization. For example, the inspection of one plant determined that in the event of fire in certain areas of the plant, systems required to shutdown the reactor may not be available due to fire damage. Therefore, in addition to a significant civil penalty, NRC management issued an order which would not permit the plant to resume operation until certain fire protection program deficiencies were corrected or sufficient interim compensatory actions (e.g., fire watches) were implemented.

Occasionally, the inspection team may not be able to fully complete all of its planned activities, or the operating organization may not be able to provide a complete response to certain issues. If the issue is not of a high safety significance, it may be classified as an "Open Item" in the inspection report, and tracked by both the NRC and the operating organization until an acceptable resolution is achieved. Specific examples of Open Items identified during previous inspections include:

- Lack of an analysis which demonstrates that the environmental conditions (temperature, radioactivity levels) within the reactor containment building will be suitable for operators to enter and perform actions necessary to achieve cold shutdown conditions.

- Inability to provide sufficient objective evidence (e.g., training attendance records) necessary to verify that operators received training in revised procedures.

- Lack of an analysis or other documentation which demonstrates that the portable radio communication system would remain available for the assumed 72-hour loss of offsite power.

- Lack of administrative controls (procedures) which govern the replacement of fuses in electrical distribution panels required for safe shutdown.

7. CHARACTERISTICS OF A TYPICAL U.S. NUCLEAR POWER PLANT FIRE PROTECTION PROGRAM

The purpose of a reactor plant fire protection program is to prevent fires, to ensure the capability to shutdown the reactor and maintain it in a safe shutdown condition, and to minimize radioactive releases to the environment. To obtain reasonable assurance that these objectives are achieved, U.S. plants are required to implement a fire protection program that is based on a defense-in-depth philosophy. As discussed previously, the defense-in-depth approach to fire protection is focused on achieving an adequate balance in the following features:

- **Fire Prevention** - Preventing the start of fires by administratively controlling plant activities (e.g., good housekeeping practices, control of combustible materials, control of ignition sources, etc.).

- **Fire Detection and Suppression** - Providing the ability to quickly detect and rapidly suppress fires through the use of early warning fire detection systems, fixed or automatic fire suppression systems, and manual fire fighting capability.

- **Assuring Safe Shutdown Capability** - Designing plant safety systems so that a fire that starts (in spite of the fire prevention program) and burns for a considerable period of time will not interfere with the performance of safe shutdown functions.

The fire protection program consists of fire detection and extinguishing systems and equipment, administrative controls and procedures, and trained personnel. In the following sections the fundamental attributes of a typical U.S. plant's fire protection program are discussed. In several sections the reader is referred to related sections of NRC Branch Technical Position 9.5-1, (BTP 9.5-1) "Guidelines for Fire Protection for Nuclear Power Plants", which is included in Appendix 4 to this document. This document provides a single, comprehensive, source of NRC staff positions on acceptable elements of a fire protection program (It should be noted that BTP 9.5-1 was specifically written to provide applicants for operating licenses docketed after July 1976 with detailed guidance on the administrative and technical aspects of nuclear plant fire protection. As such, BTP 9.5-1 does not constitute a regulatory requirement).

7.1 Fire Prevention

The fire prevention program consists of administrative controls and procedures which address the following programmatic elements: control of combustibles, control of ignition sources, periodic housekeeping inspections, and employee training. An effective fire prevention program will include a fire protection organization that is supported by management's commitment to ensure the safety of the facility.

An effective fire prevention program provides a degree of compensation for weaknesses (both known and unknown) that may exist in plant design features installed to suppress fires and to protect safe shutdown equipment.

7.1.1 Fire Protection Organization

(See also: USNRC guidance contained in BTP 9.5-1, Section C.1.a.)

The NRC does not specify a particular organizational structure for the fire protection organization. In fact, several different organizational structures have been used effectively by the industry. Figure 7.1 depicts a typical fire protection organization at a U.S. nuclear plant.

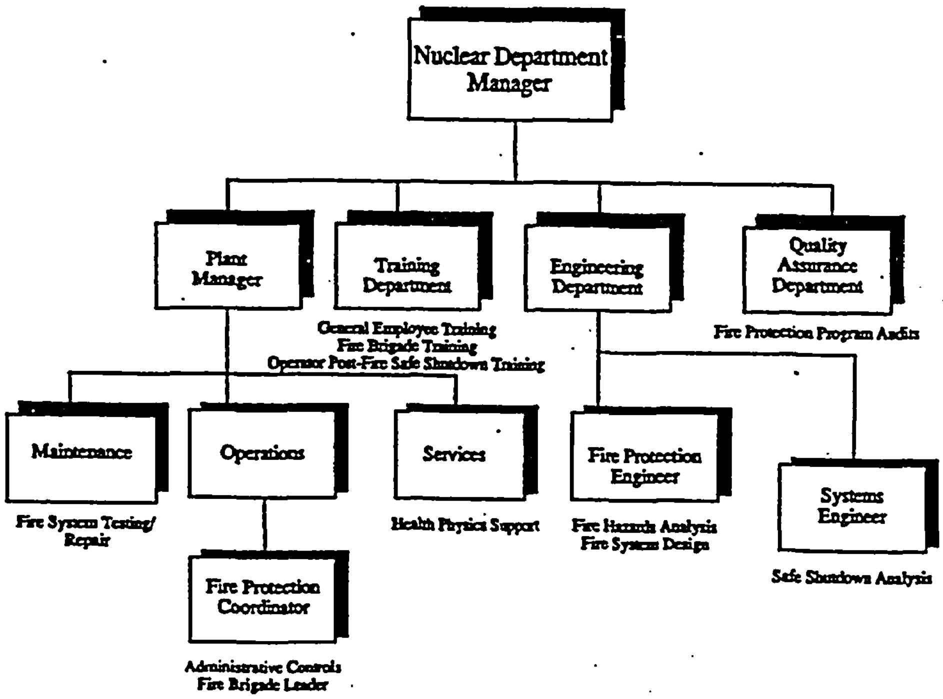


Figure 7.1 Typical Fire Protection Organization and Responsibilities

Some plants maintain the fire protection organization within the Operations Department of the plant. A potential problem with this approach is that fire protection may be seen as an impediment to operations and would therefore not be given adequate priority. Conversely, locating the fire protection responsibility outside of the operations department could possibly lead to an attitude by operations personnel that fire protection is not an operations department responsibility. All plant personnel should understand that they have a responsibility in assuring the fire safety of the facility. Therefore, a successful fire protection program may integrate fire protection responsibilities between operations, maintenance, engineering, quality assurance and emergency response personnel.

Many U.S. reactor plants have created a staff position that is frequently titled "fire protection coordinator". This position could report to a number of places organizationally. The fire protection coordinator is usually responsible for ensuring that the fire protection program is in place and is effective. This coordinator is typically the liaison between all of the various plant departments which have some direct involvement with implementation of the fire protection program.

7.1.2 Administrative Controls

(See also: USNRC Guidance on Administrative Controls contained in BTP 9.5-1, Section C.2.)

The most effective fire protection programs are those where responsibilities are clearly defined and where fire safety is integrated into efficient plant operations. For example, if combustible control procedures do not permit a maintenance team to bring the material they need into the plant, then it is likely the procedure will be circumvented and its objectives not accomplished. On the other hand, if the fire safety program acknowledges that combustibles need to be periodically brought into the plant and provides a method for the work to be accomplished safely, then the fire safety program would be maintained and operations would not be negatively impacted.

Administrative control procedures also are established to compensate for inoperable automatic fire protection equipment or impaired fire doors and barriers. The most often used compensatory measure at U.S. plant is the establishment of fire watches. Assigned individuals provide additional detection capability and are often trained in the use of fire extinguishers. Thus, fire watches provide both prevention and mitigation functions. Fire watches are intended to ensure that any fire is detected and extinguished before the impaired system or barrier would have been necessary.

Combustible Control

Combustible control procedures define how combustible materials and flammable liquids are to be stored and handled. The objectives of these administrative procedures are to:

- Prohibit bulk storage of combustible materials inside or adjacent to safety-related buildings or systems during operation or maintenance

- Govern the handling and limit the use of transient fire loads such as combustible and flammable liquids and gases, plastic and wood products, and dry ion-exchange resins (for example, requiring the use of safety containers for flammable liquids and limiting the amounts that can be brought into safety-related areas of the plant at any one time, can greatly reduce the hazards associated with their use).

- Control the removal of all waste, debris, scrap, oil spills, or other combustible materials resulting from a work activity, following the completion of the work activity, or at the end of each work shift, whichever comes first (for example, if necessary to support an operating condition, combustible packing containers may be unpacked in safety related areas. However, all combustible packing material should be removed from the safety-related areas immediately following unpacking).

To ensure continued compliance with administrative controls governing combustible material, periodic housekeeping inspections are performed. Procedures which instill a good housekeeping attitude among plant personnel and require materials to be used in a safe manner are often more effective than complex procedures. Some U.S. plants have implemented detailed combustible control procedures which require the B.T.U. content (fire heat-load) of materials to be calculated and then compared to the safe threshold established for the fire area in which the material is to be used. While this type of procedure can accomplish the objective of limiting combustibles, it can be cumbersome to implement.

Control of Ignition Sources

Safe work practices associated with cutting and welding are fundamental to industrial fire protection programs. Hot-work permits, approved by plant operations and/or fire safety personnel, are used in most U.S. plants. Such permits serve several purposes: they allow for a review of the proposed work to ensure that no unacceptable work practices will take place; hot-work permits provide for notification to the operators that an ignition source will be introduced in the plant; and they identify personnel to serve as fire watches; and they provide a method for ensuring that appropriate extinguishing devices are readily available.

Testing and Maintenance of Fire Suppression and Detection Equipment

Specific operability tests for critical fire suppression and detection equipment are either established within a plants technical specifications or within the fire protection program.

Emergency Notification and Fire Fighting

All plant personnel should clearly understand how to report a fire, what actions they should take upon discovering a fire, and in what order they should be taken (e.g., report the fire first). These actions should be defined by a written procedure and included in a training program.

The actions of personnel directly involved in fire response activities are often delineated in documented procedures called fire pre-plans. In addition to providing a fire response strategy, these procedures define and coordinate the functions of personnel (e.g., plant operators, fire brigade, health physics technicians) responding to the fire, and provide key information about a given area of the plant. Fire pre-plans are discussed later in this report (in section 7.2.2).

7.1.3 Testing and Maintenance of Fire Safety Features

The USNRC has established guidance for fire protection surveillance tests and frequencies within the NRC's Standard Technical Specifications (TS). The tests generally are based upon NFPA codes and standards. These tests become requirements when they are incorporated into a plant's individual technical specifications or safety analysis report. A description of the types of tests is provided below. While there is some variation of testing requirements and test frequencies, most US plants conform closely to the Standard Technical Specifications. It should be noted that as a result of Generic Letter 86-10, many plants have removed their testing requirements from technical specifications and have included them within plant procedures. This allows for the plant to much more easily modify their procedures to reflect plant modifications.

Fire Detection Instrumentation

Periodic tests are performed to verify the operation of individual fire detection devices and the circuitry between the detectors and the associated alarm panels.

Fire Suppression Water System

Various tests are performed to verify that all aspects of water suppression systems are functional. Periodic tests include:

- Verifying water supply volume.
- Starting fire pumps and confirming that they operate properly; this includes periodically testing the pumps under full flow conditions.
- Checking valves to confirm they are in the proper position.
- Periodically cycling selected valves.
- Flushing underground piping to keep it free of debris.

Spray and/or Sprinkler Systems

Sprinkler systems are tested to verify that the valves function properly. Open head systems are inspected to verify that the nozzles are not blocked.

Gaseous Suppression Systems

The types of gaseous systems used are carbon dioxide (CO_2) and Halon. Gaseous systems are routinely tested and inspected to ensure their availability and verify that all of their automatic functions perform properly.

Fire Hose Stations and Fire Hydrants

Fire hoses and hose stations are periodically inspected for damage and to confirm that all components and fittings are available and in working order. Fire hydrants are periodically cycled to confirm operation. Fire hoses are hydrostatically tested at a pressure of 150 psi, or 50 psi above the maximum fire main operating pressure, whichever is greater.

Penetration Fire Barriers

Sealing devices in fire barriers, including fire doors, fire dampers and penetration seals, are inspected periodically to confirm they are functional. Due to their high number and difficulty of access, penetration seals are generally inspected on a rotating basis, with 10% inspected at a time.

7.1.4 General Employee Training

Most U.S. plants include general fire protection training as part of the overall general employee training course. This course is given to new employees and then annually to all employees thereafter. The topics that are covered include:

- Methods of notifying key plant personnel of a fire.
- Plant alarm sounds and required personnel responses.
- Housekeeping requirements.

The U.S. Occupational Safety and Health Administration (OSHA) requirements mandate that if personnel are expected to use fire extinguishers, they must be provided with appropriate training. Due to the difficulty at most plants of providing adequate training to all personnel, including contractors, most reactor plants do not require personnel to use fire extinguishers. Plants usually train selected personnel (e.g., fire brigade members and fire-watches) in the use of manual fire fighting equipment. Personnel not trained in the proper use of fire extinguishers are usually taught to notify key personnel of any fire condition and then evacuate to a safe location.

7.1.5 Quality Assurance

Quality Assurance Program

(See also USNRC guidance on Quality Assurance contained in BTP 9.5-1, Section C.4.)

The Quality Assurance (QA) program ensures that established guidelines for design, procurement, installation and testing and the administrative controls for the fire protection systems for safety related areas are satisfied.

To ensure compliance with the established fire protection program, U.S. plants are required to perform periodic audits of instructions, procedures, drawings, and inspection and test activities. Most plants incorporate fire protection auditing requirements within their technical specifications (TS). Typically, the TS requirements include:

- Audit of the fire protection program and implementing procedures at least once per 24 months.

- An independent fire protection and loss prevention inspection and audit annually utilizing either qualified off-site licensee personnel or an outside fire protection firm.

- Inspection and audit of the fire protection and loss prevention program by an outside qualified fire consultant at intervals no greater than 3 years.

7.2 Fire Protection

7.2.1 Detection and Suppression

Providing the ability to quickly detect and rapidly suppress fires through the use of early warning fire detection systems, fixed or automatic fire suppression systems, and manual fire fighting capability.

7.2.1.1 Fire Detection System Requirements

(See also: USNRC Guidance on Fire Detection contained in BTP 9.5-1, Section C.6.a.)

Fire detection systems are required for all areas of the plant that contain or present a fire hazard to safe shutdown or safety-related equipment. The detection system must be capable of operating with or without offsite power. Specific criteria for detector installation, such as detector spacing are established in NFPA codes. Examples of factors that may influence the installation include:

- Potential for false alarms due to detector location in high air flow areas and normally humid or dusty areas.
- The ability to access the detector for testing purposes.
- Stratification of smoke in areas having high ceilings.

7.2.1.2 Fire Protection Water Supply System

(See also: USNRC Guidance on Fire Protection Water Supplies contained in BTP 9.5-1, Section C.6.b.)

Typical fire protection water supply systems consist of a fire main loop which is supplied by two separate sources of water. Each supply is usually capable of providing the maximum expected water demands to the fire main loop for 2 hours. Fire water supply systems are installed to meet criteria specified in NFPA codes listed in Appendix A. Consideration should be given to possible fouling of the pipes by biological sources, and from silt and scale. Many U.S. plants have had to modify fire water systems to include purification systems and/or strainers. Although most U.S. plants are not required to have seismically qualified fire water systems, many plants have had to modify fire water systems because of post seismic flooding concerns.

7.2.1.3 Water Sprinkler and Hose Standpipe Systems

(See also USNRC Guidance on Water Sprinkler and Hose Standpipe System contained in BTP 9.5-1, Section C.6.c.)

In 1983 the NRC issued Information Notice 83-41, titled: "Actuation of Fire Suppression System Causing Inoperability of Safety Related Equipment." to alert reactor plant operating organizations of the potential for fire suppression system actuations to adversely affect the performance of safety-related systems. Particular attention must be paid during the design and installation of water sprinkler systems to ensure that their normal or inadvertent operation will not affect plant safety.

7.2.2 Fire Preplans

(See also: USNRC Guidance on Fire Protection is contained in BTP 9.5-1, Section C.2.o.)

Fire preplans are documented strategies for fighting fires in safety-related areas and areas presenting a hazard to safety-related equipment. For each fire area the fire preplans include such information as:

- Fire hazards in the area.
- The type and location of fire extinguishers best suited to fight a fire.
- Most favorable direction from which to attack a fire.
- Vital heat-sensitive components that need to be kept cool while fighting the fire.
- Potential radiological and toxic hazards.
- Instructions for plant operators and general plant personnel during the fire.

Fire preplans can not replace a well trained fire brigade or operating crew. Rather, the preplans are to serve as a training tool and as a reference during a facility fire. Many operating organizations have found fire preplans to contain some valuable information for day-to-day operations, such as the location of specific equipment and components. This has an added benefit of keeping personnel familiar with the documents and aware of the information that is available to them.

7.2.3 Fire Brigade Training

Most U.S. plants have a fire brigade made up of operators and other plant personnel. Fire Brigade training consists of fundamental fire fighting techniques including the use of self contained breathing apparatus and personnel protective clothing. Brigade members are taught how to properly attack a fire and proper operation of suppression systems and equipment. A typical fire brigade is comprised of a minimum of five trained personnel. With so few people, there is a high reliance on automatic suppression systems and physical design features to prevent and mitigate fires.

Because most brigades contain at least some operating personnel, there already is a knowledge of plant systems and an understanding of safe shutdown considerations in the group. Those plants which do not rely on plant operators as fire brigade members have to provide additional training on plant systems and related operational considerations.

7.3 Post-Fire Safe Shutdown

10CFR50.48, *Fire Protection*, specifies that each operating nuclear power plant must have a fire protection plan that includes, in part, an "outline [of] the plans for fire protection, fire detection and suppression capability, and limitation of fire damage." Additionally, 10CFR50.48 specifies that "the plan must describe the means to limit fire damage to structures, systems, or components important to safety so that the capability to safely shut down the plant is ensured."

The development of the fire protection plans required by 10CFR50.48 is typically accomplished by completion of two major analyses: 1) Fire Hazard Analysis (FHA); and 2) Safe Shutdown Analysis (SSA).

7.3.1 Fire Hazards Analysis

The FHA identifies fire areas including the hazards and the fire protection features within the fire areas.

(See also: USNRC guidance on Fire Hazards Analysis contained in BTP 9.5-1, Section C.1.b)

7.3.1.1 Fire Areas

A fire area is defined as a location that is completely surrounded by barriers of a known and tested configuration. As a result, a fire within the area is not expected to affect the operability of any systems or components that are independent (both physically and electrically) of the area. Conversely, a fire that occurs outside of the area is not expected to affect the operability of equipment located within the area.

It is not uncommon for the physical configuration of fire areas to be modified during the fire hazards analysis process. For instance, if it cannot be established that safe shutdown conditions are achievable in a designated fire area, a number of options may be explored to resolve the problem. Redefining the equipment necessary to achieve post-fire safe shutdown conditions, or installing new safe shutdown equipment outside the area are possible solutions. However, rearranging previously defined fire areas may also provide an acceptable solution. Often, upgrading the fire resistance of a fir area boundary door or wall can accomplish the needed separation, and it can be done at much lower cost than modifying nuclear plant systems.

Many U.S. plants subdivided fire areas into zones and performed their analysis on the basis of these zones. Since fire zones are not necessarily surrounded by rated barriers, fire propagation between zones must be considered. However, it may be shown through analysis that a fire will not travel from one zone to another based on combustible loading, spacial separation and installed suppression equipment. These cases typically require NRC approval in the form of a licensing exemption.

7.3.1.2 Defining Hazards

Documenting the combustibles present in any given location helps to establish a relative ranking of hazards. Most fire hazards analyses document combustible loading in terms of an area-wide average (BTUs/square foot). However, it is also important to document the specific location of the hazard. For example, if a large fire area such as the turbine building is being evaluated, a low area-wide average fire load may be obtained. If this information is not supplemented by an evaluation of the actual configuration of combustibles within the area, potentially significant concentrations of combustibles may be masked (such as a lube oil tank that is directly adjacent to safe shutdown cables).

7.3.1.3 Determining Fire Magnitude

Computer based fire modeling is an evolving science and only the most recent models are able to handle complex fire dynamics. The NRC currently has not endorsed any specific fire model. However, fire models have been used successfully to justify alternative methods of protection described in exemptions. While a complex fire model may be necessary in certain instances, the severity and speed of propagation of fire can frequently be anticipated from the amount of combustibles involved and the geometry of the location. For example, a fire in a vertical cable shaft with combustible cables can be expected to propagate very rapidly. A fire in a horizontal shaft with fire retardant cables should propagate much more slowly.

Time-consuming fire modeling is not generally necessary to identify the worst scenario. If however, redundant shutdown components are adjacent and cables or other combustibles are present, a more detailed analysis may be warranted to confirm that at least one redundant component would remain operable following a fire.

7.3.1.4 Suppression and Detection

The types and location of suppression and detection systems available for each fire area should be documented in a FHA. If suppression systems are present, a determination should be made whether they are adequate to address the hazards present. Even if only manual suppression capability is available, the location of hoses and hose connections can be important when determining the capability to suppress a fire quickly.

7.3.1.5 Emergency Lighting

(See also: USNRC guidance on Emergency Lighting contained in BTP 9.5-1, Section C.5.g)

Emergency lighting units having at least an 8-hour battery power supply are required in all areas needed for operation of safe shutdown equipment and in access and egress routes to those areas. The availability and capability of emergency lighting should be evaluated and documented.

7.3.1.6 Communications

(See also: USNRC guidance on Communications contained in BTP 9.5-1, Section C.5.g)

An emergency communications system is required to monitor operator actions outside the main control room. A typical U.S. plant has several communication systems available, including:

- Plant paging system.
- Plant telephone system.
- Sound-powered phone system.
- Portable radio communication system.

With the exception of the portable radio system, all of the above systems are "hard-wired" and, in many cases, the routing of this wiring is not well documented. Therefore, most plants designate the portable radio communications system as the preferred means of communication when implementing alternative shutdown procedures from outside the main control room. However, this system also require analysis to ensure that its operability will not be affected by fire. The availability of required communications should be considered for each fire area requiring an alternative shutdown capability.

7.3.1.7 Ventilation

(See also: USNRC guidance on Ventilation Systems contained in BTP 9.5-1, Section C.5.f)

The following issues should be addressed with respect to ventilation:

- Methods are available to remove the products of combustion (smoke and heat) from the affected fire area.
- The release of smoke and gases containing radioactive materials to the environment is monitored in accordance with established emergency plans.
- Sufficient ventilation capability will remain available to ensure equipment operability and human habitability in unaffected fire areas.
- Ventilation openings within fire area boundaries are provided with fire dampers that are capable of operating under normal and emergency air flow conditions.

7.3.2 Safe Shutdown Analysis (SSA)

(See also: USNRC guidance on Safe Shutdown Capability contained in BTP 9.5-1, Section C.5.b. and c.)

The overall objective of this study, which is commonly called a "Safe Shutdown Analysis" (SSA) is to demonstrate that a fire in any area of the plant will not prevent the performance of necessary safe shutdown functions.

7.3.2.1 Safe Shutdown Analysis Methodology

There are many acceptable methods of performing a fire safe shutdown analysis, and the NRC does not prescribe or endorse any specific approach. The analysis method selected by a particular plant operating organization is typically based on a number of plant specific factors including plant design, system configuration, equipment location, and operating preferences. In general, however, two basic approaches are used to perform the SSA. The "fire area" approach or the "systems" approach.

In the fire area approach, fire areas are defined and analyzed individually. With this method, the specific systems and equipment relied on to achieve a given safe shutdown safety function (i.e. reactor coolant make-up, decay heat removal) may vary from fire area to fire area. For a given fire area that is bounded on all sides by 3-hour rated fire barriers, shutdown system selection is largely determined from an analysis of redundant cables, equipment and associated circuits located within the area. Protection is then provided within the affected fire area for selected components and cables of the least affected train of safe shutdown systems. For certain fire areas, no additional protection may be necessary, since the analysis may reveal that sufficient equipment is located outside the area. For example, assuming associated circuit concerns are addressed, if a fire area was found to contain only Train A equipment and cables, then no further protection is necessary since Train B equipment, located outside that fire area, would be available to accomplish safe shutdown.

In the systems approach to performing an SSA, a plant-wide minimum set of systems capable of accomplishing shutdown safety functions in the event of fire are identified. The equipment, components and cabling, including non-essential circuits (i.e. associated circuits of concern) whose fire damage may adversely affect the successful accomplishment of a safe shutdown safety function, are then identified for each system and their location verified. Cable trays that contain required cables are then identified. Their locations, along with the locations of required equipment, are documented on a set of color-coded drawings (to ensure the adequacy of separation, field verifications of actual equipment locations are performed). The color-coded drawings are then used to identify any "interactions" between redundant safe shutdown paths. An interaction is defined as a location where redundant safe shutdown paths are not separated in accordance with the requirements of Appendix R, Section III.G.2. Interactions are identified, documented, and evaluated for their impact on safe shutdown capability and appropriate resolutions are determined and documented.

Either of the tww methods described above is capable of achieving the fundamental objective of identifying locations in the plant where components of redundant shutdown trains do not satisfy the separation requirements of Appendix R. Resolutions typically consist of modifications, use of alternate equipment, manual operator actions governed by written procedure, and/or exemptions from the specific requirements of the regulation (see examples given in Section 8 of this report).

In demonstrating the safe shutdown capability of the plant, the SSA integrates the following evaluations:

(1) **Safe Shutdown System Selection** - Identification of redundant systems capable of accomplishing shutdown safety functions (e.g., reactivity control, reactor coolant makeup, decay heat removal etc.).

(2) **Plant Configuration** - Equipment location and cable routing compared with the fire area boundary information established in the FHA.

(3) **Safe Shutdown System Performance** - Demonstration that following a fire sufficient equipment of adequate capacity will remain available to achieve and maintain the reactor in a safe shutdown condition.

(4) **Associated Circuits Effects** - Demonstration that a fire cannot, through its effects of non-essential electrical circuits, prevent safe shutdown equipment from performing its intended function or initiate an event that is beyond the capability of the safe shutdown systems.

In addition to identifying the systems and equipment available to accomplish safe shutdown safety functions, safe shutdown analysis documentation will include the following:

- Applicable regulatory criteria and operating license commitments.

- Results of the evaluation of associated circuit concerns.

- A detailed description of the alternate shutdown capability to be implemented in the event of fire in areas requiring control room evacuation.

- Operator actions and pre-positioned equipment needed to implement the alternate shutdown capability.

- Time critical manual operator actions.

- Evaluation of emergency lighting, communications, ventilation and other essential support systems.

Safe Shutdown Analysis Assumptions

The following items demonstrate the types of "typical" assumptions and considerations that are used in developing a safe shutdown analysis:

- The safe shutdown analysis is based on the occurrence of a single fire. The only failures considered are those that are directly attributable to the fire. No other failures or independent events are assumed to occur concurrently with the fire.

- Exposure Fire - An exposure fire is defined as a fire in a given area that involves either in situ (permanently installed) or transient combustibles, but is external to any structures, systems, or components located in (or adjacent to) that same area. The effects of such fire (e.g., smoke, heat, or ignition) can adversely affect those structures, systems, or components important to safety. Thus, a fire involving one train of safe shutdown equipment may constitute an exposure fire for the redundant train located in the same area. Also, a fire involving combustibles other than either redundant train may constitute an exposure fire to both redundant trains located in the same area. For analysis purposes, it is assumed that only a single exposure fire will occur in a fire area at a given time. By assuming only a single exposure fire, the analysis process is simplified to the area under concern (i.e. the area where the fire is occurring). During a comprehensive SSA all areas of the plant will be individually analyzed for an exposure fire.

- The offsite source of AC power may be unavailable for up to 72 hours. The analysis should demonstrate the capability of achieving and maintaining cold shutdown conditions where offsite power is available and where offsite power is unavailable for 72 hours.

- Automatic Equipment Operation - Automatic equipment operation may or may not occur during a fire. For fire in areas requiring alternative shutdown capability (i.e., areas where control room evacuation may be necessary), a loss of automatic functions must be assumed. For example, in the event of a loss of offsite power the emergency diesel generators will normally start automatically on undervoltage. However, in developing the alternative shutdown capability operation of this automatic start feature can not be assumed. For other fire areas, automatic operation of components and logic circuits may be credited in the analysis, but only if the control circuits associated with the automatic operation are known to be unaffected by the postulated fire (i.e. satisfy separation requirements of Section III.G.2 of Appendix R).

- Local manual operations are acceptable in achieving safe shutdown provided no unrecoverable plant condition can occur prior to performing the manual operation (manual operation of valves, switches, and circuit breakers is not considered to be a repair activity).

- The plant is operating at 100% power upon the occurrence of the fire, with a three-month 100% power history.

- Components or systems required for safe shutdown will be available at the time of the fire (i.e., not out of service).

- Components are in their normal operating position or status prior to the fire.

- All relay, position switch, and control switch contacts in the control circuits are in the position or status that correspond to the normal operation of the device. Test and transfer switches in control circuits are in their normal position.

- Repair activities (e.g., wiring changes, fuse replacement) are not permitted for systems required to achieve hot shutdown conditions.

- Modifications and repair activities are allowed for cold shutdown systems if:

  (a) It can be demonstrated that the repair can be accomplished within 72 hours (for areas not requiring an alternative shutdown capability from outside the main control room), or

  (b) The repair can be performed and cold shutdown achieved within 72 hours (for areas requiring alternative shutdown capability).

The difference between case (a) and (b) should be noted. In case (a), the fire has occurred in an area that will not require control room evacuation and implementation of the alternate shutdown capability. Under these conditions, the fire protection regulations (Appendix R) allows plants up to 72 hours to complete all repairs necessary to achieve and maintain cold shutdown conditions. For case (b), the fire has occurred in an area which may require control room evacuation and subsequent shutdown of the reactor from the remote shutdown facility. Under these conditions, Appendix R is more strict in terms of the time allowed to complete cold shutdown repairs. In this case, Appendix R requires plants to complete repairs and achieve cold shutdown conditions within 72 hours.

Safe Shutdown Functions and Performance Goals

The SSA must demonstrate that during a post-fire shutdown reactor coolant system process variables will be maintained within those predicted for a loss of normal ac power, and the integrity of the fission product boundary will not be affected; i.e. there is no fuel clad damage, rupture of any primary coolant boundary, or rupture of the containment boundary.

Performance goals for the shutdown functions identified in the SSA are as follows:

- **Reactivity Control Function** - The reactivity control function shall be capable of achieving and maintaining cold shutdown reactivity conditions.

- **Reactor Coolant Makeup Function** - The reactor coolant makeup function shall be capable of maintaining the reactor coolant level above the top of the core for boiling water reactors (BWRs) and within the level indication of the pressurizer for pressurized water reactors (PWRs).

- **Reactor Heat Removal Function** - The reactor heat removal function shall be capable of removing decay heat from the reactor.

- **Process Monitoring Function** - The process monitoring function shall be capable of providing direct readings of the process variables necessary to perform and control the above functions.

- **Supporting Function** - The supporting functions shall be capable of providing the process cooling, lubrication, etc., necessary to permit the operation of the equipment used for safe shutdown functions.

USNRC regulations (Appendix R Section III.L) specify safe shutdown functions and performance goals for the functions. How the performance goals are achieved is left to the individual facilities to determine and demonstrate.

Fire Protection of Safe Shutdown Capability

In those instances where cables or equipment of redundant trains of systems necessary to achieve and maintain hot shutdown conditions are located within the same fire area, NRC regulations (Appendix R Section III.G) define prescriptive methods of providing a suitable level of fire protection. Specifically, an acceptable level of protection for one of the redundant trains of equipment required to achieve and maintain hot shutdown conditions may be achieved by one of the following means:

- **3-Hour Barrier** - Separation of redundant cables and equipment and associated non-safety circuits is achieved by a fire barrier having a 3-hour rating. Structural steel forming a part of or supporting such fire barriers must be protected to provide a fire resistance equivalent to that required of the barrier.

- **Separation** - Separation of redundant cables, equipment and associated non-safety circuits is achieved by a horizontal distance of 20 feet (6.1 meters) with no intervening combustibles. Additionally, fire detectors and an automatic fire suppression system must be installed in the area.

- **1-Hour Fire Barrier** - Separation of redundant cables and equipment and associated non-safety circuits is achieved by enclosure in a fire barrier having a 1-hour rating. Additionally, fire detectors and an automatic fire suppression system must be installed in the area.

Inside noninerted containments, one of the fire protection means described above will provide acceptable separation, or any of the following methods are also acceptable:

- **Horizontal Separation** - Separation of redundant cables and equipment and associated non-safety circuits is achieved by a horizontal distance of 20 feet (6.1 meters) with no intervening combustibles.

- **Detection and Suppression** - Installation of fire detectors and an automatic fire suppression system in the fire area.

- **Radiant Energy Shields** - Separation of redundant cables and equipment and associated non-safety circuits is achieved by installation of a noncombustible radiant energy shield.

Alternative and Dedicated Shutdown Capability

If one train of systems required to achieve and maintain hot shutdown conditions can not be adequately protected (in accordance with Appendix R section III.G.2), or if redundant trains of systems required for hot shutdown are subject to damage from the rupture or inadvertent operation of fire suppression systems, the NRC requires (Appendix R Section III.L) plants to provide an alternative or dedicated shutdown capability that is independent of the area under consideration.

Alternative Shutdown capability is provided by rerouting, relocating, or modifying existing systems. An example of an alternative shutdown capability would be the case where isolation switches are installed to isolate safe shutdown required circuits from potential fire damage. Alternative shutdown capability can also be provided through the implementation of procedures specifying "alternative" methods of operation such as local manual operations and/or shutdown from a control station that is remote from the control room.

Dedicated Shutdown capability is provided by installing new structures and systems for the sole function of post-fire safe shutdown. Examples of dedicated shutdown capability include installation of emergency generators, process instrumentation, or other equipment which is intended to be used only for safe shutdown purposes.

Alternative or dedicated shutdown capability may vary from fire area to fire area or it may be one unique combination of systems for several or all areas. For those areas requiring alternative or dedicated shutdown capability, fire detection and a fixed fire suppression system must be installed in the fire area of concern.

Safe Shutdown Procedures

After the safe shutdown configuration and methodology have been specified in the safe shutdown analysis, plant operations personnel develop the abnormal operating procedures necessary to perform a post-fire safe shutdown.

As the safe shutdown procedures are developed, additional reviews are required to verify that the SSA has been correctly translated into the procedures. This analysis and verification will include:

- Confirmation that the procedural steps or actions can be performed by verifying that operators will have access to required equipment.
- Confirmation that the analysis criteria are satisfied. For example, the performance of time sensitive steps within allotted times.
- Confirmation that required support equipment such as ladders and valve handles, are available (pre-positioned and administratively controlled) to the operators in the plant.
- Confirmation that the safe shutdown communication systems are effective. Of particular interest is the confirmation that portable radio communication systems can be used in all required areas in the plant.
- Because safe shutdown operating procedures frequently require performance of manual operations throughout the plant, the availability and adequacy of emergency lighting must be confirmed.

8. CASE STUDIES

An important feature of the fire protection regulations established by the U.S. NRC (Appendix R) is the degree of flexibility that is afforded plants in developing acceptable methods of compliance. Certain requirements of Appendix R, such as the fire protection features specified in Section III.G.2, are prescriptive in nature. However, through the NRC's licensing exemption process, plants may propose alternative methods of satisfying such specific technical requirements of the rule. Requests for exemption must be submitted to the NRC Office of Nuclear Reactor Regulation (NRR) for evaluation, where the technical merits of the request and its plant-specific application are examined in detail. If the proposed approach is determined to provide an equivalent level of safety to that afforded by the rule, the request for exemption is typically approved.

This section provides six specific examples (case studies 1 through 6) which demonstrate how the licensing exemption process has been applied at operating U.S. plants. Note that exemption requests are evaluated by the NRC on a site-specific, case-by-case basis. Therefore, because an exemption was approved at one plant does not, by itself, provide sufficient basis for acceptance of a similar design configuration or shutdown methodology at a different plant.

In the event of fire in areas where redundant trains of safe shutdown equipment or cables may be exposed to fire damage, Sections III.G.3 and III.L of Appendix R require U.S. reactor plants to provide an alternative shutdown capability that is both physically and electrically independent of the fire affected area. Case studies 7 through 10 illustrate how this capability has been achieved at operating plants. Note that since the methods described in these examples satisfy the rule, an exemption is not necessary.

8.1 Case 1

Requirement: 10CFR50 Appendix R section III.G.2.a.

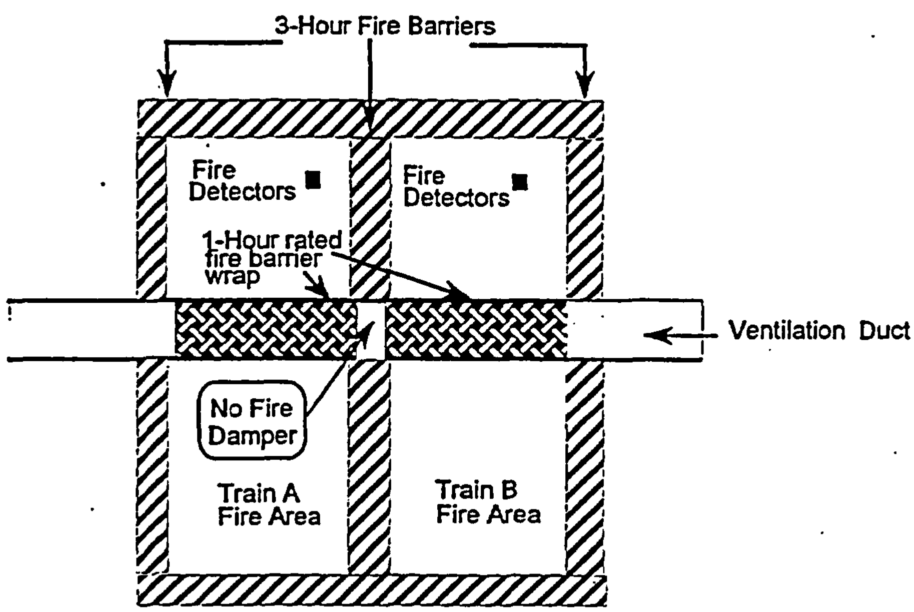
"Separation of cables and equipment and associated non-safety circuits of redundant trains by a fire barrier having a 3-hour rating. Structural steel forming a part of or supporting such fire barriers shall be protected to provide fire resistance equivalent to that required of the barrier."

Intent of Requirement:

Provide a means of ensuring that one train of equipment required to achieve and maintain safe shutdown remains free of fire damage

Proposed Approach (Approved Exemption):

Protecting ventilation duct with a 1-hour fire wrap in lieu of installing a 3-hour rated fire damper in the wall.



Basis For Acceptance:

The ventilation duct-work passes through fire areas containing redundant trains of safe shutdown equipment. The area also lacks automatic suppression. However, the low combustible loading in each fire area, along with detection in each area, makes it likely that a fire would be detected early and controlled quickly.

8.2 <u>Case 2</u>

Requirement: 10CFR50 Appendix R section III.G.2.b.

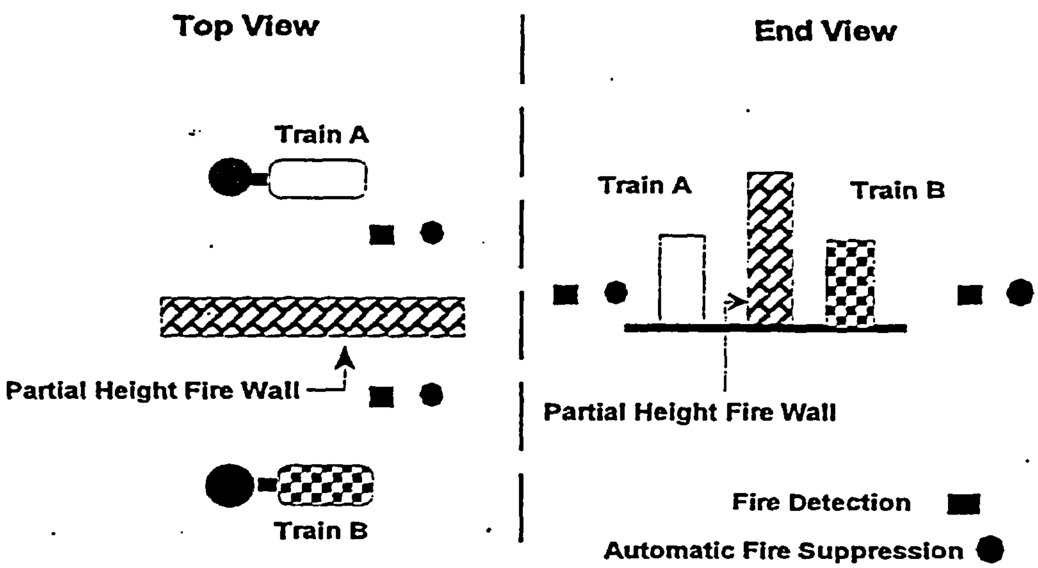
"Separation of cables and equipment and associated non-safety circuits of redundant trains by a horizontal distance of more than 20 feet with no intervening combustible or fire hazards. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area."

Intent of Requirement:

Provide a means of ensuring that one of the redundant trains required for safe shutdown is free of fire damage and available to safely shut down the plant.

Proposed Approach (Approved Exemption):

Use a partial height fire wall with fire detection and automatic fire suppression capability installed in lieu of 20 feet of horizontal separation and no intervening combustibles or fire hazards.



Basis For Acceptance:

With an absence of intervening combustibles the partial height fire wall will prevent the propagation of fire to the redundant safe shutdown equipment. Additionally, with fire detection and automatic fire suppression capability installed, a fire will be detected and suppressed prior to propagating to the redundant safe shutdown equipment.

8.3 <u>Case 3</u>

Requirement: 10CFR50 Appendix R section III.G.2.b.

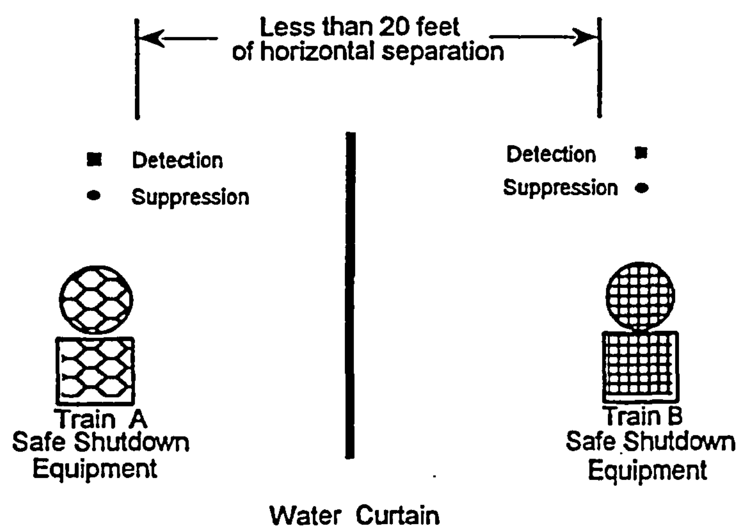
"Separation of cables and equipment and associated non-safety circuits of redundant trains by a horizontal distance of more than 20 feet with no intervening combustible or fire hazards. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area."

Intent of Requirement:

Provide a means of ensuring that one of the redundant trains required for safe shutdown is free of fire damage and available to safely shut down the plant.

Proposed Approach (Approved Exemption):

Fire detector activated water curtain used in lieu of separation by a horizontal distance of more than 20 feet free of intervening combustibles. Fire detectors and automatic fire suppression capability are installed in the fire area.



Basis For Acceptance:

In the absence of intervening combustibles and fire hazards, the water curtain functions as an active fire barrier to compensate for less than 20 feet of horizontal separation. With fire detection and an automatic fire suppression capability installed, a fire will be detected and suppressed prior to propagating through or around the water curtain to the redundant safe shutdown equipment.

8.4 Case 4

Requirement: **10CFR50 Appendix R section III.G.2.b.**

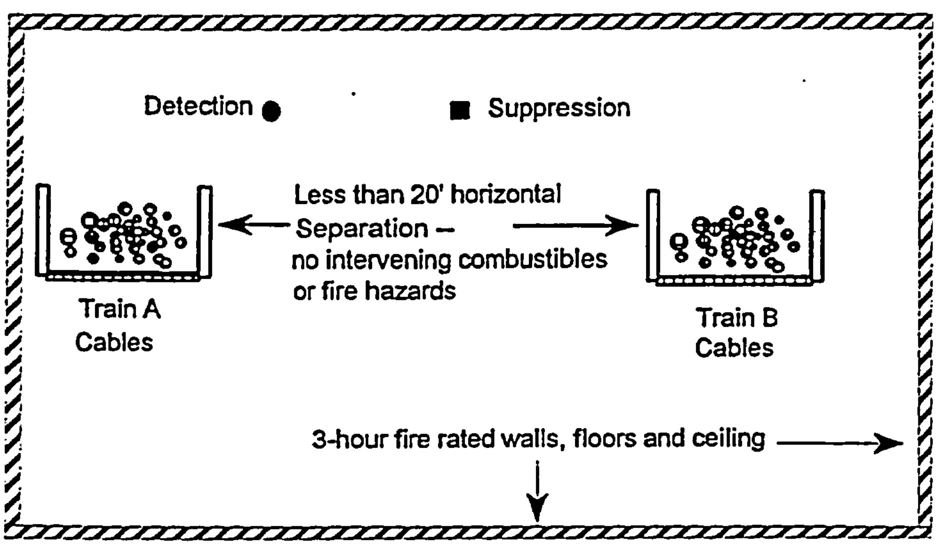
"Separation of cables and equipment and associated non-safety circuits of redundant trains by a horizontal distance of more than 20 feet with no intervening combustible or fire hazards. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area."

Intent of Requirement:

Provide a means of ensuring that one of the redundant trains required for safe shutdown is free of fire damage and available to safely shut down the plant.

Proposed Approach (Approved Exemption):

Redundant safe shutdown and associated non-safety circuits with less than 20 feet horizontal separation between the redundant cables. No intervening combustibles and minimal combustible loading in area of concern. Fire detectors and automatic fire suppression are installed in the fire area of concern.



Basis For Acceptance:

The redundant cables have some separation, generally more than 10 feet. Suppression and detection are provided in the area. There are no intervening combustibles or fire hazards. The combustible loading in the subject area is low. Any fire should be detected early and controlled quickly prior to the redundant cables being exposed to fire.

8.5 Case 5

Requirement: **10CFR50 Appendix R section III.G.2.c.**

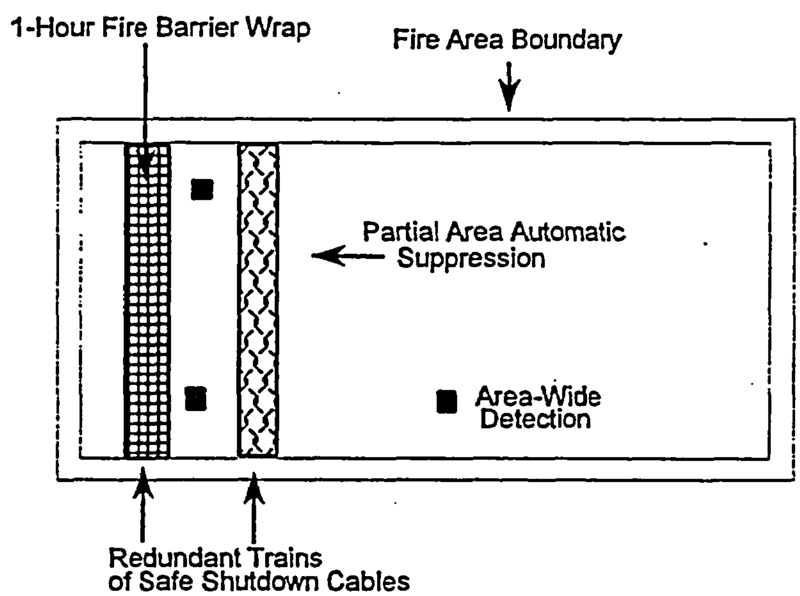
"Enclosure of cable and equipment and associated non-safety circuits of one redundant train in a fire barrier having a 1-hour rating. In addition, fire detectors and an automatic fire suppression system shall be installed in the fire area."

Intent of Requirement:

Provide a means of ensuring that one of the redundant trains required for safe shutdown is free of fire damage and available to safely shut down the plant.

Proposed Approach (Approved Exemption):

Provide 1-hour fire barrier around safe shutdown train with detection throughout fire area. Automatic fire suppression capability is installed in the local area of concern in lieu of total fire area suppression.



Basis For Acceptance:

The local automatic fire suppression, in conjunction with the area-wide detection capability, is adequate to protect the redundant safe shutdown train.

8.6 Case 6

Requirement: **10CFR50 Appendix R Section III.J.**

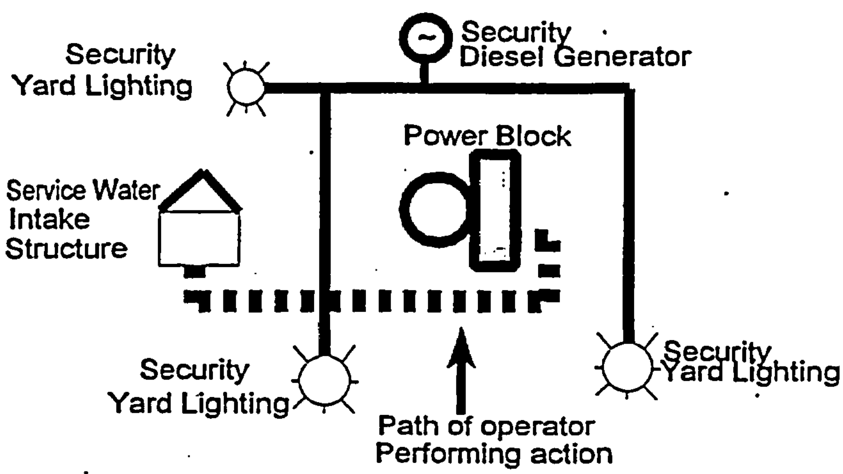
"Emergency lighting units with at least an 8-hour battery power supply shall be provided in all areas needed for operation of safe shutdown equipment and in access and egress routes thereto"

Intent of Requirement:

Provide emergency lighting of sufficient capacity for necessary operator actions.

Proposed Approaches (Approved Exemptions):

1. Limited use of pre-positioned or administratively controlled hand held portable lights.
2. Exterior yard lighting provided by security lights which have an emergency generator back-up power source that will not be damaged by the fire (i.e., power source and lighting are electrically and physically independent of the fire area of concern).



Basis For Acceptance:

On a case-by-case basis, the proposed methods described above were found to provide an acceptable emergency lighting capability for specific plant areas. Note that exemptions to the Appendix R requirement for an 8-hour emergency lighting capability have only been granted for specific areas of the plant. Plant-wide exemptions to this requirement are not acceptable.

8.7 Case 7

Requirement: 10CFR50 Appendix R Section III.G.3.

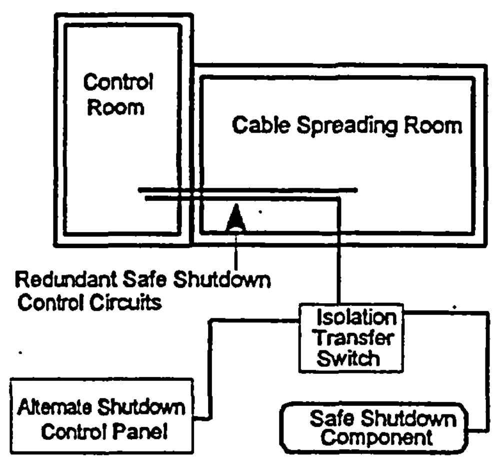
"Alternative or dedicated shutdown capability and its associated circuits, independent of cables, systems, or components in the area, room or zone under consideration shall be provided:

Intent of Requirement:

Provide an alternate method for achieving safe shutdown conditions when the redundant safe shutdown trains are not protected from fire damage.

Alternative Shutdown Method:

Isolation switches are used to isolate safe shutdown equipment from the fire area of concern. The isolation switches also allow operation of the safe shutdown equipment from alternate (remote) shutdown panels.



Basis For Acceptance:

Alternate (remote) shutdown panel(s) are independent of the fire area of concern.

8.8 Case 8

Requirement: 10CFR50 Appendix R Section III.G.3.

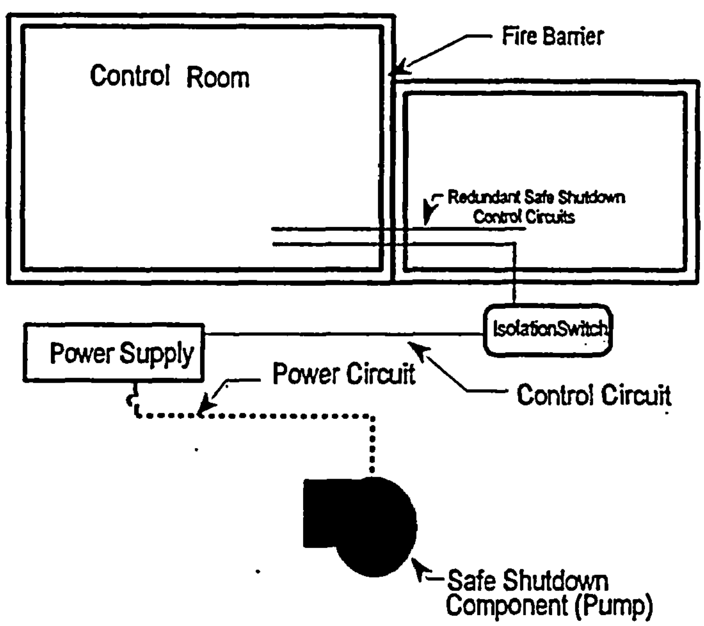
"Alternative or dedicated shutdown capability and its associated circuits independent of cables, systems, or components in the area, room or zone under consideration shall be provided where the protection of systems whose function is required for hot shutdown does not satisfy the requirement of paragraph G.2 of this section..."

Intent of Requirement:

Provide an alternate method for achieving safe shutdown conditions when the redundant safe shutdown trains are not protected from fire damage.

Alternative Shutdown Method:

Isolation switches are used to electrically isolate the required safe shutdown equipment from the fire affected area. Operator may then operate the equipment locally, independent of the fire affected area.



Basis For Acceptance:

For the safe shutdown component shown (pump), operator action to isolate potentially affected control circuits (at the isolation switch) and control pump operation (on/off) at the power supply breaker provides a manual operation capability that is independent of the fire affected area.

8.9 Case 9

Requirement: 10CFR50 Appendix R Section III.L.7

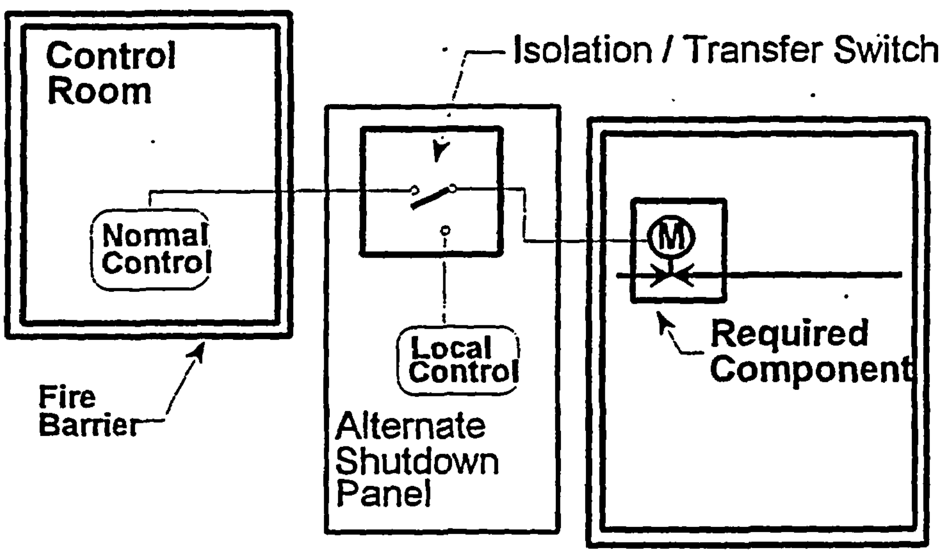
"The safe shutdown equipment and systems for each fire area shall be known to be isolated from associated non-safety circuits in the fire area so that hot shorts, open circuits, or shorts to ground in the associated circuits will not prevent operation of the safe shutdown equipment..."

Intent of Requirement:

All possible functional failure states must be evaluated, that is, the component could be energized or de-energized by one or more failure modes such as hot shorts, open circuits, and shorts to ground. A method for achieving safe shutdown must be available in the event of the above circuit failure modes.

Alternative Shutdown Method:

Spurious operations are prevented by isolating control circuits of the component subject to spurious operation. The isolation is typically achieved by use of an isolation / transfer switch will isolate potentially affected circuits from the fire affected area, and allow transfer of control to a remote location.



Basis For Acceptance:

Operation of the isolation / transfer switch will: (1) prevent fire-initiated circuit faults from causing spurious component operation; and (2) allow control of the required component to be transferred to a remote location in the plant (e.g., alternate shutdown panel).

8.10 Case 10

Requirement: 10CFR50 Appendix R Section III.L.7

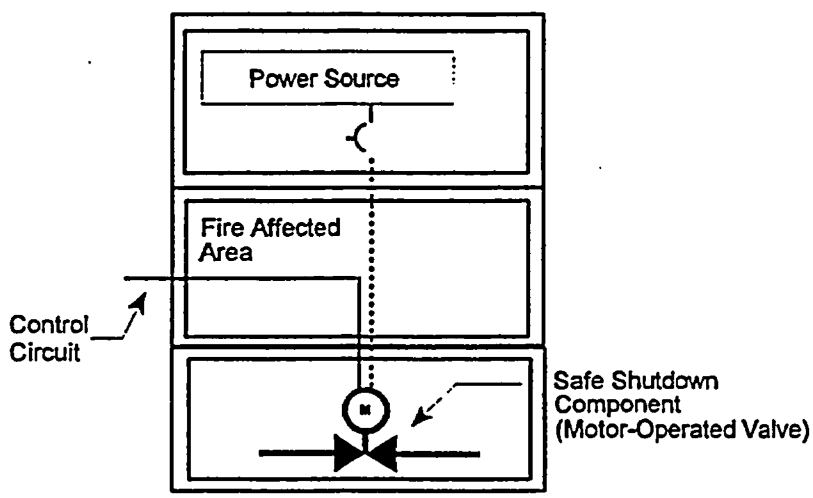
"The safe shutdown equipment and systems for each fire area shall be known to be isolated from associated non-safety circuits in the fire area so that hot shorts, open circuits, or shorts to ground in the associated circuits will not prevent operation of the safe shutdown equipment."

Intent of Requirement:

All possible functional failure states must be evaluated, that is, the component could be energized or de-energized by one or more failure modes such as hot shorts, open circuits, and shorts to ground. A method for achieving safe shutdown must be available in the event of the above circuit failure modes.

Alternative Shutdown Method:

The valve and circuit breaker position are administratively controlled to prevent fire induced spurious operation(s). Spurious operation is prevented by positioning a valve to the desired open or closed position, the circuit breaker is opened to remove power from the valve operator and the circuit breaker is racked out to prevent spurious closing of the circuit breaker.



Basis For Acceptance:

The safe shutdown component (motor-operated valve) is maintained in the desired position during normal plant operation at power - With power removed, spurious actuation of the component can not occur as a result of fire in the fire affected area.