NUCLEAR ENERGY INSTITUTE

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Mr. John Hannon
Chief, Plant Systems Branch
Office of Nuclear Reactor Regulation
Mail Stop O11-A11
U. S. Nuclear Regulatory Commission
Washington, DC 20555-0001

PROJECT NUMBER: 689

Dear Mr. Hannon:

We are enclosing Revision E of NEI 04-02, *Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program under 10 CFR 50.48(c).* While this document substantially incorporates NRC comments on the previous revision, there are a few points requiring further discussion. The rulemaking and guidance development activities are nearly complete. Therefore, we propose an early meeting (late April) to clarify these points. With the results of this meeting and the Commission's decision on the proposed final rule, we will provide an additional revision in May for a more detailed staff review.

Please address any comments or questions to me or to Fred Emerson. We look forward to your early response with regard to our proposed meeting.

Sincerely,

Alex Marion

Alex Marion

Enclosure

c: NRC Document Control Desk
Mr. Sunil Weerakkody, NRC
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NEI 04-02
REVISION E

NUCLEAR ENERGY INSTITUTE

GUIDANCE FOR IMPLEMENTING A RISK-INFORMED, PERFORMANCE-BASED FIRE PROTECTION PROGRAM UNDER 10 CFR 50.48(c)

April 2004

ACKNOWLEDGEMENTS

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FOREWARD (later)

[Possibly include regulatory history, similar to NUMARC 93-01 Revision 3]

EXECUTIVE SUMMARY (later)

TABLE OF CONTENTS

1.0 INTRODUCTION

On [date to be determined] the Nuclear Regulatory Commission (NRC) amended 10 CFR Part 50.48 "Fire protection" to add a new subsection, 10 CFR 50.48(c), that established acceptable fire protection requirements (67 FR 66578). The change to 10 CFR 50.48 endorses with exceptions the National Fire Protection Association's (NFPA) 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants – 2001 Edition," as a voluntary acceptable approach for demonstrating compliance with 10 CFR 50.48 Section (b) and Section (f).

This document provides guidance for implementing the requirements of this rule change, and to the degree endorsed by the NRC, represents methods acceptable to the NRC for implementing in whole or in part a risk-informed, performance-based fire protection program.

1.1 Background

Fire protection requirements predating the [insert date] Amendment to 10 CFR 50.48 are prescriptive in nature and were established well before the emergence of risk-informed, performance-based analytical techniques. Consequently, the prescriptive requirements do not include the benefits of probabilistic risk assessments (PRAs) for fires, nor do they reflect insights into fire risk evident from the significant body of operating experience developed through risk-based assessments. As PRA technology developed and additional operating experience was accumulated, the NRC, in SECY-93-143, "Report on the Re-assessment of the NRC Fire Protection Program," determined that the situation had changed sufficiently to support a recommendation for a revised 10 CFR 50.48 that would take risk concepts into account. In addition, as discussed in SECY-96-134, "Options for Pursuing Regulatory Improvement in Fire Protection Regulations of Nuclear Power Plants," dated June 21, 1996, a revised fire protection rule that would allow flexibility and facilitate the use of alternate approaches to meet the fire safety objectives may reduce the need for exemptions. The NRC in SECY-98-058, "Development Of A Risk-Informed, Performance-Based Regulation for Fire Protection at Nuclear Power Plants," assessed options for developing a new risk-informed, performance-based fire protection regulation. In it, the NRC staff recommended that NRC be authorized to work with NFPA on the development of a risk-informed, performance-based standard for nuclear plant fire protection. They further recommend that rulemaking to adopt the standard and a regulatory guide to interpret the standard be initiated following issuance of the standard.

As discussed in SECY-98-058, the NRC's adoption of NFPA 805 was considered consistent with the Commission's policy specified in Direction Setting Issue (DSI) 13, "The Role of Industry"; Office of Management and Budget Circular A-119, "Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities"; and Public Law 104-113, "National Technology Transfer Act of 1995." These guidance documents encourage the U.S. Government's adoption of national consensus standards to carry out its policy objectives and activities.

NEI, representing the nuclear industry, is a proponent of the use of risk-informed, performance-based processes. NEI has worked to ensure that the adoption of a new fire protection licensing basis is optional, and not a requirement. NEI has also worked to ensure that the process of adoption of a new fire protection licensing basis is effective and comprehensive, without placing an unnecessary burden on licensees pursuing risk-informed, performance-based initiatives.

Subsequently, NFPA 805 was developed to provide a comprehensive risk-informed, performance-based standard for fire protection. The NFPA 805 Technical Committee on Nuclear Facilities is comprised of nuclear plant licensees, the NRC, insurers, equipment manufacturers, and subject matter experts. The standard was developed in accordance with NFPA processes, and consisted of a number of technical meetings and reviews of draft documents by committee and industry representatives. The scope of NFPA 805 includes goals related to nuclear safety, radioactive release, life safety, and plant damage/business interruption. The standard addresses fire protection requirements for nuclear plants during all plant operating modes and conditions, including shutdown and decommissioning, which had not been explicitly addressed by previous requirements and guidelines. NFPA 805 became effective on February 9, 2001. Although NFPA 805 provides many of the tools and processes necessary for risk-informed, performance-based fire protection, additional guidance and clarification is warranted. This implementing guidance is intended to provide that additional guidance and clarification.

1.2 Purpose and Scope

This implementing guidance for NFPA 805 has two primary purposes:

- Provide direction and clarification for adopting NFPA 805 as an acceptable approach to fire protection, consistent with 10 CFR 50.48 (c), and
- Provide additional supplemental technical guidance and methods for using NFPA 805 and its appendices to demonstrate compliance with fire protection requirements.

NFPA 805 establishes a comprehensive set of requirements for fire protection programs at nuclear power plants. It incorporates both deterministic and risk-informed, performance-based concepts. The deterministic aspects of NFPA 805 are comparable to traditional requirements, and thus need little additional guidance. Although there is a significant amount of detail in NFPA 805 and its appendices,[1] clarification and additional guidance for select issues will help ensure consistency and effective utilization of the standard. Accordingly, this implementing guidance focuses attention on the risk-informed, performance-based fire protection goals, objectives, and performance criteria contained in NFPA 805 and the risk-informed, performance-based tools considered acceptable for demonstrating compliance.

NFPA 805 addresses primarily technical issues and does not provide a framework or guidance pertaining to the regulatory processes for adopting NFPA 805 as a new licensing basis. This document provides that framework and detailed guidance for transitioning to a risk-informed, performance-based licensing basis.

NFPA 805 also does not address use of the analytical tools and processes within an existing licensing basis. The rule does not approve the use of NFPA 805 methods and analytical

[1] Appendices B, C, and D are not part of the requirements but the methodologies in them are considered by the NRC to be specified in NFPA 805 for the purposes of Section (c)(4), so that their use by licenses does not require prior NRC approval in a license amendment. 67 Fed. Reg. at 6653-84.

approaches for purposes other than demonstrating compliance with NRFPA 805, any other use of those methods and analytical approaches requires the necessary NRC approvals under 10 CFR 50.90, 10 CFR 50.12, or other applicable regulations. This implementing guidance addresses these regulatory process matters in Chapter 6.

The scope of the implementing guidance includes:

- Discussion of the regulatory framework for adopting NFPA 805 as the basis for compliance to fire protection regulations (Chapter 2);
- Overview of the risk-informed, performance-based fire protection program process and available options (Chapter 3);
- Implementing guidance for transitioning to a new fire protection licensing basis (Chapter 4);
- Guidance for program maintenance and configuration control processes (Chapter 5); and
- Guidance for using NFPA 805 analysis tools within a current licensing basis (CLB) (Chapter 6).

This implementing guidance addresses only those elements of NFPA 805 that are within the scope of the NRC's jurisdiction under 10 CFR 50.48. The goals of Life Safety and Plant Damage/Business Interruption within NFPA 805 and its appendices are outside of the scope of 10 CFR 50.48 and thus are not addressed in this guidance.

1.3 Relationship with Other Rules, Regulatory Guidance, Standards, and Programs

- 10 CFR 50.48 and 10 CFR 50, Appendix R - refer to Section 2.0 of this document.

- NEI 00-01 – (To the extent finally endorsed by the NRC) discuss use of NEI 00-01 as an acceptable method of demonstrating compliance with certain aspects of NFPA 805 and refer to appropriate Appendices of the document.

  (NOTE: The reference to NEI 00-01 has been included as a place-holder should the NRC endorse that document, with or without exceptions. Depending on the timing of the NRC's decision, the reference to this document will be revised in accordance with the situation at that time. In particular, if the NRC is still in the endorsement process, the introductory phrase in parentheses would be added to this guidance.

- NEI 02-03 – "Guidance For Performing a Regulatory Review of Proposed Changes to the Approved Fire Protection Program" – This document provides the framework for making changes to the fire protection program under 50.59(c)(4). The process to implement this regulation would be revised if a plant were to adopt NFPA 805 as its licensing basis. See Section 6 of this document.

- Regulatory Guide 1.189, NUREG 0800 Standard Review Plan Section 9.5.1 with Branch Technical Position CMEB 9.5-1, Branch Technical Position (BTP) APCSB 9.5-1, and Appendix A to APCSB 9.5-1 – These documents contain acceptable methods of demonstrating compliance with NRC Fire Protection Regulations. Licensees should refer to their plant-specific licensing bases to determine the applicability of specific guidance to a specific plant. Licensee's commitments to these documents will be used as input into the transition process. See Section 4.0 of this document.

- 10 CFR 50.59 and NEI 96-07 Revision 1 - 10CFR 50.59 establishes the conditions under which licensees may make changes to the facility or procedures and conduct tests or experiments without prior NRC approval. NEI 96-07 provides guidance for developing an effective and consistent 10 CFR 50.59 implementation processes. If a utility adopts the NFPA 805 licensing basis, the NFPA 805 change process is an acceptable method of evaluating fire protection program changes.

- 10 CFR 50.72 and 10 CFR 50.73 - The process to implement these regulations remain unchanged as a result of adopting 10 CFR 50.48(c).

- Reactor Oversight Process/Significance Determination process – This process would not change if a plant chooses to adopt the NFPA 805 regulation. However, modifications to terminology (safe shutdown versus nuclear safety, etc.) may be required. See Section 6.0 of this document.

- 10 CFR 50.65 and NUMARC 93-01 - Maintenance Rule – the technique(s) used in the maintenance rule program may be used in the "monitoring" program in NFPA 805. See Section 5.0 of this document.

- Corrective Action Program - This process would not change if a plant chooses to adopt 10 CFR 50.48(c). However, modifications to terminology (safe shutdown versus nuclear safety, etc.) may be required. See Section 6.0 of this document.

- NUMARC 91-06 (Shutdown) and NUREG-1409 - These documents provide input to the evaluation of non-power modes of operation. See Appendix F.

- Generic Letter 91-18, Rev.1 – This document discusses guidance for compensatory actions during temporary non-compliances. This process would not change if a plant chooses to adopt the 10 CFR 50.48(c). However, its use during the transition period (See Section 4.0) may be modified. In addition, modifications to terminology (safe shutdown versus nuclear safety, etc.) may be required. See Section 6.0 of this document.

- RIS 2000-17 adopting NEI 99-04 – This document discusses how licensees can modify regulatory commitments. This process would not change if a plant chooses to adopt 10 CFR 50.48(c); however, the change process (See Section 4.4 of this document) provides more specific detail of when a plant change process would change for the fire protection program.

1.4 Responsibilities and Qualifications

1.4.1 Responsibilities

Licensees adopting 10 CFR 50.48 (c) should use this guidance to assist in developing and maintaining plant-specific risk-informed, performance-based programs. Other licensees may use the processes and techniques in this guidance within a CLB. Responsibilities associated with establishing and maintaining a fire protection plan are delineated in Section 3.2 of NFPA 805.

1.4.2 Qualifications

Qualifications for individuals responsible for administration of a fire protection program are discussed in Section 3.2 and Appendix A of NFPA 805. This includes recommendations that individuals responsible for day-to-day administration of the fire protection programs be experienced in nuclear power plant fire protection, preferably with qualifications consistent with member grade status in the Society of Fire Protection Engineers.

Due to the technical nature of risk-informed, performance-based fire protection analyses, additional minimum qualifications are recommended for individuals practicing fire modeling and quantitative fire protection risk assessments.

1.4.2.1 Fire Modeling

The qualifications necessary for personnel involved in the fire modeling projects depends to a great extent on their role, and the nature of the analysis. In general, the individual responsible for conducting quantitative engineering analysis related to fire hazard quantification should be an experienced engineer with formal training in fire dynamics and use of the methods or models being used. The user should also have knowledge of available data sources and validation studies for the method being used. In addition to modeling and analysis expertise, the successful application of modeling will involve an individual or team with experience in NPP systems and plant operations, all relevant regulations, plant configurations and QA/QC programs. For simple screening calculations where well defined and isolated fuel arrays are being evaluated, and less expertise is required, an engineer with training in the calculation methods being used is adequate.

1.4.2.2 Fire Risk Assessment

The qualifications necessary of personnel involved in quantitative fire risk assessment (i.e., Fire PRA) should be consistent with that applicable to individuals performing PRA studies. In general, the individual responsible for PRA should be an experienced engineer with formal training in PRA and fire PRA. As such, the licensee should apply the same training and/or qualification standard to individuals conducting fire risk assessments. Individuals should also have experience in fire risk assessments, such as involvement in an Individual Plant Examination for External Events (IPEEE) effort.

1.5 Applicability

As stated in 10 CFR 50.48 (c)(3)(i), any licensee's adoption of a risk-informed, performance-based program that complies with the rule is voluntary. Compliance with this rule may be adopted as an acceptable alternative method for complying with either 10 CFR 50.48 (b), for plant licensed to operate before January 1, 1979, or the fire protection license conditions for plants licensed to operate after January 1, 1979, or (f), plants shutdown in accordance with 10 CFR 50.82(a)(1). Accordingly, the use of this guidance is also voluntary.[2]

[2] If a licensee chooses not to adopt NFPA 805 as a complete, self-contained fire protection methodology to support its new fire protection licensing basis, that licensee may still use NFPA 805 methodologies and approaches on an optional basis, to support proposed changes to its CLB, provided that the licensee obtains the necessary regulatory

2.0 REGULATORY FRAMEWORK

2.1 *Introduction*

The NRC has adopted NFPA 805, with a few specific exceptions, as an alternative, risk-informed, performance-based regulation for fire protection at nuclear power plants. Licensees may continue to comply with the current fire protection requirements or voluntarily transition to the new requirements. This Section describes the regulatory actions that a licensee should take to transition its fire protection licensing basis to compliance with NFPA 805.[3]

2.2 *Overview of the Rule*

NFPA 805, with a few specific exceptions, has been adopted by the NRC as a regulation. Chapter 1 of NFPA 805 establishes performance criteria, performance objectives, and goals for nuclear safety and radioactive release. Chapter 3 of NFPA 805 establishes the fundamental elements of a fire protection program and the minimum design requirements for the fire protection systems and features. Chapters 2 and 4 of NFPA 805 establish the general approach for instituting fire protection requirements at a nuclear power plant and the methodology to determine the fire protection systems and features required to achieve the performance criteria outlined in Section 1.5 of NFPA 805. The methodology shall be permitted to be either deterministic or performance-based.

2.2.1 Incorporation by Reference

To avoid the need to reprint NFPA 805 in the CFR, the NRC obtained permission from the Federal Register to incorporate NFPA 805 by reference. This means that NFPA 805 is to be treated as if it had been included in its entirety in the CFR. The NRC has incorporated other industry standards by reference, most notably the Boiler and Pressure Vessel Code promulgated by the American Society of Mechanical Engineers (ASME) and adopted as 10 CFR 50.55a, "Codes and Standards." Thus, the NRC has developed precedent for dealing with standards that have been incorporated by reference and that precedent will apply to questions involving NFPA 805.

Because the NRC has adopted this particular version of NFPA 805 as its own rule, any subsequent changes to NFPA 805 that may be made by the National Fire Protection Association (NFPA) do not change the rule. Therefore, if the NFPA were to revise NFPA 805, NRC licensees cannot apply those changes unless the NRC adopts the revised version through the rulemaking process. (10 CFR 50.48(c)(1)). For the ASME Code, the NRC conducts rulemakings periodically to adopt new versions of the Code.

Similarly, licensees may not rely on interpretations of NFPA 805 by the NFPA unless the NRC has accepted those interpretations. A licensee can request the NRC's Office of General Counsel (OGC) for an informal NRC opinion on the acceptability of an interpretation by the NFPA. If a

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approvals from the NRC. The rule approves its methods only for determining compliance with NFPA 805. When those methods are used for other purposes, those uses are subject to NRC review. See Section 6 for additional guidance.

[3] Section 6 of this implementing guidance describes the use of the methods, analytical approaches and other tools in NFPA 805 for changes to a licensee's current fire protection licensing basis.

licensee relies on an NFPA interpretation before it has been accepted by the NRC, that licensee runs the risk of being in noncompliance if the NRC does not accept that interpretation.[4]

2.2.2 Relationship to Other Fire Protection Requirements

NFPA 805 is codified as 10 CFR 50.48(c). The new rule was placed deliberately in this location to show how it relates to existing fire protection requirements. The new rule establishes alternative requirements that a licensee may voluntarily adopt instead of continuing to comply with its current fire protection licensing basis. A fire protection program that complies with NFPA 805, as adopted by the NRC, is an acceptable alternative to compliance with either 10 CFR 50.48(b) (for plants licensed to operate before January 1, 1979 "Appendix R Plants"), or the fire protection license conditions (10 CFR 50.48(c)(3)(i)) for plants licensed to operate after January 1, 1979 (Post-Appendix R Plants). For plants that have shut down and submitted the certifications required by 10 CFR 50.82(a)(1), compliance with NFPA 805 may be adopted as an acceptable method for complying with 10 CFR 50.48(f).

2.2.3 Alternative Requirements in the New Rule

The new rule affects the actions which are required to be taken to establish compliance with 10 CFR 50.48(a), which requires each operating nuclear power plant to have a fire protection program plan that satisfies General Design Criterion 3 (GDC 3), as well as specific requirements in that section. The transition process described in 10 CFR 50.48(c)(3)(ii) provides, in pertinent parts, that a licensee intending to adopt the new rule must, among other things, "modify the fire protection plan required by paragraph (a) of that section to reflect the licensee's decision to comply with NFPA 805." Therefore, to the extent that the contents of the existing fire protection program plan required by 10 CFR 50.48(a) are inconsistent with NFPA 805, the fire protection program plan must be modified to achieve compliance with the requirements in NFPA 805.

A comparison of the current requirements in Appendix R with the comparable requirements in Section 3 of NFPA 805 shows that the two sets of requirements are consistent in many respects. However, there are differences. Among them are the elimination of specific requirements for: (1) emergency lighting; (2) an alternative shutdown capability; and (3) cold shutdown. Therefore, these topics need not be addressed in the revised fire protection plan.

2.3 Demonstration of Compliance with the New Requirements

Compliance with the performance criteria of Chapter 1 of NFPA 805 may be demonstrated by using either the deterministic or performance-based approaches in the standard (Chapter 4 of NFPA 805). Alternative methods and analytical approaches may be used only if approved by the NRC in a license amendment in accordance with 10 CFR 50.48(c)(4). In deciding whether to grant such a license amendment, the Director of the Office of Nuclear Reactor Regulation will determine whether the alternative method and analytical approach: (1) satisfies the performance criteria, performance objectives, and goals for nuclear safety and radiological release; (2) maintains safety margins; and (3) maintains post-fire defense-in-depth (fire prevention, fire suppression, and post-fire safe shutdown capability.)

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4 Note that 10 CFR 50.3 states "Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission."

Compliance with Chapter 3 of NFPA 805 may be demonstrated by showing that the specific requirements are met either directly or by the use of alternative methods and analytical approaches. Alternative methods and analytical approaches must be approved by the NRC in a license amendment per 10 CFR 50.48(c)(4). Contrary to Section 3.1 of NFPA 805, performance-based methods may be used. (Reference: 10 CFR. 50.48(c)(2)(v). Note licensees contemplating applying for permission to use an alternative method or analytical approach could pursue a generic approval process with other utilities and/or NEI. See Section 2.4 of this document.

Compliance with Chapter 3 may also be demonstrated by showing that the NRC has previously approved an alternative to a fundamental program attribute. A claim of prior NRC approval must be based on docketed correspondence from the NRC. Note that the plant configuration(s) addressed in this docketed correspondence/approval may have been modified subsequently during the course of plant operation. If those modifications were made in accordance with an approved process (10 CFR 50.59, Generic Letter 86-10, etc.) they are part of the plant's licensing basis, but they are not considered previously approved by the NRC for the purposes of Chapter 3 of NFPA 805 unless they have been explicitly reviewed and approved by the NRC.

2.3.1 Previous Approval Determination

To implement the transition to compliance with NFPA 805, a licensee must accurately determine its plant's fire protection CLB and the extent to which the NRC has approved the fundamental program elements in that CLB and the Appendix R / NUREG-0800 compliance. Determination of the extent of previous NRC approval requires a detailed review and assessment of the plant's docket. Chapter 4 of this document provides the details of the documentation of the transition process.

Note that the prior approval determination is not limited to the "classical" fire protection program attributes in Chapter 3 of NFPA 805. The prior approval determination is also made for the licensee's compliance with 10 CFR 50, Appendix R, Section III.G and III.L or applicable sections of NUREG-0800, either as a requirement or as a licensing commitment, in order to transition to the new fire protection licensing basis. This is consistent with the methodology depicted in Figure 2.2 of NFPA 805. Exemptions/deviations from the original licensing basis are part of a licensee's CLB.

Previous NRC acceptance or approval is found by comparing licensee submittals with NRC responses. For each instance for which a licensee wants to demonstrate prior NRC approval of a particular fire protection program attribute, the following strategy should be used:

1. Review correspondence from the NRC to determine whether the NRC has explicitly accepted or approved the program attribute. If so, retain supporting documentation as evidence of prior NRC approval. No additional steps need to be taken.

2. If final correspondence, such as an SER from the NRC, contains only general statements of acceptance or approval, it is necessary to find the related chain of supporting correspondence between the NRC and licensee and other related documentation, such as NRC meeting minutes, to determine what information the NRC requested from the

licensee and what information the licensee provided in responding to the NRC's request. Examples of the types of correspondence that may provide support are letters, requests for and grants of exemptions, licensee responses to Notices of Violation (NOVs) and NRC acknowledgements of the corresponding corrective actions, licensee responses to Unresolved Issues (URIs) and NRC acknowledgement of resolution of its concerns, licensees' responses to requests for additional information and NRC closeouts of them, and licensee presentations at NRC management meetings followed by NRC acknowledgement of them.

Where the available documentation indicates that the NRC has been aware of and accepted a specific attribute of the fire protection program, but does not include an explicit NRC statement to that effect, the licensee should document its basis for that conclusion in the Transition documentation (See Section 4.0 of this document).

If a fundamental design requirement or a program element does not meet Chapter 3 and there is not "prior approval" a licensee shall 1) conform to specific requirements of Chapter 3, or 2) obtain a license amendment.[5] If a fire area Appendix R / NUREG 0800 compliance strategy doesn't meet the nuclear safety criteria the licensee may meet the deterministic requirements of Section 4.2.3 of NFPA 805, or use the performance-based approach to demonstrate that the nuclear safety performance criteria is satisfied and perform a change analysis to ensure that the change is acceptable (See Section 4.4 and Appendix I of this implementing guidance).

2.3.2 Improper Determination of Previous NRC Approval

Where a licensee chooses to rely on an aspect of the current fire protection licensing basis as previously approved by the NRC, those elements relied upon remain subject to NRC inspection for compliance with the regulations that were applicable at the time of the NRC's approval. Such reliance will be documented as part of the transition process (See Section 4). If an inspection shows that the licensee's reliance on previous NRC approval was erroneous, either because such approval had not been granted or the requirement was not met, the licensee has the option of either coming into compliance with the original requirement or demonstrating compliance with the new, alternative requirement in NFPA 805.

2.3.3 Non-compliance with the Current Fire Protection Licensing Basis

If, during the process of transitioning the licensing basis, the licensee discovers a non-compliance with its current fire protection licensing basis, it will be entered into the licensee's corrective action program (CAP). Two alternatives are available to address the noncompliance. One option is for the licensee to come into compliance with the requirement in the current fire protection licensing basis and then rely on that compliance to the extent permitted by NFPA 805 to demonstrate compliance with the new standard. The other option is to come into compliance with the corresponding requirement in NFPA 805 by using by using any of the methods permitted by that standard. As with any non-compliance, the time taken to come into compliance will depend on the safety significance of the non-compliance.

[5] Note: In accordance with 10 CFR 50.48(c)(2)(v) the fire protection program elements and minimum design requirements of Chapter 3 may be subject to the performance-based methods permitted elsewhere in the standard.

2.4 *Alternate Methods and Approaches*

10 CFR 50.48(c)(4) authorizes licensees to submit requests to use alternative methods and analytical approaches to demonstrate compliance with NFPA 805, including fundamental fire protection program and minimum design requirements identified in Chapter 3 of NFPA 805, in lieu of the methods and approaches specified in NFPA 805. Prior NRC approval of these alternatives will be necessary. Three licensing paths are available for obtaining NRC approval of an alternative: (1) Topical Report (TR); and (2) license amendment; and, (3) Safety Evaluation Report (SE) issued by NRR.

2.4.1 Topical Report

To minimize licensee resources needed to obtain NRC approval, a licensee contemplating applying for permission to use an alternative method or analytical approach could first determine whether other licensees are interested in that alternative. If a sufficient number of licensees indicate interest, those licensees could collaborate to develop a TR supporting that alternative. After the TR has been reviewed and approved by the NRC, as evidenced by the NRC's issuance of a SE, each licensee would be able to adopt the approved alternative by showing that it has met the criteria in the TR for such adoption.

To be accepted for the TR program a requested report should meet all four of the following criteria established by the NRC[6]:

(1) The report deals with a specific safety-related subject regarding a nuclear power plant that requires a safety assessment by the NRC staff, for example, component design, analytical models or techniques, or performance testing of components and/ or systems that can be evaluated independently of a specific license application.
(2) The report is, or is expected to be, referenced in a number of license amendments or standardized reference design approval applications.
(3) The report contains complete and detailed information on the specific subject presented. Conceptual or incomplete preliminary information will not be reviewed.
(4) NRC approval of the report will increase the efficiency of the review process for applications that reference the report.

Exceptions to these criteria may be allowed. The applicant should provide the NRC with justification for such exceptions. The justification should show that it is in the public interest to evaluate the proposed report. The justification for the exception may consider savings to the industry, or contribution to closing a safety-related subject, or advancement of technologies that would maintain safety or reduce unnecessary burden. A decision to accept a report that does not meet the four criteria must find that the resources expended in the review of the TR are worth the reduction of resources committed to other activities, such as licensing actions.

The NRC staff's process for reviewing a proposed TR will basically follow the NRC's internal process for reviewing a license amendment request. However, there will be no opportunity for public participation in the TR approval process.

6 NRR Office Instruction LIC 500, Rev. 1, Processing Requests for Reviews of Topical Reports.

After the NRC has approved a TR, it may be either referenced in either a license amendment application or, if the change resulting from adoption of the TR is not significant enough to warrant a license amendment, in the documentation for the change process performed in lieu of 10 CFR 50.59. The advantage of referencing a TR is that the only issue for determination is whether the licensee has met the criteria for using the TR. The substance of the TR is no longer an issue for review of the license amendment.

2.4.2 License Amendment

Where a licensee cannot meet the four TR criteria or justify a deviation from them, a license amendment can be submitted to the Office of Nuclear Reactor Regulation (NRR) for review and approval. A license amendment also will be necessary if the alternative is determined to meet the NRC's criteria in the Perry[7] decision. Under Perry, a license amendment will be required if the licensee's proposed action will result in a greater operating authority or otherwise alter the original terms of a license. Under NEI 96-07 Revision 1, approved by NRC, a license amendment is not required if the NRC has previously approved the application. A license amendment is not required where the results of the change are encompassed within the delineated categories of authorized conduct. Therefore, a license amendment will not be required where the change is just another way of complying with existing regulatory requirements.

2.4.3 Internal NRR Approval

Where an alternative does not require a license amendment under the NRC's criteria in the Perry decision, a licensee may submit an alternative for NRR review and approval. NRR approval will be documented in a Safety Evaluation.

3.0 RISK-INFORMED, PERFORMANCE-BASED FIRE PROTECTION PROCESS

3.1 Process Summary

The process for transitioning to the new risk-informed, performance based option is discussed in NFPA 805. The process is summarized in Section 3.2. Section 3.3 provides additional details and provides directions for the overall process for adoption of a new risk-informed, performance based fire protection licensing basis.

3.2 NFPA 805 Process

Included within Figure 3-1 are processes addressed specifically by NFPA 805. The NPFA 805 process is discussed in Section 2.2 of NFPA 805 and is shown in Figure 2.2 of NFPA 805, which is included below as Figure 3-1 of the implementing guidance.

[7] *Cleveland Electric Illuminating Company, et al.*, (Perry Nuclear Power Plant, Unit 1), 44 NRC 315 (December 6, 1996).

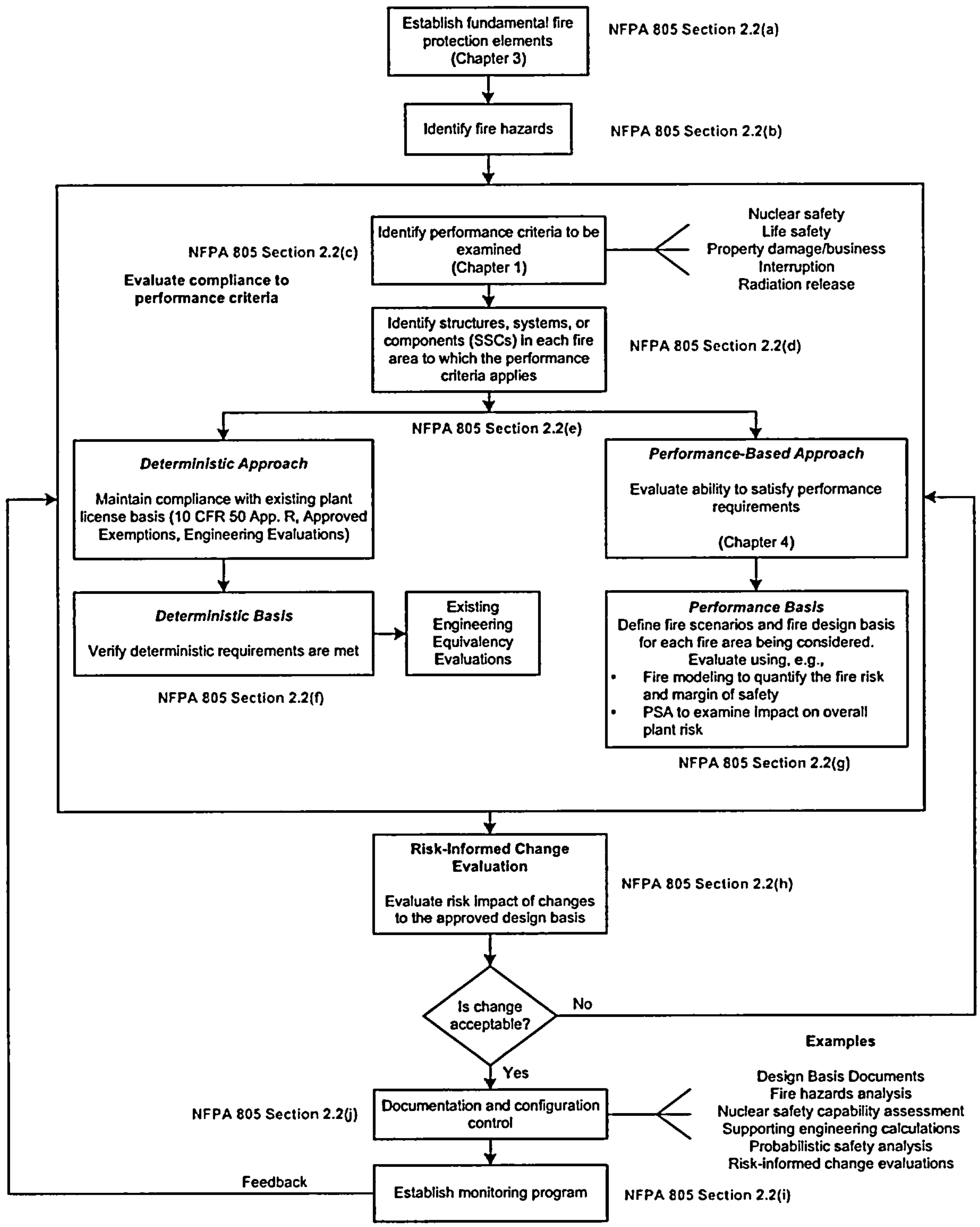


Figure 3-1 – NFPA 805 Process (Figure 2.2 of NFPA 805)

3.3 *Overall Process for Implementing a New Licensing Basis*

Certain elements of the process that need to be followed are not established by NFPA 805 and its appendices, since NFPA 805 does not address the details of how to achieve regulatory compliance and feasibility evaluations. NFPA 805, due to its structure and content, does not always provide a clear process of the steps that should be followed. The following simplified flowchart (Figure 3-2) is intended to show the overall process for implementing a risk-informed, performance-based fire protection application:

- The **Process Phase** column categorizes the sequential phases of a licensee transition. Descriptions of the transition phases are discussed in Section 4.1.2.
- The **Simplified Process** column shows the major steps in the transition to a new risk-informed, performance-based fire protection program. The **Simplified Process** steps include a preliminary assessment, which is not part of the NFPA 805 standard. The rest of the steps are a simplified representation of steps addressed in NFPA 805. Table 3-1 provides a cross reference of steps in the **Simplified Process** to the steps within NFPA 805. References to applicable sections in the implementing guidance are provided in braces {}.
- The **Regulatory Documentation** column shows the major documentation developed, submitted, and received as part of the adoption of a new fire protection licensing basis.
- The flowchart does not show continuous processes (regulatory interface, etc.) and feedback loops (adjusting effort due to unfavorable results, requests for additional information, iterative decisions on practicality of risk-informed, performance-based approach, and iterative decisions on whether to adopt the new rule or use the process).

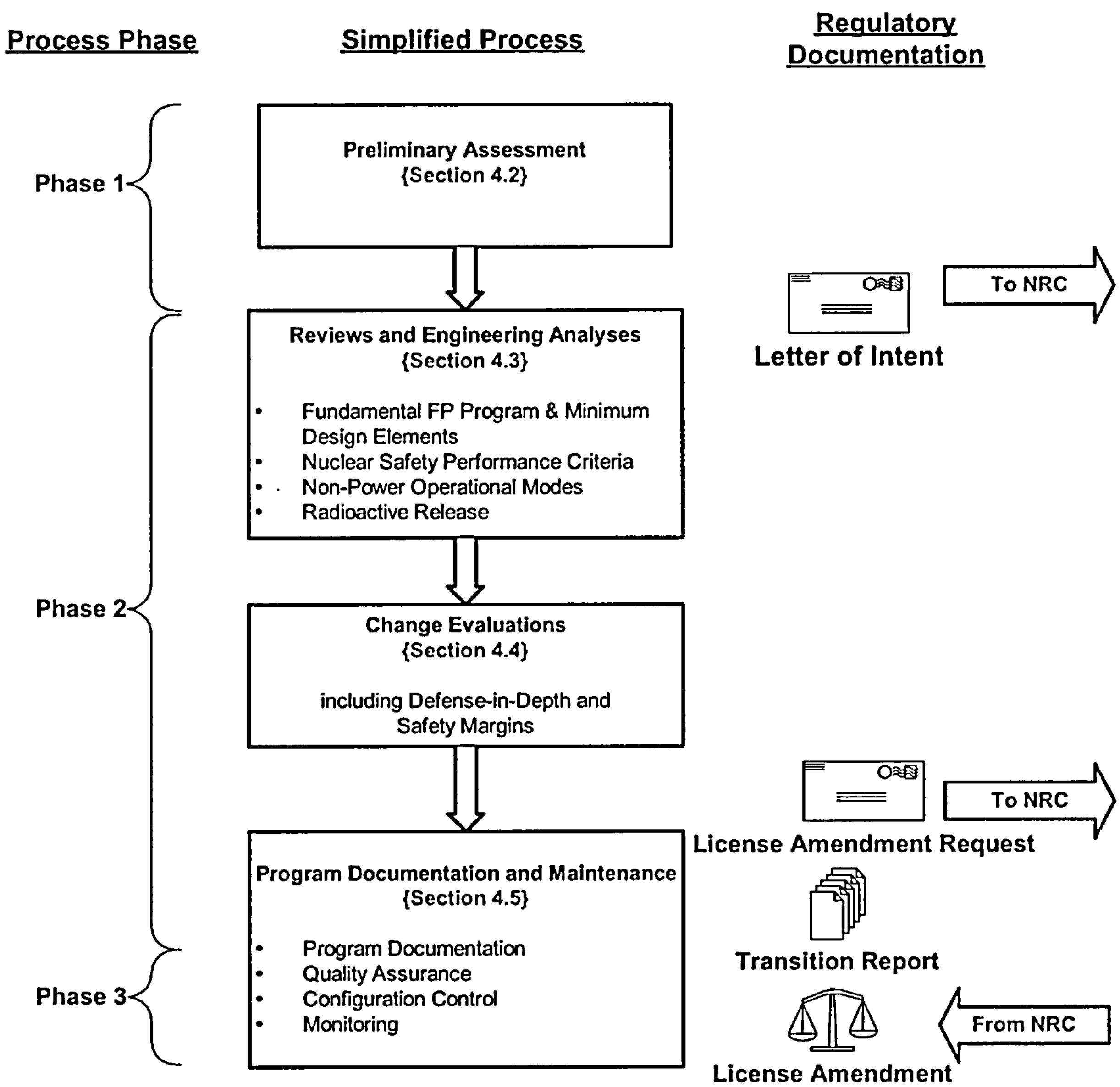


Figure 3-2 Implementing the New Licensing Basis

Table 3-1
Risk-Informed, Performance-Based FP Process Summary

Step – Process	NFPA 805 Section	Step
Preliminary Assessment	N/A	Preliminary assessment is the work performed to assess the feasibility and practicality of transitioning to a new licensing basis.
Review and Engineering Analysis	2.2(a) – 2.2(g)	These steps follow the technical guidance in NFPA 805. • Establish the fundamental fire protection program (NFPA 805 Chapter 3). • Identify fire areas and associated fire hazards • Identify the performance criteria that apply to each fire area (NFPA 805 Section 1-5). • Identify systems, structures, and components (SSCs) in each fire area to which the performance criteria apply. • Select the deterministic and/or risk-informed performance-based approach for the performance criteria (see NFPA 805 Chapter 4). • When applying a deterministic approach, demonstrate compliance with the deterministic requirements (see NFPA 805 Chapter 4). • When applying a risk-informed /performance-based approach, perform engineering analyses to demonstrate that applicable requirements are satisfied. These analyses should include, for example, engineering evaluations, probabilistic risk assessments and fire modeling calculations (NFPA 805 Section 2-3).
Change Evaluation	2.2(h)	• Perform the plant change evaluation that demonstrates that changes in risk, defense-in-depth and safety margins are acceptable (see NFPA 805 Section 2-3.4). If any one of these is unacceptable, additional fire protection features or other alternatives shall be implemented.
Program Documentation & Maintenance	2.2(i) – 2.3(j)	• Develop a monitoring program to monitor plant performance as it applies to fire risk. This program shall provide feedback for adjusting the fire protection program, as necessary (NFPA 805 Section 2-9). • For the resulting plant fire protection program, provide adequate documentation, ensure the quality of the analyses, and maintain configuration control of the resulting plant design and operation (NFPA 805 Section 2-5).

3.4 Licensee Transition Documentation Overview

Three documents must be prepared to support the transition to compliance with NFPA 805. They are:

(1) A Letter of Intent to be sent to the NRC before beginning the transition process;
(2) The License Amendment Request (LAR) required by 10 CFR 50.48(c)(3)(i); and
(3) A Transition Report that details the new licensing basis and how it was derived from the current fire protection licensing basis.

Section 4 and Appendix H provide additional discussion of the transition documentation and sample letters and reports.

3.5 *Compliance during the Transition Period*

When the Licensee decides to go forward with transition to a NFPA 805 licensing basis, a "Letter of Intent" will be submitted. It will include a schedule for submitting a "License Amendment Request" and a description of the tasks involved in preparing for the transition. This will provide the Staff an understanding of the circumstances if a protracted schedule is requested. The time interval between submittal of the "Letter of Intent" and the "License Amendment Request" is expected to be six months and two years depending on the extent of analysis required and any site-specific circumstances.

It is possible that while conducting the engineering analyses that are necessary to prepare the NFPA 805 licensing basis, the licensee may identify issues that do not comply with the 'current licensing basis.' In the event that a non-compliance is identified, the licensee would enter it into the corrective action program, implement compensatory actions and submit notification to NRC as appropriate. The issue could be evaluated and resolved under the new risk informed licensing basis. During the interim between identification of the non-compliance and resolution under the NFPA 805 licensing basis, "Enforcement Discretion" would be in effect. "Enforcement Discretion" would start when the "Letter of Intent" is submitted and continue until the risk-informed licensing basis is in effect.

A schedule extension may be requested with adequate justification. Enforcement Discretion would be extended accordingly.

The "License Amendment Request" would include a schedule for transition to the risk informed licensing basis, a schedule for any plant modifications that would be necessary to achieve final compliance and a summary of the risk informed licensing basis. Any performance-based analysis conducted to demonstrate compliance with a NFPA 805, Chapter 3 issue would be submitted as part of the License Amendment Request

Enforcement discretion would end when the NFPA 805 licensing basis is implemented and any associated modification(s) are complete. Schedular extensions would be possible if site-specific extenuating circumstances arise, but must be requested and granted by NRC.

4.0 TRANSITION FOR ADOPTION OF A NEW LICENSING BASIS

4.1 *Transition - Introduction*

4.1.1 Transition Process Overview

The transition process for adopting a new fire protection licensing basis is a critical step in the overall process. A comparison of the potential benefits with the known burdens associated with the transition to a new licensing basis is a significant consideration in a licensee's evaluation of the option. One critical aspect of any assessment of the benefits and burdens is the extent to which the CLB can be incorporated ("brought forward") into the new licensing basis as compared with the extent to which it will be necessary to take additional actions to establish compliance with various components of the new licensing basis.

All licensees choosing to adopt NFPA 805 as basis for compliance to fire protection regulations, independent of whether they choose a deterministic or risk-informed, performance-based compliance strategy, must demonstrate compliance with Chapters 1, 2, 3, and 4 of the standard. Chapter 1 establishes the goals, performance objectives, and performance criteria. Chapter 2 of NFPA 805 sets forth the general methodology for establishing fire protection requirements and engineering analyses requirements, including the analyses that support a risk-informed, performance-based fire protection design. Chapter 3 of NFPA 805 contains fundamental elements of a fire protection program and specifies the minimum design requirements for fire protection systems and features. Chapter 4 of NFPA 805 provides a method for determining that the required fire protection systems and features to satisfy the performance criteria of Section 1.5 of the standard.

The extent to which the fire protection CLB can be incorporated into the new, licensing basis is determined by the extent to which the fire protection CLB can be shown to comply with the requirements in NFPA 805, except for:

- Previously approved alternatives from the fundamental fire protection program attributes of NFPA 805 Chapter 3 [NFPA 805 Chapter 3 Section 3.1]
- Previously approved exemptions/deviations from 10 CFR 50 Appendix R / NUREG 0800 [NFPA 805 Figure 2.2]. Note these exemptions/deviations will be reviewed during the transition process to ensure the basis for acceptability is still valid. See Section 4.3.2.
- Existing Engineering Equivalency Evaluations [NFPA 805 Figure 2.2]. Note these equivalency evaluations will be reviewed during the transition process to ensure the quality level and the basis for acceptability is still valid. See Section 4.3.2.

The methodology requirements in Chapters 2 and 4 of NFPA 805 are very similar to those used to demonstrate compliance with the traditional NRC requirements (other than for fires originating in non-power operational modes and radioactive release). Accordingly, a plant's previously approved CLB[8] for compliance with safe shutdown fire protection requirements should largely satisfy the nuclear safety requirements established by the amended regulation, 10 CFR 50.48 (c), for implementing a fire protection program based upon NFPA 805 Chapters 1, 2 and 4, except for non-power operations and radiological releases. Where the NFPA requirements are not fully met, engineering equivalency evaluations may be used to show that the existing fire protection configurations and procedures comply. Otherwise, either programmatic changes or approval to use alternative methods will be necessary to demonstrate compliance.

To demonstrate compliance with the "fundamental elements of the fire protection program" and "minimum design requirements for fire protection systems and features" that are contained in

[8] Exemptions/deviations from the original licensing basis have been reviewed and approved by the NRC and, are therefore considered acceptable as previously approved alternatives.

Chapter 3 but are not contained in previously approved fundamental fire protection program attributes, a licensee, notwithstanding the prohibition in Section 3.1 against the use of performance-based methods, may utilize the performance-based methods permitted elsewhere in the standard (See 10 CFR 50.48.c (2)(v)). The use of this alternate method would require a license amendment.

In conclusion, although the traditional fire protection program requirements contained in 10 CFR 50.48 are not in direct alignment with those under the new rule, the requirements are similar enough to allow a structured transition without a complete design and licensing basis reconstitution. The intent of the transition assessment is to:

- Provide confirmation that the transitioning fire protection program, to the extent that the NRC has not previously approved its fundamental program attributes, meets the fundamental program elements and minimum design elements of Chapter 3 of NFPA 805, (Section 4.3.1)
- Provide confirmation that the transitioning fire protection program meets the nuclear safety deterministic criteria. (Section 4.3.2)
- Identify acceptable approaches and perform analyses to address fires originating in non-power operational modes and fire protection to effectively minimize radioactive release. (Sections 4.3.3 and 4.3.4)
- Address risk-informed, performance-based attributes (i.e., safety margin, defense-in-depth) where the requirements of NFPA 805 are not met and are not previously approved in the licensee's CLB. This may include performance of a change evaluation for nuclear safety aspects of the transition. (Section 4.4)
- Verify/establish a monitoring program to ensure the availability and reliability of fire protection systems and features and to assess the fire protection program. (Section 4.5.3)
- Confirm/establish adequate quality, documentation and configuration control to transition to a new licensing basis. (Section 4.5)

A simplified flowchart is provided as Figure 4-1.

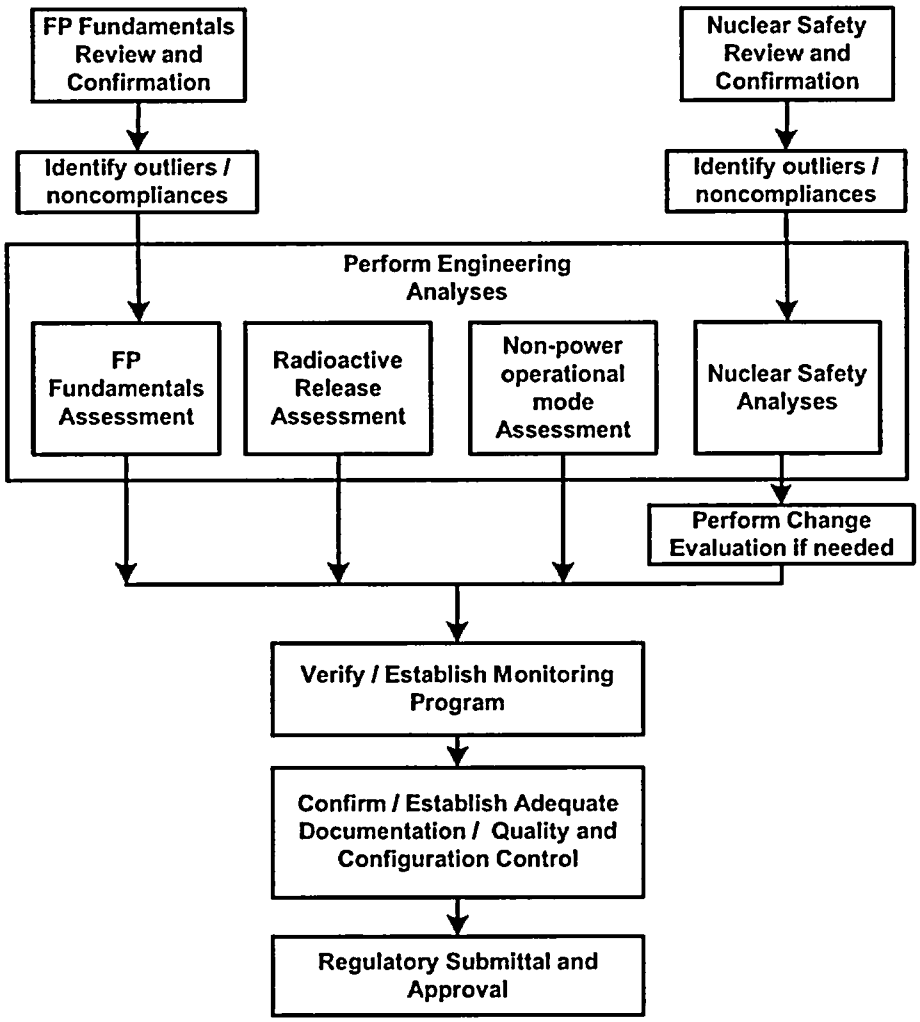


Figure 4-1 Transition Process (Simplified)

4.1.2 The Three Phases of the Transition Timeline

To transition from compliance with the current fire protection licensing basis to a new fire protection licensing basis consistent with the new requirements in NFPA 805, a licensee must take several steps. These steps can be grouped logically into a three-phase timeline for the transition process. Each phase is completed by the publication of a document. The three phases of the transition, their component steps, and their associated documents are identified below and are shown on Figure 3-2. The phases described below assume that a decision to transition to a new licensing basis has already been made.

Phase 1: Decision and Letter of Intent

- Make decision to transition the licensing basis.
- Make preliminary determination of the activities that will be necessary to support the transition.
- Make initial determination of any changes to the plant or fire protection program that may be necessary.
- Establish a tentative schedule for completing all of the actions necessary for the transition.
- Submit a Letter of Intent to the NRC. The letter's contents are described in Section 4.2.2 and Appendix H.

Phase 2: Analysis and License Amendment Request

- Conduct the transition activities to demonstrate compliance. Section 4.3 describes in detail how the current fire protection licensing basis can be used to support demonstrations of compliance with the requirements in NFPA 805.
- Determine extent to which the current fire protection licensing basis can be shown to demonstrate compliance with the new fire protection requirements.
- Determine any changes to the plant that will require a license amendment.
- Determine any alternative methods and analytical approaches that will be relied on to demonstrate compliance with the new fire protection requirements and will require a license amendment.
- Update the schedule for completion of transition activities.
- Submit a License Amendment Request (LAR) to the NRC. The LAR's contents are described in Section 4.6.1 and Appendix H.

Phase 3: Completion of Transition

- While the NRC reviews the LAR, complete all of the transition activities which do not require prior NRC approval, including plant changes which do not require a license amendment under the current license condition, procedure changes, and training.
- After the NRC issues the license amendment, complete any changes to the plant which required a license amendment.
- Rely on alternative methods and analytical approaches approved by the NRC to demonstrate compliance with the new fire protection requirements.
- Adopt the new licensing basis. Document the new fire protection licensing basis in a Transition Report. The report's contents are described in Section 4.6.2 and Appendix H.

4.2 *Preliminary Assessment*

4.2.1 Technical and Regulatory Assessment

This step involves an initial scoping to assist in assessing the feasibility and practicality of adoption of the new fire protection rule. This step will include a cost-benefit review and will consider items such as:

- Alignment/mapping of CLB elements with comparable NFPA 805 Chapter 3 elements and features;
- Clarity of existing fire protection licensing basis in documenting prior approval;
- Level of rigor associated with post-fire safe shutdown analysis and documentation of exceptions such as Generic Letter 86-10 evaluations of fire area boundaries, partial suppression/detection evaluations, manual action feasibility, etc.;
- Availability and reliability of cable and raceway data;
- Depth and status of fire risk analysis (i.e., fire PRA, IPEEE);
- "Economies of scale" that may be attained due to application of process to similar units and sites;
- Plans for license renewal;
- Estimated costs of additional analyses and plant implementation of fire protection programs for other modes of operation and consideration of radioactive release;
- Estimated cost of resolving outstanding fire protection issues (i.e., condition reports, inspection/assessment findings) using traditional deterministic methods;
- Perceived regulatory risk of pursuing a risk-informed, performance-based option without a significant proven process for acceptance and approval; and
- Cost benefit associated with reduced focus on non-safety significant issues.

4.2.2 Transition Letter of Intent

Following the management decision to transition to a new licensing basis, a Letter of Intent is prepared. The Letter of Intent must provide the NRC with enough information about the licensee's transition plans to enable the NRC to justify the exercise of enforcement discretion for any non-compliances found as a result of conducting the transition process. A Letter of Intent will provide adequate information if it contains the following information:

- Identification of the plant(s) intended to be transitioned to a new licensing basis.
- Outline of activities needed to support the transition and estimated completion dates.
- Proposed transition schedule, including initiation and estimated duration of the transition.
- Formal request for NRC exercise of enforcement discretion discussion (unless the NRC issues an Enforcement Guidance Memorandum (EGM)).

A sample Letter of Intent is provided in Appendix H.

4.3 Reviews and Engineering Analyses

The need to perform additional engineering analyses as part of transitioning to a new fire protection licensing basis stems from results of the transition reviews as discussed in the subsections below. Assessment of radioactive release due to fire suppression activities for and the impact of fires occurring in non-power operational modes are not in most cases addressed in a licensee's CLB. Thus, engineering analyses should be performed to evaluate the fire protection program against the performance criteria for these elements of NFPA 805.

4.3.1 Fundamental Fire Protection Program and Design Elements Transition Review

NFPA 805 Chapter 3 contains the fundamental elements of the fire protection program and specifies the minimum design requirements for fire protection systems and features. These requirements are very similar to the guidelines of BTP 9.5-1 APCSB (5/1/76), BTP 9.5-1 Appendix A (2/24/77), or NUREG-0800 BTP 9.5-1 CMEB (7/81). Each nuclear plant has an approved fire protection program that must demonstrate compliance with 10 CFR 50.48. For these reasons, a substantial part of an existing fire protection program can be transitioned to a new NFPA 805 licensing basis by performing a transition review

Chapter 3 states, "These fire protection program elements and minimum design requirements shall not be subject to the performance-based methods permitted elsewhere in this guidance. Previously approved alternatives from the fundamental program attributes of Chapter 3 of NFPA 805 [by the NRC] take precedence over the requirements contained herein." Notwithstanding the prohibition in Section 3.1, the final rule is expected to indicate that licensees may apply for license amendments to use performance-based methods to demonstrate compliance.

It is important that the "previously approved alternatives" be clearly determined in order to understand the level of review and potential upgrades necessary to meet the requirements in Chapter 3 of NFPA 805. Fire protection program features and systems, although previously reviewed and approved by the NRC, may have been changed since initial NRC approval. Such changes are part of the CLB if they have been made in accordance with the correct application of the guidelines of Generic Letter 86-10, an evaluation of plant changes under the requirements of 10 CFR 50.59, or the fire protection standard license condition (NEI 02-03). The fire protection standard license condition allows changes to the "approved fire protection program without prior approval of the Commission if those changes would not adversely affect the ability to achieve and maintain safe shutdown in the event of a fire." Where the changes from the original NRC review and approval have been made appropriately using an approved change process, the changes are considered an acceptable part of the CLB. Licensees may rely on these changes to claim compliance but the NRC may inspect those changes and conclude that they do not comply with NFPA 805. However, they are not considered previously approved by the NRC for the purposes of superseding requirements in Chapter 3.

A simplified flowchart of the fundamental program and design elements transition review is provided as Figure 4-2.

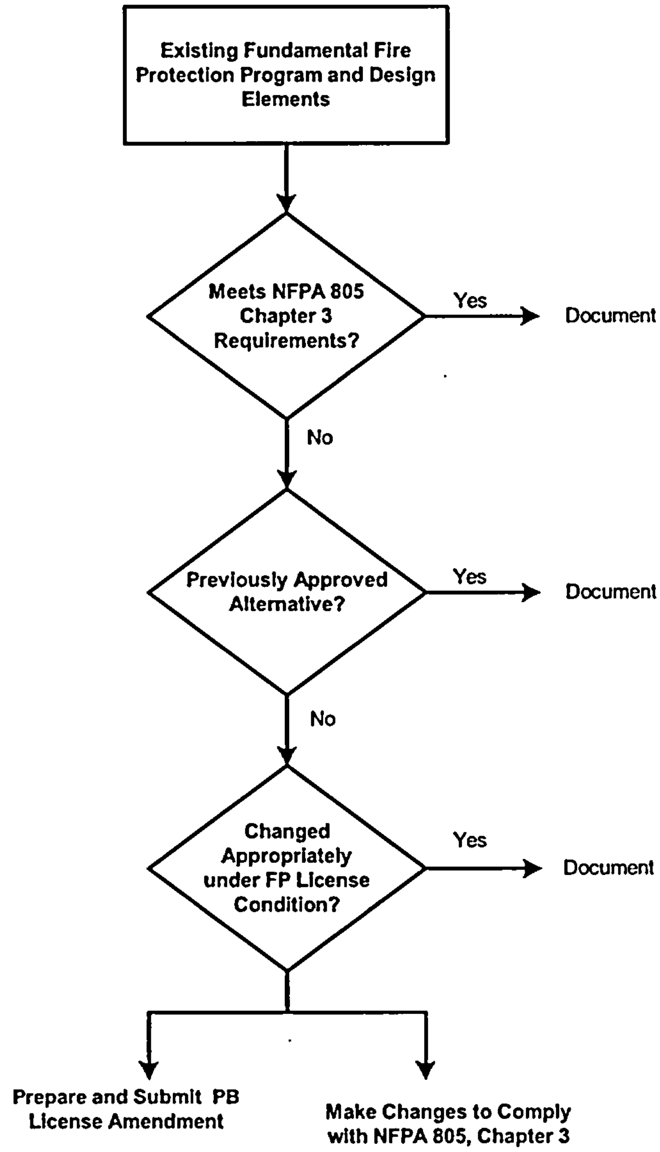


Figure 4-2 - Fundamental Program and Design Elements Transition Process (Simplified)

A systematic approach should be taken when assessing the transitioning plant fire protection program against NFPA 805 Chapter 3 requirements. This is necessary to provide clear documentation of acceptance prior to moving forward with a new licensing basis. Specific acceptance of a plant configuration, as well as changes since original acceptance, should be documented. Each section and subsection of Chapter 3 should be reviewed against the current fire protection program. Licensees should provide specific compliance statements (deviations, exemptions, etc) to demonstrate "previous approval" of an alternative or compliance with the Chapter 3 attribute.

Differences from NFPA 805 Chapter 3identified during the transition review must be reconciled prior to transition to a new risk-informed, performance-based licensing basis. For those cases where compliance cannot be demonstrated, or prior NRC approval is not adequately documented, the licensee may choose to comply with the deterministic requirements of NFPA Chapter 3 or prepare performance-based license amendment request for submittal to the NRC.

A sample table showing NFPA 805 requirements, fundamental program and design elements, items for review, method of compliance, and licensing basis references are shown in Appendix B-1.

4.3.2 Nuclear Safety Performance Criteria Transition Review

The nuclear safety performance goals, objectives, and criteria are very similar to the requirements contained in Sections III.G and III.L of 10 CFR 50, Appendix R or applicable sections of NUREG-0800. Each nuclear plant has an approved fire protection program that must demonstrate compliance with the safe shutdown requirements in Sections III.G and III.L of 10 CFR 50, Appendix R (or applicable sections of NUREG-0800), or has documented exemptions/deviations from these requirements. For these reasons, a substantial part of an existing fire protection program can be transitioned to a new NFPA 805 licensing basis by performing a transition review and by addressing NFPA 805 topics not typically addressed in a previously approved fire protection program (i.e., fires originating in non-power operational modes and fires resulting in radioactive release).

The deterministic branch of Figure 2.2 of NFPA 805 recognizes as an acceptable approach bringing forward the existing plant licensing basis (including approved exemptions / deviations, and correctly implemented engineering equivalency evaluations) to the extent that they can be shown to comply with Chapters 1, 2 and 4. This would be considered compliance with deterministic compliance in NFPA 805 Chapter 4. Otherwise, additional engineering evaluations may be used to demonstrate equivalence.

Just as in the Fundamental Fire Protection Program and Design Elements review discussed in Section 4.3.1, Fire protection program features and systems, associated with compliance with Appendix R / NUREG-0800, although previously reviewed and approved by the NRC, may have been changed since initial NRC approval. Such changes are part of the CLB if they have been made in accordance with the correct application of the guidelines of Generic Letter 86-10, an evaluation of plant changes under the requirements of 10 CFR 50.59, or the fire protection standard license condition. The fire protection standard license condition allows changes to the "approved fire protection program without prior approval of the Commission if those changes would not adversely affect the ability to achieve and maintain safe shutdown in the event of a fire." Where the changes from the original NRC review and approval have been made appropriately using an approved change process, the changes are considered an acceptable part of the CLB. Licensees may rely on these changes to claim compliance but the NRC may inspect those changes and conclude that they do not comply with NFPA 805. However, they are not considered previously approved by the NRC for the purposes of superseding requirements in Chapter 3.

A systematic approach should be taken when assessing the transitioning plant fire protection program against the nuclear safety requirements of Chapters 1, 2 and 4 of NFPA 805. This is necessary to provide clear documentation of acceptance prior to moving forward with a new licensing basis. Specific acceptance of a plant configuration, as well as changes since original acceptance, should be documented. The review should consist of two fundamental items:

1. Review of the safe shutdown methodology for basic attributes (Chapters 1 and 2 of NFPA 805)
2. Fire area by fire area review (Chapter 4 of NFPA 805)

The safe shutdown methodology review evaluates the existing post-fire safe shutdown analyses against the guidance provided in Section 2.4.2 of NFPA 805 for the Nuclear Safety Capability Assessment. This review ensures that the basic elements (systems and equipment selection, circuit selection, equipment and cable location, and fire area assessment) are adequate to support transition to a new licensing basis for fires originating at power operations. Differences identified during the transition review must be reconciled prior to transition to a new risk-informed, performance-based licensing basis. Guidance on performing of the NFPA 805 Chapter 2 reviews is provided in the tables in Appendix B-2 of this guidance.

A simplified flowchart of the fire area by fire area transition review is provided as Figure 4-3 below.

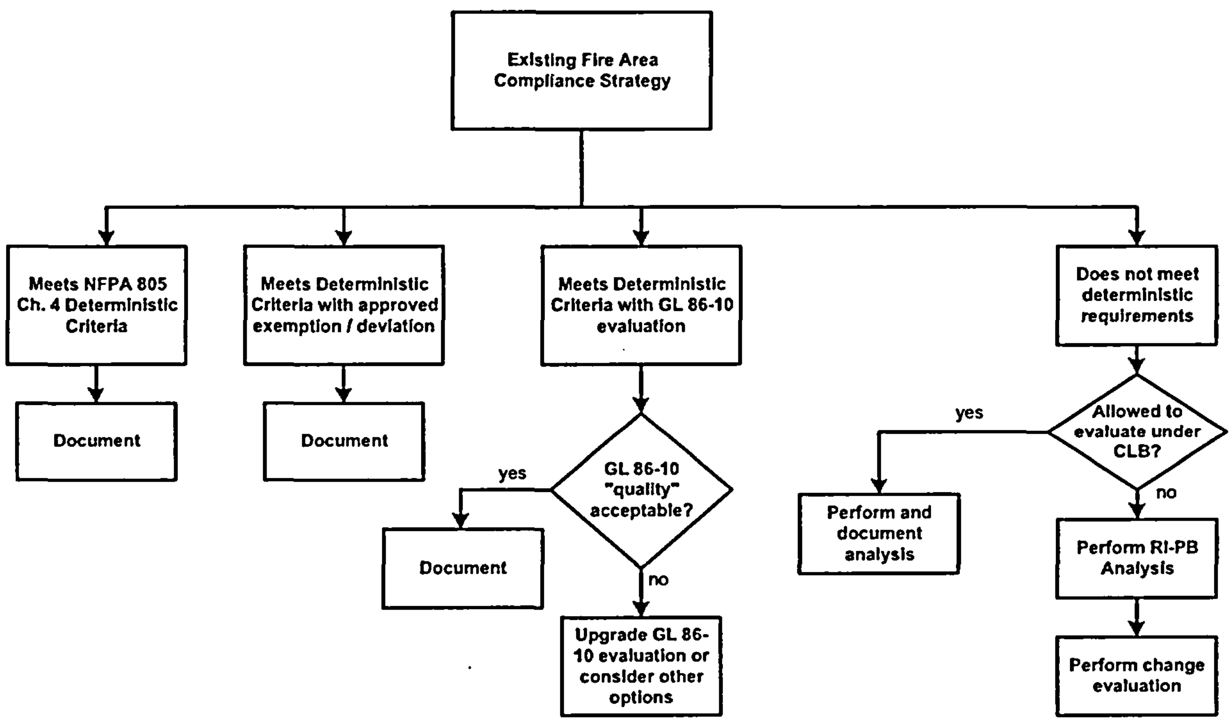


Figure 4-3 - Fire Area by Fire Area Transition Process (Simplified)

The fire area by fire area review determines whether the CLB is intact and documented adequately to support the transition. The review is intended to identify and document how each fire area:

1. Aligns with the NFPA 805 Chapter 4 deterministic methods for meeting the nuclear safety performance criteria in NFPA 805 Section 1.5; or
2. Aligns with the NFPA 805 Chapter 4 deterministic methods for meeting the nuclear safety performance criteria in NFPA 805 Section 1.5 with approved exemptions or deviations from 10 CFR 50 Appendix R; or
3. Aligns with the NFPA 805 Chapter 4 deterministic methods for meeting the nuclear safety performance criteria in NFPA 805 Section 1.5 with correctly implemented supporting engineering evaluations (i.e., Generic Letter 86-10 evaluations or calculations); or
4. Does not align with the NFPA 805 Chapter 4 methods for meeting the nuclear safety performance criteria in NFPA 805 Section 1.5 and either can or cannot be evaluated under the CLB. Items outside the CLB would be evaluated using risk-informed, performance-based methods as part of the transition review.

Differences identified during the fire area by fire area transition review must be reconciled prior to transition to a new risk-informed, performance-based licensing basis. Items that can be addressed within the bounds of the CLB prior to the transition (i.e., by performance of a Generic Letter 86-10 evaluation) should be addressed and documented as part of the transition process. Differences that cannot be resolved within the bounds of the CLB may also be resolved by changing the plant/program to align with the NFPA Chapter 4 deterministic methods for meeting the nuclear safety performance criteria in NFPA 805 Section 1.5.

Guidance on the performance of the NFPA 805 Chapter 4 reviews is provided in the tables in Appendix B-2 of this guidance.

4.3.3 Non-Power Operational Modes Transition Review

The nuclear safety goal of NFPA 805 requires the evaluation of the effects of a fire "during any operational mode and plant configuration". The concept of protection of equipment from the effects of fire during plant shutdown conditions is discussed in NUREG-1449. In general, the underlying concerns are the differences between the functional requirements (i.e. different (or additional) set of systems and components) and time dependencies on decay heat removal system operation during non-power operations and full power operations. The current industry approaches for evaluating risk during shutdown conditions involves both quantitative and qualitative assessments and is based on NEI 93-01 and NUMARC 91-06.

To demonstrate that the nuclear safety performance criteria are met for High Risk Evolutions (HREs as defined by NUMARC 91-06) during non-power operational modes, the following strategy is recommended:

- Review existing plant outage processes (outage management and outage risk assessments) to determine equipment relied upon to provide Key Safety Functions (KSF) including support functions. Each outage evolution identifies the diverse methods of achieving the KSF. For example to achieve the Decay Heat Removal KSF a plant may credit DHR Train A, DHR Train B, HPI Train A, HPI Train B, and Gravity Feed and Chemical and Volume Control.

- Identify locations where 1) fires may cause damage to the equipment (and cabling) credited above, or 2) recovery actions credited for the KSF are performed (for those KFSs that are achieved soley by recovery action i.e., alignment of gravity feed).

- Identify fire areas where a single fire may damage all the credited paths for a KSF. This may include fire modeling to determine if a postulated fire (MEFS – LFS) would be expected to damage required equipment.

- For those areas consider one or more of the following options to mitigate potential fire damage depending upon the significance of the potential damage:
  - Prohibition or limitation of hot work in fire areas during periods of increased vulnerability
  - Verification of operable detection and /or suppression in the vulnerable areas.
  - Prohibition or limitation of combustible materials in fire areas during periods of increased vulnerability
  - Provision of additional fire patrols at periodic intervals or other appropriate compensatory measures (such as surveillance cameras) during increased vulnerability
  - Use of recovery actions to mitigate potential losses of key safety functions.
  - Identification and monitoring insitu ignition sources for "fire precursers" (e.g., equipment temperatures).

It is important to note that shutdown PRAs do not exist at this time.

Appendix F provides examples of this process and the documentation requirements anticipated.

4.3.4 Radioactive Release Transition Review

Independent of whether the deterministic or risk-informed, performance-based option is chosen; a licensee must also show that the fire protection goals, objectives and criteria are met as they relate to potential radioactive release scenarios. Therefore, licensees must now evaluate fire risks and fire protection for various scenarios (not involving fuel damage) that could lead to radioactive release to an unrestricted area.

The treatment of radiological release to any unrestricted area due to fire is focused on potential radioactive release due to potential fuel damage and fire fighting activities:

- The Nuclear Safety Goal, Objectives, and Performance Criteria all require the prevention of fuel cladding damage. As such, radiological release due to fuel damage should not require a separate examination since no such damage is assumed to occur without violating the basic requirements of NFPA 805. This effectively limits the source of radiation (release source term). Therefore, containment integrity should not require specific examination. This means the scope of the fire protection analyses need not be expanded to include all containment isolation valves.

- The potential for radiological release due to fire fighting activities should be addressed via fire pre-plans. The objective is to address the potential for the loss of boundary control for contaminated spaces

Refer to Appendix G for examples of this process and the documentation requirements anticipated.

4.4 Licensing Basis Transition - Change Evaluations

It is expected that a plant change evaluation performed as part of the transition to a new licensing basis would be limited to cases where the nuclear safety performance criteria are not met and are outside of the CLB, although there may be instances where risk-informed, performance-based methods could be used in a license amendment request to demonstrate conformance with criteria in NFPA 805 Chapter 3 criteria. The scope of plant change evaluations as part of the licensing basis transition is limited because:

1. An evaluation of fires originating in non-power operational modes would typically not exist prior to transition to a new licensing basis. Therefore, there would be no basis for measuring or determining the acceptability of a "change."

2. An evaluation of the impact of fire on radioactive release would typically not exist prior to transition to a new licensing basis. Therefore, there would be no basis for measuring or determining the acceptability of a "change."

Refer to Appendix I of this document for additional guidance on risk-informed, performance-based change evaluations.

After the transition, changes to a plant Fire Protection Program are likely to occur during the course of plant life. These changes can involve either physical components of the plant or specific details of the fire protection program. The need to perform a Change Evaluation can arise through a number of events or conditions.

1. An in-situ condition could be discovered that is inconsistent with the new Licensing Basis. A Change Evaluation can be performed to determine if the in-situ condition can remain and be treated as an acceptable change to the fire protection program.

2. A plant modification could be proposed that requires altering the fire protection program features in order to implement the modification in a cost-effective manner. A Change Evaluation can be performed to examine a number of proposed alternatives to develop an optimal acceptable configuration.

3. A programmatic change in the fire protection program may alter a feature that has been explicitly or implicitly incorporated into the Licensing Basis (CLB pre-transition or NFPA 805 Licensing Basis post-transition). A feature that forms the basis for the acceptance of an exemption or deviation (i.e., specific reference to a response by the fire brigade) would represent implicit incorporation into the Licensing Basis. A Change Evaluation is required in this case to determine if this modification is acceptable.

The traditional fire protection regulatory framework includes requirements for the evaluation of such changes for acceptability under the fire protection standard license condition. The transition from this regulatory framework to a risk-informed, performance-based approach for fire protection would retain this requirement in the form of a Change Evaluation, but would modify the acceptance criteria. A review of the NFPA change evaluation process and comparison between it and the traditional process shows that the principal difference between the traditional and NFPA change evaluation process is the consideration of risk.

The plant change evaluation criteria are established by Sections 2.2.9 and 2.4.4 of NFPA 805. NFPA 805 Section 2.2.9 addresses changes to previously approved fire protection program elements. A risk-informed, performance-based plant change evaluation is to be performed and the results are to be used as described in Section 2.4.4 of NFPA 805. Each change must be shown to ensure that the public risk associated with fire-induced nuclear fuel damage is low and that adequate defense-in-depth and safety margins are maintained.

Section 2.4.4 overlaps somewhat with Section 2.2.9. It states that:

> *A plant change evaluation shall be performed to ensure that a change to a previously approved fire protection program element is acceptable. The evaluation process shall consist of an integrated assessment of acceptability of risk, defense-in-depth, and safety margins. [NFPA 805, Section 2.4.4]*

Additional details are provided in Sections 2.4.4.1, 2.4.4.2, and 2.4.4.3 of NFPA 805.

- Section 2.4.4.1 requires the change in public health risk from any plant change be acceptable to the NRC as demonstrated by the change in Core Damage Frequency (CDF) and Large Early Release Frequency (LERF). The NRC already has established acceptable changes to the CDF and LERF in Regulatory Guide 1.1.74. Specifically, these criteria should be applied to show that the public health risk associated with fire-induced nuclear fuel damage related to the change is low.

- Sections 2.4.4.2 and 2.4.4.3 for defense-in-depth and safety margin simply repeat the criterion in Section 2.2.9 requiring the adequate maintenance of these factors. Criteria complying with these requirements also are provided in Regulatory Guide 1.1.74 and this guidance. Note that sections 2.4.4.2 and 2.4.4.3 also indicate that these requirements shall be deemed to be satisfied by complying with the deterministic approach for meeting the performance criteria.

These NFPA 805 provisions show, in a general way, that the plant Change Evaluation is similar to that already required under the traditional regulatory framework. The traditional regulatory framework allows for changes to be made to the plant under processes such as 10 CFR 50.59, fire protection standard license condition, the exemption process under 10 CFR 50.12, or other regulatory processes. In addition to technical acceptability, a key consideration in the traditional regulatory framework was the need for prior NRC approval. NEI 02-03, "Guidance for Performing a Regulatory Review of Proposed Changes to the Approved Fire Protection," provides a generic regulatory review process that may be used to determine if a change to the approved fire protection program can be made without prior NRC approval. NRC approval is generally not required if the ability to achieve and maintain safe shutdown is not adversely impacted. Under the risk-informed, performance-based regulatory framework, changes will generally be made without prior NRC approval, unless other regulatory processes (i.e., Technical Specifications) require it or unless safe shutdown is adversely impacted.

The key difference in the change process under risk-informed, performance-based regulatory framework is the consideration of risk. The evaluation of risk is limited to the determination of whether an increase has occurred, and if so, whether the increase is within acceptable limits. The Change Evaluation process involves the comparison of a baseline condition or configuration against a proposed alternative.

1. The baseline is defined as that plant condition or configuration that is consistent with the Licensing Basis (CLB pre-transition or NFPA 805 Licensing Basis post-transition).

2. The changed or altered condition or configuration that is not consistent with the Licensing Basis is defined as the proposed alternative.

In all instances, maintaining the plant in a condition (configuration) consistent with the Licensing Basis (CLB pre-transition or NFPA 805 Licensing Basis post-transition) eliminates the need for a Change Evaluation. A Change Evaluation is also not required if the proposed change complies with the deterministic requirements of NFPA 805, Section 4.2.3. However, both types of changes would still require an evaluation of the maintenance of defense-in-depth and safety margin.

The Change Evaluation process begins by defining the change to be examined and the baseline configuration as defined by the Licensing Basis (CLB pre-transition or NFPA 805 Licensing Basis post-transition). A screening is then performed to identify and resolve minor changes to the fire protection program. This screening is consistent with fire protection regulatory review processes in place at nuclear plants under traditional licensing bases. This is followed by engineering evaluations that may include fire modeling and risk assessment techniques. The results of these evaluations are then compared to the acceptance criteria. Changes that satisfy the acceptance criteria can be implemented. Changes that do not satisfy the acceptance criteria of NFPA 805 Section 2.4.4.1 cannot be implemented within the framework provided by NFPA 805. The acceptance criteria require that the resultant change in CDF and LERF be consistent with the requirements of Regulatory Guide 1.174. The acceptance criteria also include consideration of defense-in-depth and safety margin, which would typically be qualitative in nature, but depending on the application, could be measured using quantitative methods (i.e., safety factors, margins, etc.).

The following sections provide a discussion of the Change Evaluation Process, the integration of fire modeling and risk assessment techniques, and the determination of the acceptability of the change.

4.4.1 Overall Change Evaluation Process

The overall Change Evaluation process involves a graded and potentially iterative process. The intent of the graded approach is to provide analysis flexibility to address a wide range of issues and conditions. It also provides the mechanism to recognize and incorporate the diverse set of plant fire risk analyses in the industry. In general, the Change Evaluation process focuses on performing those Engineering Analyses needed to establish the acceptability of the change.

The overall Change Evaluation process is shown in Figure 4-4. A summary discussion for each process step follows the figure.

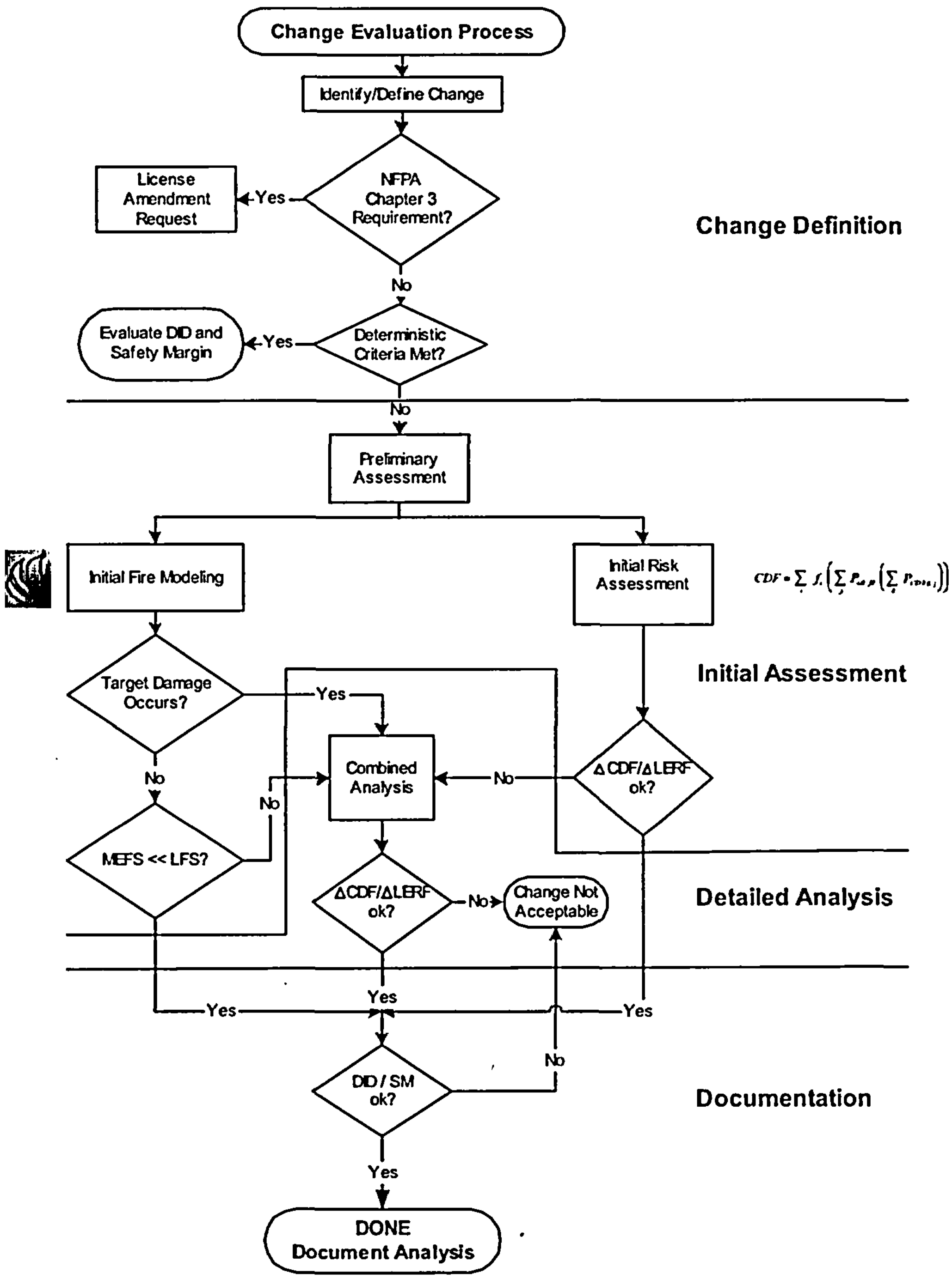


Figure 4-4

- **Identify/Define Change** – It is important to identify the applicable Licensing Basis (CLB pre-transition or NFPA 805 Licensing Basis post-transition) related parameters and the discrepancy or inconsistency that is causing the need for the Change Evaluation.
- **Fundamental Program Element or Minimum Design Requirement Affected?** –10 CFR 50.48(c)(2)(v) allows licensees to use performance-based methods to demonstrate compliance with NFPA 805 Chapter 3 requirements. These alternate methods must be approved via the license amendment process (10 CFR 50.48(c)(4)).
- **Deterministic Criteria Met?** – The requirements of NFPA 805 include a deterministic approach with associated acceptance criteria. If the change being evaluated involves the consideration of new plant system components, functions, or features not previously credited, or otherwise involves changes, that results in at least one success path meeting the deterministic requirements of NFPA 805, Section 4.2.3, then no further analysis is required and the change can be accepted.
- **Preliminary Assessment** – An initial assessment of the change should be performed to determine the need for and nature of engineering analysis that may be necessary to support the change. For routine minor changes, this is the step where engineering judgment would be applied and the need for formal engineering analyses would be determined. For more complex changes, an assessment would be made of whether a fire modeling approach alone, or a risk assessment approach alone would be successful. The path that is expected to most easily demonstrate the acceptability of the change should be the only path taken. If neither approach is expected to succeed alone, then the analysis should begin with the risk assessment or proceed directly to the detailed integrated analysis.
- **Initial Fire Modeling** – Fire modeling analyses are applied to examine the response of the "target" identified in the change definition given fire conditions. Refer to Appendix D of this document for guidance on the preparation of fire modeling analyses. The target is defined as the plant feature being examined by the Change Evaluation. This may be a physical feature such as a cable or a characteristic of the analysis such as a specific failure mode.
- **Target Damage Occurs?** – The fire modeling analysis must define and evaluate a postulated scenario involving the Maximum Expected Fire Scenario (MEFS). If target damage is predicted to occur, fire modeling alone will not be sufficient to demonstrate the acceptability of the change.
- MEFS<<LFS? – The performance of fire modeling involves a degree of uncertainty. This uncertainty is addressed indirectly by the determination of the Limiting Fire Scenario (LFS). A comparison of MEFS and LFS is used to determine if a sufficient margin exists. If sufficient margin exists, then fire modeling alone can be used to demonstrate the acceptability of the change. This approach eliminates the need for risk assessment because it effectively demonstrates that target damage does not occur.
- **Initial Risk Assessment** – An initial risk assessment can be performed using the existing available plant fire risk analysis, IPEEE, or the plant internal events PRA model. The analysis would simply determine the change in the calculated core damage frequency (CDF) with and without the postulated fire induced failure of the plant feature being examined by the Change Evaluation.

- **Acceptability Determination** – The resulting change CDF is compared against the acceptance criteria (refer to Section 4.4.2). If the change meets the acceptance criteria, then a risk assessment alone can be used to demonstrate the acceptability of the change. This approach eliminates the need for fire modeling because it biases the analysis by assuming target damage occurs due to fire and there is no limit on fire severity assumed in the evaluation. As part of the acceptability determination, defense-in-depth and safety margins must be maintained.
- **Combined Analysis** – In the event neither approach alone is sufficient to demonstrate the acceptability of the change, a detailed combined analysis can be performed using fire modeling and risk assessments. This is discussed further in Appendix I.

4.4.2 Acceptance Criteria

The acceptance criteria for the Change Evaluation consist of two parts. One is quantitatively based and the other is qualitatively based. The quantitative figures of merit are ΔCDF and ΔLERF. The qualitative factors are defense-in-depth and safety margin.

4.4.2.1 Quantitative Risk Acceptance Criteria

The acceptance criteria for a risk increase are taken from Regulatory Guide 1.174. The criteria from the regulatory guide are depicted in Figures 4-5 and 4-6 and are a function of the total calculated CDF and LERF for the plant.

The figures show that the calculated cumulative risk for the plant from all initiators can affect the allowed risk increase for a particular proposed change. In some instances, the risk increase for a particular proposed change must be combined with that of prior accepted changes to obtain a cumulative increase. Since the potential exists that cumulative changes, while individually acceptable, may at some point in the future aggregate to an unacceptable value, it is important to be aware of and track, in some instances, proposed changes that have a net risk reduction. The acceptance criteria from Regulatory Guide 1.174 are based on three regions with a fourth implicit region. These regions are described below.

Region	ΔCDF /yr	ΔLERF /yr	Status	Comments/Conditions
I	≥ 1.0E-05	≥ 1.0E-06	Unacceptable	Proposed changes in this region are not acceptable.
II	< 1.0E-05 and ≥ 1.0E-06	< 1.0E-06 and ≥ 1.0E-07	Acceptable w/ conditions	Proposed changes in this region are acceptable provided the cumulative total CDF from all CDF initiators is less than 1.0E-04/yr. Cumulative effect of changes must be tracked and included in subsequent changes.
III	< 1.0E-06 and ≥ 1.0E-07	< 1.0E-07 and ≥ 1.0E-08	Acceptable w/ conditions	Proposed changes in this region are acceptable provided the cumulative total CDF from all initiators is less than 1.0E-03/yr. Cumulative effect of changes must be tracked and included in subsequent changes.
IV	< 1.0E-07	< 1.0E-08	Acceptable	Proposed changes in this region are acceptable regardless of the cumulative total CDF from all initiators. Tracking of these changes is not required.

Region IV is not actually depicted in the figures, but represents the area with lower ΔCDF and ΔLERF values than shown on the figures.

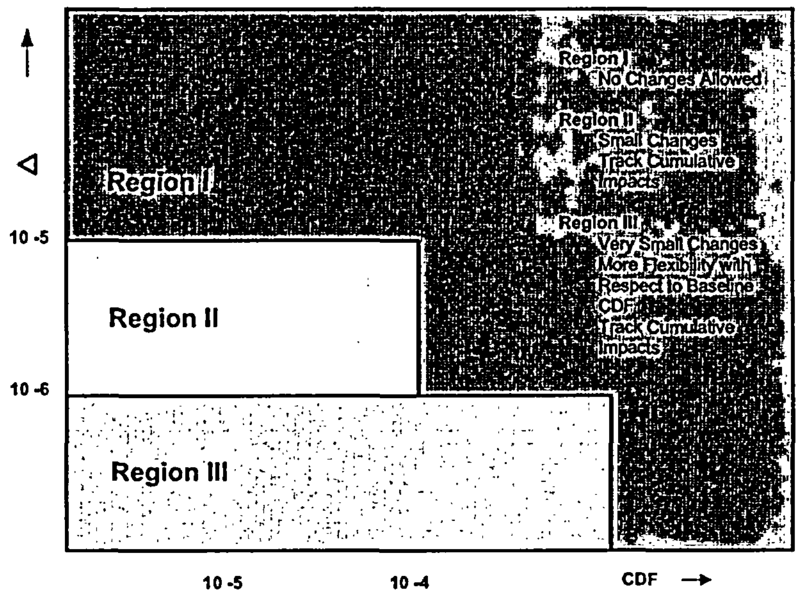


Figure 4-5 – ΔCDF Acceptance Criteria

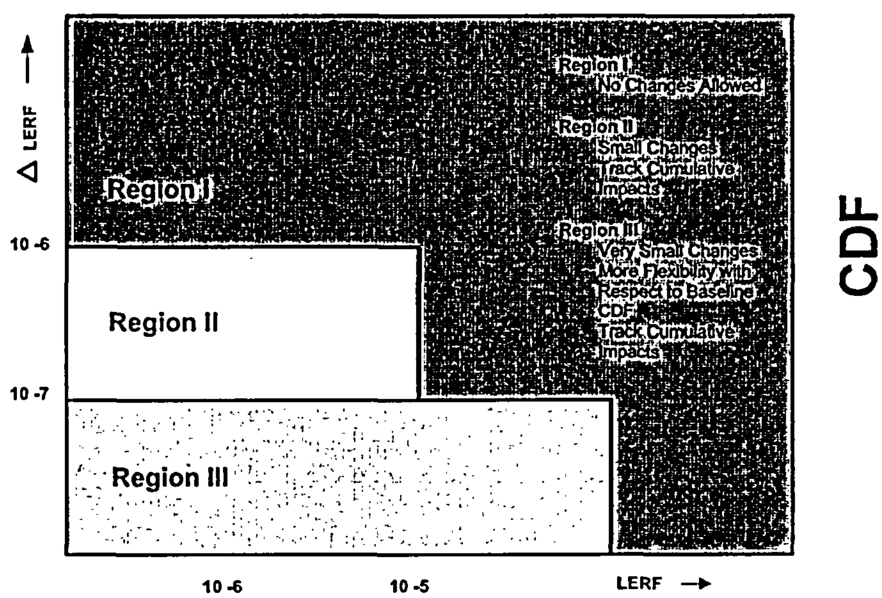


Figure 4-6 – ΔLERF Acceptance Criteria

The CDF and LERF values shown on the horizontal axis of Figures 4-5 and 4-6 are cumulative valves for the plant from all initiators. This consists of both internal and external hazards. The plant PRA should provide the CDF for the internal hazards (transients, loss of coolant accidents, loss of offsite power, etc.). The same should be applicable for LERF. The external hazards include fire and seismic. However, the CDF and LERF contributions from these external hazards may not be readily available.

If the CDF and/or LERF due to external hazards is not available or is otherwise not known, then the ΔCDF and ΔLERF for a proposed change must be limited to 1.0E-07/yr., and 1.0E-08/yr., respectively. An increase in these values is possible if there is reasonable assurance that the plant risk is in Region II or III with fire and seismic risk included. If an increased value is used, a basis or justification must be developed and documented. If an existing Fire PRA or IPEEE is available, it should be used to obtain a fire-induced CDF and LERF contribution for the plant.

It is recognized that LERF values may not be available for a Fire PRA. Instead, qualitative assessments may have been performed to justify impacts being already bounded by the existing analyses performed for the internal hazards. In these instances, there are two options for proceeding.

The ΔLERF acceptance criterion can be used in lieu of the ΔCDF value. This effectively structures the analysis to "allow" a conditional probability of containment failure of 1.0. Alternatively, a supplemental assessment can be performed for the containment isolation function. If the fire-induced consequences do not disable the containment isolation function, then the ΔLERF criterion can be considered satisfied.

4.4.2.2 Defense-in-Depth and Safety Margins

The result of the proposed change must also satisfy defense-in-depth and safety margin considerations. In general, the defense-in-depth requirement is satisfied if the proposed change does not result in a substantial imbalance in:

- Preventing fires from starting
- Detecting fires quickly and suppressing those that occur, thereby limiting damage
- Providing adequate level of fire protection for structures, systems and components important to safety so that a fire that is not promptly extinguished will not prevent essential plant safety functions form being performed

NEI 00-01 provides the following guidance with respect to maintaining defense-in-depth:

> *"Consistency with the defense- in-depth philosophy is maintained if the following acceptance guidelines, or their equivalent, are met:*
>
> 1. *A reasonable balance among prevention of fires, early detection and suppression of fires, and fire confinement is preserved.*
> 2. *Over-reliance and increased length of time or risk in performing programmatic activities to compensate for weaknesses in plant design is avoided.*
> 3. *Pre-fire nuclear safety system redundancy, independence, and diversity are preserved commensurate with the expected frequency and consequences of challenges to the system and uncertainties (e.g., no risk outliers). (This should not be construed to mean that more than one safe shutdown train must be maintained free of fire damage.)*
> 4. *Independence of defense- in-depth elements is not degraded.*

5. *Defenses against human errors are preserved.*

It should be noted that all elements of fire protection DID may not exist for beyond design basis fire scenarios. For example, a CDP of 1.0 is possible if enough fire barriers are breached. Such beyond design basis scenarios, however, should be demonstrated to be of less risk significance, with certainty. A scenario with all elements of DID, and a CDF of 9E-08/year would be treated differently than a scenario with a CDP of 1.0, and a CDF of 9E-08/year. In the end, the balance results in consideration of all aspects of the component combination, including the Risk, DID, Safety Margins, uncertainty, and other relevant issues."

The application of the NEI 00-01 guidance requires particular care when considering the LFS case. The LFS is a step in the NFPA 805 review process and may not represent a possible or credible fire scenario. A qualitative review of DID for the LFS case should focus on the degradation and failures that are necessary in order for the LFS to occur. The elements of DID that should be examined include a) preventing fires from starting, b) detecting and suppressing the fire, and c) any residual barriers related the Nuclear Safety Performance Criteria. The level of rigor in the review should consider the possibility of the occurrence of the LFS and the degree to which the traditional expected balance in all element of DID have been degraded. Instances where the LFS involves a possible event would require greater balance in the elements of DID as compared to an impossible (incredible) event.

The safety margin requirement is satisfied if:

- Codes and standards or their alternatives approved for use by the NRC are met, and
- Safety analysis acceptance criteria in the licensing basis (e.g., FSAR, supporting analyses) are met, or provides sufficient margin to account for analysis and data uncertainty.

The requirements related to safety margins for the change analysis is described for each of the specific analysis types used in support of the fire risk assessment. These analyses can be grouped into four categories. These categories are:

1. Fire Modeling
2. Plant System Performance
3. PRA Logic Model
4. Miscellaneous

Fire Modeling

The quantitative margin between the parameters describing the MEFS and the LFS and the process of judging the adequacy of that margin is the required safety margin consideration. The guidance for performing fire modeling provided Appendix I (Section I.4) provides an initial quantitative measure of adequacy. The level of review to be performed as part of the safety margin treatment considered here involves the integration of that quantitative margin with the potential consequences of the upset, or damage, that may occur given the LFS. The acceptability of the margin between MEFS and LFS needs to be judged in the context of the potential severity of the resulting plant system impact if an LFS were to occur. An LFS that causes an inter-system loss of coolant accident (ISLOCA) event would tend to demand a higher margin between MEFS and LFS as compared to an event to causes a degradation of long term decay heat removal.

Plant System Performance

The development of the fire risk assessment may involve the re-examination of plant system performance given the specific demands associated with the postulated fire event. The methods, input parameters, and acceptance criteria used in these analyses needs to be reviewed against that used for the plant design basis events. This review would serve to establish that the Safety Margin inherent in the analyses for the plant design basis events have been preserved in the analysis for the fire event and therefore satisfy the requirements of this section.

PRA Logic Model

The quantification for fire related CDF/LERF is expected to have been based on the plant PRA model. If no modifications to the underlying logic structure of the model and failure probabilities have occurred, then the Safety Margin inherent in that model is preserved. In this case, no further assessment for Safety Margin is necessary for this category.

Miscellaneous

This category is intended to address any other analyses that may have been performed that have not been addressed by the prior categories. Since the types of analyses in this category are varied, specific analysis guidance cannot be provided. Instead, the general requirements related to codes and standards, and acceptance criteria stated earlier must be addressed in the analysis documentation.

4.4.2.3 Uncertainty Considerations

Regulatory Guide 1.174 describes two types of uncertainty. These are aleatory and epistemic. Aleatory uncertainty is intrinsic, meaning that it is an irreducible uncertainty of the probabilistic phenomenon itself. This is also called process uncertainty and is random in nature. Random variables that exhibit aleatory uncertainty are considered to be independent and without correlation. Epistemic uncertainty, on the other hand, refers to a lack of knowledge. It can be further divided into modeling uncertainty (e.g., validity and accuracy of the model) and parameter uncertainty. Two variables with epistemic uncertainty that are derived from the same sources are considered to be 100% correlated. A decomposition of the sources of uncertainty into aleatory and epistemic uncertainties for each variable can provide the means for assessing the global correlation between these variables.

The treatment of aleatory, and to some degree epistemic, uncertainty can be graded based on the specific ΔCDF and ΔLERF results versus the bounding or limiting values for the associated Region in Figures 4-5 and 4-6. The importance of uncertainty becomes greater as the results approach the limiting value for a region. A proposed change that results in a Region IV characterization based on a ΔCDF of 9E-08/yr. should be examined much more critically than a Region III characterization based on a ΔCDF 2E-07/yr. The treatment of aleatory uncertainty specific to the Fire PRA can be minimized to a degree by the use of bounding or conservative values in the analysis. Alternatively, results approaching a region boundary can be treated based on the requirements of the more restrictive region.

The use of excessively conservative values in the Fire PRA has the negative impact of producing results that are not directly comparable to other PRA results and should not necessarily be included in plant total CDF characterization. In general, the CDF values from the internal events PRA which are developed based on best estimate values should not be intermingled with results based on conservative (upper bound) values. Such intermingling could inadvertently skew the focus of the overall plant risk analysis to be incorrectly biased by only fire related considerations. However, they can be combined if done solely for the purposes of the Change Evaluation.

The treatment of epistemic uncertainty includes factors that are not effectively addressed by the approach described above. These are model and completeness uncertainty. Model uncertainty specific to the fire initiator can be address indirectly by qualitatively assessing the initiating event used for quantification versus the anticipated initiating event given the fire event. In many instances, analyses treat all fires as resulting in a plant trip (general plant transient). This by itself could be sufficient to address model uncertainty for many events. The deterministic failure of non-credited plant systems could be another mechanism for addressing model uncertainty. In general, model uncertainty becomes a greater concern as the suite of plant system credited in the fire risk analysis approaches the full complement of systems in the plant.

Completeness uncertainty is treated indirectly by the approach described above. Further explicit treatment of this source of uncertainty is judged to be beyond the current state of technology.

4.5 Licensing Basis Transition - Program Documentation and Maintenance

4.5.1 Program Documentation and Quality Assurance

As part of the transition review, fire protection program documentation must be reviewed to ensure that the program is adequately documented to support the transition to a new licensing basis. This review is not intended to be a design basis reconstitution, but rather a review to ensure that the program documentation used to define the "going forward" licensing and design basis is adequate and of sufficient quality. Documentation identified during the reviews that are not of sufficient quality or that lack configuration control should be updated to meet the requirements contained in Section 2.7 of NFPA 805. The transition process should be used to summarize and categorize program documentation in a manner that facilitates the long-term maintenance of a risk-informed, performance-based program.

Refer to Section 5 of this guidance for additional information on program documentation, configuration control, and quality assurance.

4.5.2 Configuration Control

A requirement for maintaining current program documentation is consistent with expectations and requirements under a traditional regulatory framework. It is not expected that any major or fundamental changes in plant processes would be required. Documentation created as part of the transition and maintenance of a risk-informed, performance-based would need to be incorporated into existing plant programs.

4.5.3 Monitoring

Other risk-informed, performance-based attributes include the establishment of a monitoring program, as discussed in Section 2.6 of NFPA 805. This includes establishing acceptable levels of availability, reliability, and performance levels, and ensuring that processes are in place to take corrective actions when established thresholds are not met.

The intent of the monitoring transition effort is not to establish new detailed programs that define numerical values for reliability and availability for fire protection systems and features. Instead, the transition review should be performed as a confirmation of the adequacy of the existing surveillance, testing, maintenance, and compensatory measures. The adequacy of existing plant programs is sufficient to allow a transition to a new licensing basis without extensive changes. The scope of the review addresses the adequacy of existing internal and external fire protection oversight and plant corrective action programs. This review should consider:

1. The adequacy of the scope of systems and equipment within existing plant programs (i.e., are important fire protection systems and features adequately inspected and tested, and are compensatory measures appropriate).
2. The adequacy of the plant corrective action program in determining causes of equipment and programmatic failures and in minimizing their recurrence.
3. The system and equipment availability should equal or exceed the availability assumed in the risk assessment.

Deficiencies identified during the monitoring transition review should be corrected and updated as part of the licensing basis transition. Refer to Appendix E of this guidance for additional guidance on monitoring.

4.6 Regulatory Submittal and Transition Documentation

Three documents should be prepared to support the transition to compliance with NFPA 805. They are:

(1) A Letter of Intent to be sent to the NRC before beginning the transition process (discussed in Section 4.2.2)
(2) The License Amendment Request (LAR) required by 10 CFR 50.48(c)(3)(i); and
(3) A Transition Report that details the new licensing basis and how it was derived from the current fire protection licensing basis.

The LAR is required to address regulatory requirements and may also include alternative methods and analytical approaches. The Transition Report will not be submitted to the NRC but will be used on-site to support inspections. However, the first few plants which transition to the NFPA 805 licensing basis may be requested to submit a Transition Report summary which describes the transition process and how compliance with the new requirements was demonstrated.

4.6.1 License Amendment Request

The contents of the LAR are established by 10 CFR 50.48(c)(3)(i) and 10 CFR 50.48(c)(4), if necessary. The contents of the LAR will depend on how the licensee intends to demonstrate compliance with NFPA 805. If the licensee determines that it can demonstrate compliance with NFPA 805 by using only the methods and analytical approaches contained in NFPA 805, then a simple, regulatory requirements license amendment will suffice. Alternatively, if the licensee determines that it must use alternative methods and analytical approaches from those in NFPA 805 to demonstrate compliance, then a more substantive license amendment will be required. The differences between the two types of license amendments are described in detail below.

The LAR should be developed in accordance with the plant's processes for all LARs under 10 CFR 50.90. The minimum regulatory requirements to be addressed in the LAR are established in 10 CFR 50.48(c)(3)(i). It requires the licensee to:

(1) Identify all orders and license conditions that will need to be revised or superseded;
(2) Identify all of the Technical Specifications that must be revised; and
(3) Provide the proposed Technical Specification revisions as well as the supporting bases for them.

The acceptance criteria for granting such a LAR are:

(1) That the licensee has identified all of the orders, license conditions and technical specifications that must be revised or superseded, and
(2) That the proposed revisions are adequate.

NRC acceptance of a licensee's transition LAR rests on the completeness of the licensee's identification of any orders and license conditions that must be revised or superseded, as well as the adequacy of any revisions to the plant's technical specifications and their bases suggested by the licensee. Therefore, to demonstrate to the NRC that the LAR is complete and adequate, it should describe the process used by the licensee to identify all orders and license conditions that must be revised or superseded and justify all revisions to the Technical Specifications and their bases.

To satisfy 10 CFR 50.48(c)(3)(i), the LAR should include the following key components:

- A description of the process used to identify all orders, license conditions, and Technical Specifications and their bases that must be revised or superseded to implement compliance with NFPA 805. This will provide assurance to the NRC that the LAR addresses all of the changes the plant will need to adopt NFPA 805.

- The Technical Specifications to be revised or superseded (including their bases), necessary changes to the Technical Specifications and their bases, and explanations of why these changes are adequate to accomplish the plant's adoption of NFPA 805.

- The fire protection license conditions to be revised or superseded, a new license condition authorizing the use of the new fire protection licensing basis, and an explanation of why these revisions are adequate to accomplish the plant's adoption of NFPA 805.

- The orders and exemptions to be revised or superseded, the necessary revisions to orders and exemptions, and an explanation of why these revisions are adequate to accomplish the plant's adoption of NFPA 805.
- A finding of no significant hazards consideration and an environmental impact assessment finding no significant impact on the environment based on the NRC's discussion in the Statement of Consideration accompanying the rule.

- A discussion of the changes to Updated Final Safety Analysis Report (UFSAR) necessitated by the license amendment and a statement that the changes will be made in accordance with 10 CFR 50.71(e).

- Whether modifications are necessary to support the new licensing basis and, if so, a brief description of the modifications.

- An updated transition schedule that provides a basis for a request for NRC approval by a particular date.

A LAR is required for any licensee proposal to use alternative methods and analytical approaches to demonstrate compliance with NFPA 805(10 CFR 50.48(c)(4)). Where a licensee proposes to use an alternative method and analytical approach to support the transition to compliance with NFPA 805, that LAR may be incorporated in the LAR required under 10 CFR 50.48(c)(3)(i). Each request will need to be supported with the type of technical analysis that the station's procedures require to be provided for any substantive LAR. In addition, to demonstrate compliance with 10 CFR 50.48(c)(3)(i), the LAR must show that the alternative method and analytical approach meets the following requirements in 10 CFR 50.48(c)(4):

- Satisfies the goals, performance objectives, and performance criteria in Section 1.5 of NFPA 805 for nuclear safety and radiological release

- Maintains safety margins

- Maintains fire protection defense-in-depth by demonstrating an acceptable balance among fire prevention, fire suppression, and post-fire safe-shutdown capability.

A sample LAR is included in Appendix H.

A Safety Evaluation Report on a license amendment request is the vehicle that the NRC uses to document that the licensee has satisfied the submission requirements of the NFPA 805 fire protection rule. This SER will not necessarily document that a reactor plant is in compliance with NFPA 805 per se, a subject that will be addressed during the triennial fire inspections.

4.6.2 Transition Report

The Transition Report is created by the licensee to provide a clear, complete, and accurate description of the new fire protection licensing basis, how it is related to the current fire protection licensing basis, and how it demonstrates compliance with NFPA 805. The NRC can use the Transition Report to support its compliance determination under 10 CFR 50.48(c)(3). Therefore, the Transition Report should reflect the detailed, thorough process used by the licensee to transition the licensing basis. This will enable the Transition Report to serve not only as a record of the transition but also as a management control tool for ensuring that the transition completely addresses all new fire protection requirements.

The Transition Report should include the following:

- Executive Summary
- Introduction and background information on the transition
- Overview of the existing fire protection program
  - Current fire protection licensing basis
  - Applicable regulatory requirements
- Discussion of the transition process
  - License amendment request and license amendment
  - Implementation of Section 2.2 of NFPA 805
- Demonstrations of compliance with NFPA 805 requirements
  - Fundamental fire protection program elements and minimum design requirements
  - Comparison against nuclear safety performance criteria
    - Circuit analysis methodologies
    - Associated circuit methodologies
    - Equipment and cable location methodologies
    - Fire area assessments
  - Non-power operational modes assessment
  - Radioactive release performance criteria
  - Monitoring
  - Program documentation, configuration control, and quality assurance
  - Administrative implementation
  - Personnel qualifications
- Defense-in-depth and safety margins
- Compliance with NFPA 805 Goals and Objectives
  - These compliance statements will be based on a "roll-up" of the demonstrations of compliance with the underlying performance criteria.

A detailed Transition Report template is included in Appendix H.

5.0 PROGRAM MAINTENANCE AND CONFIGURATION CONTROL

The purpose of this section is to provide guidance on fire protection program maintenance and configuration control following the transition to new licensing basis.

5.1 Program Documentation, Configuration Control, and Quality Assurance

5.1.1 General Guidance for Program Documentation

As part of the transition, the fire protection program must be adequately documented to support the transition to a new licensing basis, as discussed in Section 4.

Following the transition, a risk-informed, performance-based fire protection program must be supported by appropriate documentation, maintained under configuration control and quality assurance processes. Rather than create new, restrictive processes for program documentation the intent is to ensure that basic documentation, configuration control, quality requirements and practices that are part of a nuclear power plant are reflected in the fire protection program, and that any new analyses or program documents are covered by the existing programs.

As part of the transition review, program documentation must be reviewed to ensure that the licensing and design basis meet the prerequisite requirements for transition and that any outliers are addressed. The transition process will summarize and categorize program documentation in a manner that facilitates the long-term maintenance of a risk-informed, performance-based program.

5.1.1.1 Program Documentation

Section 2.7.1 of NFPA 805 requires that analyses be documented to demonstrate compliance with NFPA 805. The intent of the documentation is that the assumptions be clearly defined and that the results be easily understood, that results be clearly and consistently described, and that sufficient detail be provided to allow future review of the analyses. The documentation must be retained for the life of the plant.

A fire protection program design basis document is discussed in Section 2.7.1.2 of NFPA 805. This does not imply or require a rigid document format or structure, as discussed in Section A.2.7.1.2. The term "design basis document" does not mean the fire protection program is required to be documented as part of the plant's design basis document program, which has specific requirements and meaning at individual sites. The design basis document, as described in NFPA 805, may be included in different forms, such as:

- Traditional design basis documents (DBDs)
- Analyses and Reports (i.e., fire hazards analysis, safe shutdown analysis)
- Calculations
- Correspondence

Section A.2.7.1.2 of NFPA 805 describes the following information that should be included or referenced to as part of the fire protection design basis:

- **Plant construction** – This information is typically included in a plant fire hazards analysis or fire barrier analysis in the current "deterministic" fire protection program.
- **Identification of hazards** – This information is typically included in a fire hazards analysis in the current "deterministic" fire protection program.
- **Fire protection systems and equipment** – This information is typically included in a fire hazards analysis in the current "deterministic" fire protection program.
- **Nuclear safety equipment** – This information is typically provided in a safe shutdown analysis in the current deterministic fire protection program. Any other equipment/system impacts resulting from a risk-informed, performance-based approach would supplement the existing safe shutdown equipment.
- **Radioactive release prevention equipment** – Due to the focus on basic plant design, prevention of core damage, and fire fighting planning as the primary methods of preventing radioactive release, it may not be necessary to include a listing of equipment, per se. Instead, the methods of ensuring that the radioactive release performance criteria from Section 1.5 of NFPA 805 should be documented and maintained. Any area-specific considerations pertaining to prevention of radioactive release should be documented (i.e., specific fire-fighting strategies that minimize radioactive release).
- **Life safety considerations** *(outside the scope of this implementing guidance)*
- **Plant damage and plant downtime** *(outside the scope of this implementing guidance)*
- **Fire scenarios** - The LFS and MEFS established for application in a performance-based analysis should be documented. This documentation should define the fire scenarios established and reference any engineering calculations, fire modeling calculations, or other engineering analysis that was prepared to demonstrate satisfactory compliance with performance criteria for each area.
- **Achievement of performance criteria** – Achievement of the applicable performance criteria should be documented.

5.1.1.2 Configuration Control

Section 2.7.2 of NFPA 805 states that:

> *"The design basis document shall be maintained up-to-date as a controlled document. Changes affecting the design, operation, or maintenance of the plant shall be reviewed to determine if these changes impact the fire protection program documentation.*

Detailed supporting information shall be retrievable records. Records shall be revised as needed to maintain the principal documentation up-to-date."

This requirement is consistent with expectations and requirements under a traditional regulatory framework. It is not expected that any major or fundamental changes in plant processes would be required. Documentation created as part of the transition and maintenance of a risk-informed, performance-based would need to be incorporated into existing plant programs.

5.1.1.3 Quality Assurance

Due to the evolving nature of fire protection engineering and use of risk in nuclear power plant decision-making, specific guidance is given in NFPA 805, Section 2.7.3 and Appendix A, on quality. The term "quality" as used in NFPA 805 and this implementing guidance is focused primarily on quality of engineering analyses, rather than "quality assurance" processes that cover a wide variety of activities at a nuclear power plant and, in particular, fire protection programs. Section A.2.7.3 of NFPA 805 provides a discussion on acceptability of technical references and the need to use methods that have gained wide acceptance within technical communities. Section A.2.7.3 provides a discussion of helpful factors in determining the acceptability of an individual method or source.

Section 2.7.3.1 of NFPA 805 addresses fundamental requirements such as independent verification of analyses, calculations, and evaluations. These are typical requirements for fire protection assessments under a traditional fire protection program and should not create any basic changes in process or practice.

Section 2.7.3.2 of NFPA 805 addresses verification and validation of calculational or numerical methods. This practice is typical for engineering calculations utilized for nuclear power plant calculations and analyses. Due to the evolving nature of fire science, the need for a specific requirement in NFPA 805 was warranted. There are no fire-related engineering methods or models that have been validated over the entire range of applications for which they might reasonably be used. There have been and are ongoing efforts directed at performing validation studies on calculation methods and modes. Refer to Appendix D for additional discussion of validation of engineering models.

Section 2.7.3.3 of NFPA 805 discusses limitations of acceptable use of engineering methods and numerical models. This is a recurring theme for the use of fire models and is discussed extensively in Appendix D.

Related to the limitations of acceptable use is the need for qualified users to use and apply engineering analysis and numerical models, as discussed in NFPA 805 Section 2.7.3.4. The competency and experience of individuals performing these analyses should be ensured as part of a plant's qualification, training, and business practices. This may vary from a qualification guide completion to demonstrate the performance of activities to management discretion, depending upon the business and training practices of the individual facilities.

An uncertainty analysis is required per Section 2.7.3.5 of NFPA 805 to provide reasonable assurance that the performance criteria have been met. Section A.2.7.3.5 provides a detailed discussion on the types of uncertainties and their relationship to risk-informed, performance-based fire protection. Uncertainty analysis with respect to risk assessments and change analysis is discussed in Section 4.4.2, while Appendix D discusses fire modeling uncertainties.

5.1.2 Fire Modeling Considerations

Appendix D contains detailed information on fire modeling in the context of NFPA 805, as a supplement to Appendix C of NFPA 805. Included within Appendix D are many aspects of documentation, configuration control, and quality that are addressed by Section 2.7.3 of NFPA 805.

Appendix D should be consulted for assistance in selection of an approach, qualifications of users, limitations of use for various models and approaches, and methods of addressing uncertainties.

Since detailed fire modeling has typically not been performed and maintained as part of a traditional fire protection program, care must be taken to ensure that the input, assumptions, methods, and results are treated in a manner consistent with the requirements of NFPA 805 and plant-specific processes for engineering calculations and analyses. It is noted that key parameters/assumptions selected in fire modeling should be considered for monitoring.

5.1.3 Fire PRA Considerations

Program documentation for probabilistic risk assessments used for risk-informed, performance-based decision-making is an issue applicable for the nuclear industry in general, and is not limited to fire protection applications. This is an evolving industry issue that is addressed in documents such as Regulatory Guide 1.174 and Draft Regulatory Guide DG-1122, *An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities* (November 2002). The American Nuclear Society (ANS) plans to issue a standard for evaluating internal fire risk. The ANS standard is intended to provide the necessary information for determining the acceptability of methods and results of fire risk analyses.

These documents should be referenced to for acceptable standards and processes for fire probabilistic risk assessments.

5.2 Monitoring

Section 2.6 of NFPA 805 discusses monitoring requirements associated with a risk-informed, performance-based fire protection program. The following are the requirements from Section 2.6:

"2-6* **Monitoring.** A monitoring program shall be established to ensure that the availability and reliability of the fire protection systems and features are maintained and to assess the performance of the fire protection program in meeting the performance criteria. Monitoring shall ensure that the assumptions in the engineering analysis remain valid.

2-6.1 Availability, Reliability, and Performance Levels. Acceptable levels of availability, reliability, and performance shall be established.

2-6.2 Monitoring Availability, Reliability, and Performance. Methods to monitor availability, reliability, and performance shall be established. The methods shall consider the plant operating experience and industry operating experience.

2-6.3 Corrective Action. If the established levels of availability, reliability, or performance are not met, appropriate corrective actions to return to the established levels shall be implemented. Monitoring shall be continued to ensure that the corrective actions are effective. "

As part of the transition review, the adequacy of the systems and equipment within plant inspection and compensatory measures programs should be reviewed. In addition, the adequacy of the plant corrective action program in determining the causes of equipment and programmatic failures and minimizing their recurrence should also reviewed as part of the transition to a risk-informed, performance-based licensing basis.

5.2.1 Existing Guidance and Programs

The Maintenance Rule and Regulatory Guide 1.174 are provided as examples in Section A.2.6 of acceptable monitoring programs. However, the intent is not to require fire protection program equipment to be included into a maintenance rule program. Flexibility is provided to allow plant-specific processes to be established for performance monitoring.

NEI Document NUMARC 93-01, *Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants*, provides an acceptable approach to meet the Maintenance Rule. It includes methods for selecting equipment, establishing and applying risk significance criteria and performance criteria, goal setting and monitoring, assessing and managing risk, performing periodic assessment of performance, and necessary documentation. Although not required, NUMARC 93-01 should be consulted for ideas in developing/updating a fire protection monitoring program. Due to the efforts expended in complying with the maintenance rule for plant safety systems, a plant may determine that the incremental effort associated with adding selected fire protection program systems and features to previously established programs may be less than establishing a new process or effort. NUMARC 93-01 is very flexible in recognizing the utilization of existing plant programs.

Plant/owner-operator specific initiatives have been undertaken to optimize fire protection surveillance and testing practices and frequencies based upon performance. This is allowed under traditional regulatory framework using a fire protection standard license condition and by ensuring that the program and its results were satisfactory to insurance representative. Therefore, there are established programs that could be used, enhanced, or modified in an effort to meet the monitoring requirements as discussed in NFPA 805. Other entities such as the Department of Defense and Department of Energy have participated in performance-based fire protection inspection and testing efforts. Therefore, there are a number of resources available to establish and maintain a risk-informed, performance-based program.

Acceptable levels of availability, reliability, and performance must be established. This does not imply or require detailed statistical analysis of all fire protection systems, features, components, and sub-components. Instead, determining acceptable levels of availability, reliability, and performance should be commensurate with their risk significance and may established at the structure, system, or component level, or aggregates of these, where appropriate. It is up to individual plants to establish goals and criteria for acceptable levels of availability and reliability. This is consistent with Maintenance Rule implementation as outlined in NUMARC 93-01.

5.2.2 Monitoring Program Development

It is expected that a monitoring program for a risk-informed, performance-based fire protection program would be established in phases, with elements added as more of the program relies upon risk-informed, performance-based techniques. For example, during the transition to a new licensing basis, a plant may only truly employ risk-informed, performance-based techniques to address a few fire areas or fire protection features/elements. It is important to identify parts of the program that may require additional attention during the transition and change evaluation process. Likely candidates would include monitoring of nuclear safety equipment or other plant equipment that is not part of the traditional 10 CFR 50, Appendix R post-fire safe shutdown analysis and whose availability is an important component of limiting fire risk. Other attributes may include features that are integral to successful fire modeling in an area, but may not have been considered important in a compliance-based approach.

It is expected that a more refined monitoring program (availability, reliability, performance goals) would be established for the parts of the program where these techniques have been employed. For example, as risk-informed, performance-based techniques are used as part of the change process (i.e., fire modeling in a fire area, change in equipment in PRA model, change in equipment relied upon to achieve the nuclear safety criteria, change in surveillance frequencies of fire protection equipment), the scope and depth of monitoring program would need to be adjusted accordingly. See Appendix E for additional guidance on establishing a monitoring program.

5.2.3 Monitoring Considerations

Monitoring programs for fire protection systems are not a new concept being introduced as part of a risk-informed, performance-based fire protection program. Surveillance, testing, and maintenance of fire protection systems and features have always been part of a sound program. In addition, the system engineer functions at nuclear power plants have stressed system and equipment health, reliability, and availability.

Risk-informed, performance-based reactor oversight has also increased attention on plant systems and features (including fire protection) with the greatest contribution to risk. Adoption of a risk-informed fire protection licensing basis, however, may introduce some different considerations that may not have been present in a traditional fire protection program.

- Calculations and analyses such as fire modeling, particularly a maximum expected and limiting fire scenario, rely on core assumptions that help form the basis for acceptability of configurations and changes to those configurations. These assumptions and input conditions may be different in content and form than previously analyzed.

For example, a fire scenario in a traditional program may have assessed fire hazards by monitoring the combustible loading represented by a BTU/square foot value in an area, which would be monitored by a plant combustible control program. Under a risk-informed, performance-based program, fire modeling, using more advanced and accurate predictions of fire, may rely on a certain quantity of oil spill from a pump motor or containment of spilled oil by a retaining berm. The factors which influence results of fire scenarios should be included within an administrative or design control/monitoring program.

- Suppression systems relied upon specifically in a calculation for core damage frequency have an inherent reliability and availability. Systems that are integral to prevention of risk-significant fire scenarios may require monitoring to meet numerical availability numbers in order to satisfy risk acceptance criteria.

- Traditional safe shutdown analyses have relied upon safe shutdown equipment being in service at the start of a fire. A risk-informed, performance-based approach, particularly in a risk model that calculates core damage frequency, considers safe shutdown and fire detection, suppression and mitigation features and equipment unavailability. As more credit is taken for risk-informed, performance-based approaches, the need for monitoring this equipment availability, with direct consideration on fire risk, would be necessary.

- The majority of equipment relied upon to ensure post-fire nuclear safety is equipment that is important for plant risk and mitigation of the consequences of design basis accidents. Therefore, most equipment important to fire risk has been subjected to inspection, testing, and performance monitoring as part of the nuclear plant processes. In addition, equipment important to risk has been identified as part of the Maintenance Rule process and subjected to a variety of plant controls and processes. However, all equipment important to fire risk may not be part of an existing monitoring program. Outliers must be identified and incorporated as necessary into a monitoring program.

- Because a fire risk assessment may rely on different equipment than a traditional safe shutdown analysis, the availability of this equipment may be important to fire risk. For example, the availability of offsite power or non-safety feedwater sources may be an integral part of a risk model. The need for monitoring these features should be determined.

- Due to different success criteria that are evaluated in a risk-informed, performance-based program, other fire protection features, which may not have been important, may require monitoring. For example, a fire barrier previously determined to be inconsequential for 10 CFR 50, Appendix R compliance may be important to preventing fire from causing a fire-induced loss of offsite power or plant trip, which may prove to be risk significant. Another example is a fire barrier installed prior to efforts for compliance with 10 CFR 50, Appendix R that was abandoned in place without any credit taken for fire protection. This barrier may prove valuable in protecting risk significant circuitry against a credible fire (as determined by fire modeling).

6.0 IMPLEMENTING GUIDANCE FOR USE OF TOOLS AND PROCESSES WITHIN EXISTING LICENSING BASIS

Licensees need not transition their fire protection licensing bases to comply with NFPA 805 in order to use its methods and tools to support changes to their current fire protection licensing bases. A licensee may use the appropriate methods and tools to support a license amendment request (LAR) under 10 CFR 50.90, an exemption under 10 CFR 50.12, a deviation, and any other request to the NRC.

The advantage of using the methods and tools from NFPA 805 is that the NRC will have already determined that these tools and methods are valid, when used appropriately. Thus, the NRC may question the appropriateness of a licensee's use of a particular method or tool in a specific situation, and the NRC may question the accuracy of the result obtained by the licensee by using that method or tool. Because the NRC has limited its approval of the tools and methods in NFPA 805 to their use to demonstrate compliance with NFPA 805, a licensee may need to obtain NRC approval to use a NFPA 805 tool or method to change the fire protection CLB.

The tools and methods in NFPA are considered "state of the art" fire protection engineering methods for nuclear power plants. As such licensees are encouraged to use the techniques in developing fire protection evaluations including exemption\deviation requests. Licensees are also encouraged to use these tools and methods in engineering evaluations for issues that do not require previous NRC approval.

6.1 Applicability of the program change process in NFPA 805

Neither 10 CFR 50.90, 10 CFR 50.12, or the Regulatory Guides specify the type of analysis that must accompany an LAR, or a request for an exemption or a deviation, respectively. However, the NRC has stated that the change control processes in Sections 2.2(h), 2.2(i), 2.2(j), 2.2.9, 2.2.10, 2.4.4, 2.6, and 2.7 substitute for 10 C.F.R. § 50.59(c)(4).[9] These provisions establish a disciplined process that has been accepted by the NRC for the risk-informed, performance-based evaluation of proposed changes to a fire protection program. Therefore, consistency suggests that these processes can be used for all fire protection program changes.

Moreover, because the NRC is the Authority Having Jurisdiction (AHJ) for the purposes of NFPA 805, Section 2.4.4.1 of NFPA 805 implies that the NRC's risk acceptance criteria are applicable to evaluating the acceptability of changes that a licensee makes to a plant's fire protection program under NFPA 805. For risk-informed, performance-based changes to any aspect of a plant's licensing basis, the NRC has established acceptance criteria in Regulatory Guide 1.174.

These criteria apply equally to the evaluation of a change to a plant's current fire protection licensing basis because the determination of risk is a technical finding, independent of the regulatory regime in which it is made. Thus, a finding that a change to a plant's fire protection

[9] 67 Fed. Reg. at 66583.

licensing basis meets the NRC's acceptance criteria in Regulatory Guide 1.174 suggests that the change should also meet the NRC's safety criteria for granting a license amendment or exemption.

6.2 Application of the Plant Change Evaluation Process

Section 4.4 of the implementing guidance identifies the steps in the plant change evaluation process under NFPA 805. Those steps are followed here for consistency. Because the acceptance criteria in NFPA 805 will be used to support a request for regulatory action, the steps leading up to the determination of compliance with those acceptance criteria will be followed.

6.2.1 Identify the Change from the Current Fire Protection Licensing Basis

In requesting a license amendment, exemption, or some other kind of regulatory relief, it is necessary to carefully define the proposed change in the current fire protection licensing basis is proposed to be changed. The proposed change is just the difference between the configuration of a fire area before and after the approval of a license amendment, exemption, or other regulatory relief. Therefore, the evaluation of the acceptability of the proposed change is an evaluation of the difference in fire-related risk for the two configurations.

6.2.2 Determine the Extent to Which the Deterministic Criteria are Met

Some changes that will meet the current deterministic fire protection requirements and some changes will be justified on the basis of a risk-informed, performance-based analysis. Consistency with NFPA 805 does not require a licensee to subject the changes that meet the deterministic requirements to a risk-informed, performance-based analysis. Section 2.2.6 of NFPA 805 provides that demonstrations of compliance with deterministic requirements are considered to satisfy the performance criteria in Section 1.5 of NFPA 805. Therefore, it is appropriate to apply risk-informed, performance-based methods only to the changes that do not meet the deterministic requirements.

6.2.3 Conduct an Initial Assessment

For a proposed change that will be analyzed using risk-informed, performance-based methods, an initial assessment is conducted to determine the kind of analysis that will be required to demonstrate that the change meets the acceptance criteria. The initial assessment is based on an integrated view of the likelihood and consequences of a fire in the fire area of concern. A qualified fire protection engineer and an experienced PRA analyst should conduct the initial assessment. They should focus on the portions of the fire area that are most likely to be risk significant. Several fire scenarios may be considered. Fire hazards associated with ignition sources and fixed and transient combustibles are considered. Licensing basis limitations are not applied (for example, combustible loadings are not limited to the combustible loads established by administrative limits). The result is a determination of whether an engineering analysis suffices to support the proposed change or whether it will be necessary to use fire modeling, or risk assessment, or a combination of the two.

An engineering analysis will not suffice if there needs to be a change to the current fire protection licensing basis. Fire modeling will not suffice if the Maximum Expected Fire Scenario (MEFS) after the change results in unacceptable fire damage to targets. Fire modeling will suffice if the MEFS does not result in target damage and there is sufficient margin between the MEFS and the Limiting Fire Scenario (LFS). Risk assessment will not suffice if the proposed change results in a fire-induced Core Damage Frequency (CDF) that does not meet the acceptance criteria. If neither fire modeling nor risk assessment support the change, it is necessary to conduct a combined analysis.

6.2.4 Conduct a Fire Risk Analysis to Show that the Acceptance Criteria are Met

Based on the results of the initial assessment, the appropriate analysis is conducted in detail to determine whether the proposed change meets the acceptance criteria for the CDF and Large Early Release Fraction (LERF) in Regulatory Guide 1.174. Also considered are defense-in-depth and safety margin. Defense-in-depth is described consistently by Regulatory Guide 1.174 and Section 2.4.42 of NFPA 805. Safety margin is maintained if there is a substantial difference between the LFS and MEFS and if the criteria in NFPA 805 are met.

6.3 Requests for Regulatory Relief

The three most used methods of obtaining regulatory relief from the NRC are license amendments, deviations, and exemptions. Each licensee has its own process and format for such requests for regulatory relief. But in all cases, the licensee must demonstrate that the grant of regulatory relief provides an adequate degree of safety.

The use of NFPA 805 tools and methods changes only the content of the safety case. It will now include a risk-informed, performance-based analysis and a demonstration that those acceptance criteria in Regulatory Guide 1.174 are met. The use of NFPA 805 tools and methods does not otherwise affect the format of the request for regulatory relief.

When used to support a LAR or a deviation request, the methods and tools from NFPA 805 should be used to demonstrate compliance with the applicable fire protection rules.

When used to support an exemption, the methods and tools from NFPA 805 may be used to support a showing that the exemption will not result in an undue risk to the public health and safety in accordance with 10 CFR 50.12(a)(1). By its very nature, there is no need to demonstrate compliance with the rules when requesting an exemption. Furthermore, because the NRC has found that NFPA 805 provides a level of fire protection equivalent to that provided by the current regulations, an exemption request can be supported by showing that the it meets the performance criteria, objectives and goals in NFPA 805. Such a demonstration would not be conclusive, however, because the grant of an exemption is left to the exercise of the NRC's discretion.

6.4 NRC Review and Approval

The NRC makes a safety determination by evaluating the safety case presented by the licensee. In all cases, the use of NFPA tools and methods must be shown to be appropriate and the results must be shown to be accurate. Thus, the safety case must include a discussion of the appropriateness of the NFPA tools and methods used in a particular case and enough calculational detail must be provided to enable the NRC to independently verify the results.

The NRC also has carefully distinguished between a risk-based analysis and a risk-informed analysis. The risk-informed analysis also considers defense-in-depth and safety margin. Both must also be addressed.

7.0 REFERENCES

- NFPA 805, *Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants*, 2001 Edition.
- 10 CFR 50, Appendix A, General Design Criterion (GDC) 3, *Fire Protection*
- 10 CFR 50.12, *Specific exemptions*
- 10 CFR 50.48, *Fire Protection*
- 10 CFR 50.55a, *Codes and Standards*
- 10 CFR 50.59, *Changes, tests, and experiments*
- 10 CFR 50.90, *Application for amendment of license or construction permit*
- 10 CFR 50, Appendix R, *Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979, Sections III.G, J, L, and O*
- Appendix A to Branch Technical Position BTP APCSB 9.5-1, *Guidelines for Fire Protection for Nuclear Power Plants Docketed Prior to July 1, 1976*
- Generic Letter 81-12, *Fire Protection Rule*
- Regulatory Guide 1.189, *Fire Protection for Operating Nuclear Power Plants,* dated April 2001
- Regulatory Guide DG-1122 (Draft), *An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities* (November 2002).
- Regulatory Guide 1.174, *An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis*, dated July 1998.
- NUREG-0800 Chapter 19.0, *Use of Probabilistic Risk Assessment in Plant-Specific, Risk-Informed Decision Making: General Guidance.*
- Generic Letter 86-10, *Implementation of Fire Protection Requirements*
- NRC Inspection Manual Chapter 71111.05, *Fire Protection Inspection*, Dated 4/03/00
- NRC Inspection Manual Chapter 0609, *Significance Determination Process*, dated 4/21/00.
- NEI 00-01, *Guidance for Post-fire Safe Shutdown Analysis* – (To the extent finally endorsed by the NRC) NEI 00-01 may be considered as an acceptable method of demonstrating compliance with certain aspects of NFPA 805. . (NOTE: the reference to NEI 00-01 has been included as a place-holder should the NRC determine to endorse that document, with or without exceptions. Depending on the timing of the NRC's decision, the reference to this document will be revised in accordance with the situation at that time. In particular, if the NRC is still in the endorsement process, the introductory phrase in parentheses would be added to this guidance)
- NEI 02-03, *Guidance For Performing A Regulatory Review Of Proposed Changes To The Approved Fire Protection*
- NEI Document NUMARC 93-01, *Industry Guideline for Monitoring the Effectiveness of Maintenance at Nuclear Power Plants*
- NUMARC 91-06, *Guidelines for Industry Actions to Assess Shutdown Management*
- 10 CFR 54, *Requirements for Renewal of Operating Licenses for Nuclear Power Plants*, Part 3, *Definitions*

- *Cleveland Electric Illuminating Company, et al.*, (Perry Nuclear Power Plant, Unit 1), 44 NRC 315 (December 6, 1996).
- NRR Office Instruction LIC 500, Rev. 1, Processing Requests for Reviews of Topical Reports.
- SECY-93-143, *Report on the Re-assessment of the NRC Fire Protection Program*
- SECY-96-134, *Options for Pursuing Regulatory Improvement in Fire Protection Regulations of Nuclear Power Plants*, dated June 21, 1996
- SECY-98-058, *Development Of A Risk-Informed, Performance-Based Regulation For Fire Protection At Nuclear Power Plants*
- EPRI FIVE Methodology, TR-100370, Final Report, April 1992
- EPRI Fire PRA Implementation Guide, TR-105928, Final Report, December 1995

Appendices

Appendix A – Definitions

The following Table provides a comparison of the definitions in NFPA 805 to existing NRC Guidance documents.

Appendix A – Fire Protection Definition Comparison [SAMPLE FORMAT]

Term identified in NFPA 805, Reg. Guide 1.189 or NUREG 0800	NFPA 805 Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants		Regulatory Guideline - 1.189 Fire Protection For Operating Nuclear Power Plants, April 2001		NUREG 0800, Fire Protection Program (Formerly NUREG 75/087)
	1.6	Definitions.		Glossary	Definitions
Acceptable	1.6.1	Considered by the authority having jurisdiction (AHJ) as adequate for satisfying the goals, performance objectives, and/or performance criteria.	--	Term not used in Reg. Guide 1.189 Glossary	Term not used in NUREG 0800 Definitions
Alternative Shutdown	--	Term not used in NFPA 805 Definitions	Pg. 108	The capability to safely shut down the reactor in the event of a fire using existing systems that have been rerouted, relocated, or modified	Term not used in NUREG 0800 Definitions
Approved	1.6.2	Acceptable to the authority having jurisdiction.	Pg. 108	Tested and accepted for a specific purpose or application by a recognized testing laboratory.	Tested and accepted for a specific purpose or application by a nationally recognized testing laboratory.
Associated Circuits	--	Term not used in NFPA 805 Definitions	Pg. 108	Circuits that do not meet the separation requirements for safe shutdown systems and components and are associated with safe shutdown systems and components by common power supply, common enclosure, or the potential to cause spurious operations that could prevent or adversely affect the capability to safely shut down the reactor as a result of fire-induced failures (hot shorts, open circuits, and short to ground).	Term not used in NUREG 0800 Definitions
Authority Having Jurisdiction	1.6.3	• The organization, office, or individual responsible for approving equipment, materials, an installation, or a procedure.	--	Term not used in Reg. Guide 1.189 Glossary	Term not used in NUREG 0800 Definitions
Automatic	--	Term not used in NFPA 805 Definitions	Pg. 108	Self-acting, operating by its own mechanism when actuated by some monitored parameter such as a change in current, pressure, temperature, or mechanical configuration.	Self-acting, operating by its own mechanism when actuated by some impersonal influence such as a change in current, pressure, temperature, or mechanical configuration.
Availability	1.6.4	The probability that the system, structure, or component of interest is functional at a given point in time.	--	Term not used in Reg. Guide 1.189 Glossary	Term not used in NUREG 0800 Definitions
BWR	1.6.5	Boiling water reactor.	--	Term not used in Reg. Guide 1.189 Glossary	Term not used in NUREG 0800 Definitions
Combustible	1.6.6	Capable of undergoing combustion.	--	Term not used in Reg. Guide 1.189 Glossary	Term not used in NUREG 0800 Definitions
Combustible Material	--	Term not used in NFPA 805 Definitions	Pg. 108	Any material that will burn or sustain the combustion process when ignited or otherwise exposed to fire conditions.	Material that does not meet the definition of noncombustible.
Combustible Liquid	1.6.7	A liquid having a flash point at or above 100°F (37.8°C). (See NFPA 30, Flammable and Combustible Liquids Code.)	--	Term not used in Reg. Guide 1.189 Glossary	Term not used in NUREG 0800 Definitions
Common Enclosure	--	Term not used in NFPA 805 Definitions	Pg. 108	An enclosure (e.g., cable tray, conduit, junction box) that contains circuits required for the operation of safe shutdown components and circuits for non-safe shutdown components.	Term not used in NUREG 0800 Definitions
Common Power Supply	--	Term not used in NFPA 805 Definitions	Pg. 108	A power supply that feeds safe shutdown circuits and non-safe shutdown circuits.	Term not used in NUREG 0800 Definitions
Compensatory Actions	1.6.8	Actions taken if an impairment to a required system, feature, or component prevents that system, feature, or component from performing its intended function. These actions are a temporary alternative means of providing reasonable assurance that the necessary function will be compensated for during the impairment, or an act to mitigate the consequence of a fire. Compensatory measures include but are not limited to actions such as firewatches, administrative controls, temporary systems, and features of components.	--	Term not used in Reg. Guide 1.189 Glossary	Term not used in NUREG 0800 Definitions
Completeness Uncertainty	1.6.9	Uncertainty in the predictions of a model due to model scope limitations. This uncertainty reflects an unanalyzed contribution or reduction of risk due to limitations of the available analytical methods.	--	Term not used in Reg. Guide 1.189 Glossary	Term not used in NUREG 0800 Definitions
Containment	1.6.10	Structures, systems, or components provided to prevent or mitigate the release of radioactive materials.	--	Term not used in Reg. Guide 1.189 Glossary	Term not used in NUREG 0800 Definitions
Control Room Complex	--	Term not used in NFPA 805 Definitions	Pg. 108	The zone served by the control room emergency ventilation system.	The zone served by the control room emergency ventilation system (see SRP Section 6.4, "Habitability Systems").

Appendix B – Detailed Transition Assessment of Fire Protection Program

Appendix B-1: Transition of Fundamental Fire Protection Program and Design Elements

Included here is the mapping of the Fire Protection Fundamentals for "water supply". This mapping will be done for each section of Chapter 3 of NFPA 805. We've provided an example of how a licensee would map over the first 2 sections. Once this mapping is completed all previous commitments will be superseded by compliance with the new rule.

Each section and subsection of Chapter 3 is a "Fundamental Fire Protection Program Attribute" defining the program and design elements of a nuclear fire protection program. The cross-reference table included as Appendix B-1 defines "previously acceptable" methods of compliance with that particular "fundamental program attribute". Licensees should provide specific compliance statements (deviations, exemptions, etc) to demonstrate "previous approval" of an alternative or compliance with the Chapter 3 attribute.

Appendix B-1: Transition of Fundamental Fire Protection Program and Design Elements

Appendix B-1 – Transition of Fundamental Fire Protection Program and Design Elements - Sample

NFPA 805 Chapter 3 Fundamental Fire Protection Program and Design Elements	Mapped to BTP 9.5-1 APCSB 5/1/76 Application Docketed but Construction Permit Not Received as of 7/1/76	Mapped to BTP 9.5-1 Appendix A 2/24/77 Plants under Construction and Operating Plants	Mapped to NUREG-0800 BTP 9.5-1 CMEB (Formerly NUREG-75/087) 7/81	Mapped to 10 CFR 50 Appendix R 9/1/82	Mapped to Regulatory Guide 1.189 4/2001	Compliance Statement	Current Licensing Basis Document Identification
3.5 Water Supply. 3.5.1 A fire protection water supply of adequate reliability, quantity, and duration shall be provided by one of the two following methods. (a) Provide a fire protection water supply of not less than two separate 300,000-gal (1,135,500-L) supplies. (b) Calculate the fire flow rate for 2 hours. This fire flow rate shall be based on 500 gpm (1892.5 L/min) for manual hose streams plus the largest design demand of any sprinkler or fixed water spray system(s) in the power block as determined in accordance with NFPA 13, Standard for the Installation of Sprinkler Systems, or NFPA 15, Standard for Water Spray Fixed Systems for Fire Protection. The fire water supply shall be capable of delivering this design demand with the hydraulically least demanding portion of fire main loop out of service.	IV.C.2. (d) Two separate reliable water supplies should be provided. If tanks are used, two 100% (minimum of 300,000 gallons each) *system capacity* tanks should be installed. They should be so interconnected that pumps can take suction from either or both. However, a leak in one tank or its piping should not cause both tanks to drain. The main plant fire water supply *capacity should be capable of* refilling either tank in a minimum of eight hours. Common tanks are permitted for fire and sanitary or service water storage. When this is done, however, minimum fire water storage requirements should be dedicated by means of a vertical standpipe for other water services. IV.C.2. (e) The fire water supply (total capacity and flow rate) should be calculated on the basis of largest expected flow rate for a period of two hours, but not less than 300,000 gallons. This flow rate should be based (conservatively) on 1,000 gpm for manual hose streams plus the greater of: (1) all sprinkler heads opened and flowing in the largest designed fire area; or (2) the largest open head deluge system(s) operating.	IV.C.2. (d) SAME IV.C.2. (e) SAME	C.6.b. (9) Two separate, reliable freshwater supplies should be provided. Saltwater or brackish water should not be used unless *all freshwater supplies have been* exhausted. If tanks are used, two 100% (minimum of 300,000 gallons each) system capacity tanks should be installed. They should be so interconnected that pumps can take suction from either or both. However, a *failure in one tank or its piping* should not cause both tanks to drain. Water supply capacity should be capable of refilling either tank in 8 hours or less. C.6.b. (11) The fire water supply should be calculated on the basis *of the largest expected flow rate* for a period of 2 hours, but not less than 300,000 gallons. This flow rate should be based (conservatively) on 500 gpm for manual hose streams plus the largest design demand of any sprinkler or deluge system as determined in accordance with NFPA 13 or NFPA 15. The fire water supply should be capable of delivering this design demand over the longest route of the water supply system	III.A Two separate water supplies shall be provided to provide necessary water volume and pressure to the fire main loop III.A Each supply shall consist of a storage tank, pump, piping, and appropriate isolation and control valves. III.A Each supply of the fire water distribution system shall be capable of providing for a period of 2 hours the maximum expected water demands as determined by the fire hazards analysis for safety-related areas *or other areas that present a fire* exposure hazard to safety-related areas.	3.2.1 a Two separate reliable freshwater supplies should be provided. Saltwater or brackish water should not be used unless all freshwater supplies have been exhausted. 3.2.1 c If tanks are used for water supply, two 100% system capacity tanks [minimum of 1,136,000 L (300,000 gallons) each] should be installed. They should be so *interconnected* that pumps can take suction from either or both. However, a failure in one tank or its piping should not cause both tanks to drain. Water supply capacity should be capable of refilling either tank in 8 hours or less. 3.2.1 b The fire water supply should be calculated on the basis of the largest expected flow rate for a period of 2 hours, but not less than 1,136,000 L (300,000 gallons). This flow rate should be based (conservatively) on *1900 L/m (500 gpm) for* manual hose streams plus the largest design demand of any sprinkler or deluge system as determined in accordance with NFPA 13, "Standard for the Installation of Sprinkler Systems," or NFPA 15, "Standard for Water Spray Fixed Systems for Fire Protection." The fire water supply should be capable of delivering this design demand over the longest piping route of the water supply system.	The fire water storage system consists of two dedicated fire water storage tanks sized at 350,000 gallons each. The fire pumping system consists of two 100% capacity pumps, one diesel driven and one motor driven. The fire pumps are capable of supplying the most hydraulically demanding sprinkler system while flowing 500 gpm for hose stations considering the most hydraulically demanding portion of the fire main system out of service. The fire water storage tanks were sized on the basis of the largest expected flow rate for a period of 2.5 hours. The fire water pumping system is designed in accordance with NFPA 20.	UFSAR Volume 9, Fire Hazards Analysis, Section 9.5-1, page 34. NRC Safety Evaluation Report, page 44-45. P&ID 8031-M-22, Page 2 of 10 Under Turbine System WP10-2 Hydraulic Calculation (Largest Demand System), M50-22-21. XYZ Letter to NRC, FP25, 5/15/72 NRC Letter to XYZ, 6/28/72.

Appendix B-2: Transition of Nuclear Safety Performance Criteria

Methdology Review

Nuclear Safety Performance Criteria ("NSPC") are established in Section 1.5.1 of NFPA 805. There are four substantial differences between these NSPC and traditional fire protection requirements from 10 CFR 50, Appendix R/NUREG-0800. These differences arise from the statements of the criteria, the scope of their applicability, and the nuclear safety goal they support. These differences are described below and guidance is provided on how apply these differences in an evaluation of the extent to which traditional fire protection programs meet NFPA 805.

The NSPC established in Section 1.5.1 of NFPA 805 require that:

> Fire protection features shall be capable of providing reasonable assurance that, in the event of a fire, the plant is not placed in an unrecoverable condition.

First, this requirement on fire protection features introduces a change from the traditional requirements, which focus on achieving and maintaining safe shutdown in the event of a fire. By shifting the focus from safe shutdown to avoiding an unrecoverable condition, NFPA 805 introduces flexibility in the analysis necessary to show that the NSPC have been met. In particular, in many cases it will be sufficient to show that a plant can achieve and maintain hot shutdown (standby) in the event of a fire.

A second substantial difference between the NSPC and traditional requirements arises from the scope of applicability of the NSPC. Section 1.1 of NFPA 805 provides that:

> This standard specifies the minimum fire protection requirements for existing light water nuclear power plants during all phases of plant operation, including shutdown and decommissioning.

By including all phases of plant operation, including shutdown, and decommissioning, NFPA 805 requires additional analyses of fire protection features that have not generally been conducted by power plant licensees. Strategies for addressing this broadened scope of analysis of fire protection features for all plant conditions are discussed in the guidance in Appendix F.

A third substantial difference between the NSPC and traditional requirements arises from the Nuclear Safety Goal ("NSG") in Section 1.3.1 of NFPA 805. It provides:

> The nuclear safety goal is to provide reasonable assurance that a fire during any operational mode and plant configuration will not prevent the plant from achieving and maintaining the fuel in a safe and stable condition.

By including any plant configuration, the NSG may require additional analyses of fire protection features. Because analyses of all configurations cannot be performed, bounding configurations must be identified and analyzed. An evaluation may show that traditional fire protection analyses have included the bounding configurations for operation.

The fourth substantial difference arises from the focus on maintaining the fuel in a safe and stable condition. Safe and Stable Conditions are defined in Section 1.6.56 of NFPA 805. They are:

> For fuel in the reactor vessel, head on and tensioned, safe and stable conditions are defined as the ability to maintain K(eff) < 0.99, with a reactor coolant temperature at or below the requirements for hot shutdown for a boiling water reactor and hot standby for a pressurized water reactor. For all other configurations, safe and stable conditions are defined as maintaining K (eff) < 0.99 and fuel coolant temperature below boiling.

Thus, the definition of safe and stable conditions provides more flexibility in showing that the NSPC have been met than for non-power modes of operation.

Five performance criteria are identified in NFPA 805 as constituting a demonstration that the NSPC for fire protection features have been met. They are:

a) *Reactivity Control.* Reactivity control shall be capable of inserting negative reactivity to achieve and maintain subcritical conditions. Negative reactivity shall occur rapidly enough such that fuel design limits are not exceeded.
b) *Inventory and Pressure Control.* With fuel in the reactor vessel, head on and tensioned, inventory and pressure control shall be capable of controlling coolant level such that subcooling is maintained for a PWR and shall be capable of maintaining or rapidly restoring reactor water level above top of active fuel for a BWR such that fuel clad damage as a result of fire is prevented.
c) *Decay Heat Removal.* Decay heat removal shall be capable of removing sufficient heat from the reactor core or spent fuel such that fuel is maintained in a safe and stable condition.
d) *Vital Auxiliaries.* Vital auxiliaries shall be capable of providing the necessary support equipment and systems to assure that the systems required under (a), (b), (c), and (e) are capable of performing their required nuclear safety functions.
e) *Process Monitoring.* Process monitoring shall be capable of providing the necessary indication to assure the criteria addressed in (a) through (d) have been achieved and are being maintained.

The suggested methodology for transition of the Nuclear Safety is as follows:

Section 2.4.2 establishes the methodology for conducting a safety capability assessment for determining achievement of the nuclear safety criteria in Chapter 1. To a large extent, the activities to be undertaken to implement this methodology have already been completed for the purposes of determining compliance with the traditional requirements.

Appendix B-2: Transition of Nuclear Safety Performance Criteria

The table outlines a recommended method to review the acceptability of a program for transition by examining the basic components of a nuclear safety capability assessment:

1. Nuclear Safety Capability System and Equipment Section
2. Nuclear Safety Capability Circuit Analysis
3. Nuclear Safety Equipment and Cable Location
4. Fire Area Assessment

The recommended review is against the methodology provided in Appendix B to NFPA 805 or NEI 00-01. This review is intended to ensure that the transitioning nuclear safety analysis meets basic established criteria for identification and analysis of equipment and cables. Exceptions and clarifications identified during the transition review should be documented in order to provide a well-established baseline for future changes.

Table B-2 shows how to use the existing evaluations to demonstrate compliance with the Chapter 1 nuclear safety performance criteria.

Fire Area – by – Fire Area Transition

The current fire protection licensing basis for each fire area should be reviewed and summarized. Information to be reviewed for each fire area and summarized include:

- The current fire protection licensing basis (i.e., compliance with Sections III.G.2, III.G.3 of 10 CFR 50, Appendix R, etc.) including approved exemptions/deviations. It is important that the bases for exemptions/deviations be captured during the transition process in order to effectively move forward to a new basis. This will allow the change process to focus on changes from the original bases more effectively. If the basis for an exemption or deviation is found during the review to be incorrect, the issue(s) should be entered into a corrective action program for resolution as part of the transition.
- Detection – Licensing and design basis references for detection system (exemptions/deviations, SERs, Generic Letter 86-10 evaluations/code compliance evaluations, etc.). Requirements for detection systems used to meet the nuclear safety performance criteria require assessment in accordance with Chapter 3 of NFPA 805.
- Suppression – Licensing and design basis references for detection system (exemptions/deviations, SERs, Generic Letter 86-10 evaluations/NFPA code compliance evaluations, etc.). Requirements for suppression systems used to meet the nuclear safety performance criteria require assessment in accordance with Chapter 3 of NFPA 805.
- Emergency Lighting – Licensing and design basis references such as exemptions/deviations, SERs, calculations)
- Manual Actions – Manual action information for the fire area including: 1) whether or not manual actions are relied upon for the fire area, 2) whether or not the manual actions are previously approved by the NRC, 3) whether or not the manual actions are relied upon for post-fire safe shutdown.
- Outstanding Current Licensing Basis Issues – References to items that have been identified as being outside of the current licensing basis (such as corrective action documents, inspection findings and violations, and generic industry issues). This will provide a complete

and concise description of items that will require resolution as part of the transition or as part of a risk-informed performance-based assessment. This compilation of corrective action items includes pre-existing items and those that were identified as part of the transition reviews.

Items that have applicability for multiple fire areas can be addressed in a generic manner, such as by topic. In addition, multiple fire areas can be grouped together if their supporting licensing bases and engineering evaluations are applicable to multiple fire areas (e.g., plants that have multiple alternative/dedicated shutdown fire areas that are being transitioned to a new licensing basis).

Manual actions relied upon for post-fire safe shutdown is an industry issue that is planned to be addressed by the rulemaking process. During a transition to a risk-informed, performance-based licensing basis, it is expected that licensees would ensure that manual operator actions relied upon for post-fire safe shutdown (prior to transition) would meet industry acceptance criteria at the time of the transition.

Table B-2

NFPA 805 Chapter 2 – Nuclear Safety Transition Review Guidance

NFPA 805 Requirement	Implementing Guidance
2.4.2.1 Nuclear Safety Capability System and Equipment Section A comprehensive list of systems and equipment and their interrelationships to be analyzed for a fire event shall be developed. The equipment list shall contain an inventory of those critical components required to achieve the nuclear safety performance criteria of Section 1.5. Components required to achieve and maintain the nuclear safety functions and components whose fire-induced failure could prevent the operation or result in the maloperation of those components needed to meet the nuclear safety criteria shall be included. Availability and reliability of equipment selected shall be evaluated. *(See Appendix B for acceptable methods used to identify equipment)*	Review the methodology of the current Safe Shutdown Equipment List against the methodology outlined in NEI 00-01 or NFPA 805 Appendix B. If the selection criteria and methodology are consistent, then no further analysis or evaluation is required. If the current criteria and methodology are not consistent with the referenced documents, modify and perform the additional analysis needed. Document the results and any exceptions/clarifications.
2.4.2.2 Nuclear Safety Capability Circuit Analysis. **2.4.2.2.1 Circuits Required in Nuclear Safety Functions.** Circuits required for the nuclear safety functions shall be identified. This includes circuits that are required for operation, that could prevent the operation, or that result in the maloperation of the equipment identified in 2.4.2.1. This evaluation shall consider fire-induced failure modes such as hot shorts (external and internal), open circuits, and shorts to ground, to identify circuits that are required to support the proper operation of components required to achieve the nuclear safety performance criteria, including spurious operation and signals. This will ensure that a comprehensive population of circuitry is evaluated. *(See Appendix B for considerations in analyzing circuits.)*	Review the methodology of the current Circuit Analysis against the methodology outlined in NEI 00-01 or NFPA 805 Appendix B. If the selection criteria and methodology are consistent, then no further analysis or evaluation is required. If the current criteria and methodology are not consistent with the referenced documents, modify and perform the additional analysis needed Document the results and any exceptions/clarifications.
2.4.2.2.2 Other Required Circuits. Other circuits that share common power supply and/or common enclosure with circuits required to achieve nuclear safety performance criteria shall be evaluated for their impact on the ability to achieve nuclear safety performance criteria.	Review the methodology of the current Associated Circuits analysis against the methodology outlined in NEI 00-01 or NFPA 805 Appendix B. If the selection criteria and methodology are consistent, then no further analysis or evaluation is required. If the current criteria and methodology are not consistent with the referenced documents, modify and perform the additional analysis needed.

Table B-2 NFPA 805 Chapter 2 – Nuclear Safety Transition Review Guidance	
(a) *Common Power Supply Circuits.* Those circuits whose fire-induced failure could cause the loss of a power supply required to achieve the nuclear safety performance criteria shall be identified. This situation could occur if the upstream protection device (i.e., breaker or fuse) is not properly coordinated with the downstream protection device. *(See Appendix B for considerations when analyzing common power supply concerns.)* (b) *Common Enclosure Circuits.* Those circuits that share enclosures with circuits required to achieve the nuclear safety performance criteria and whose fire-induced failure could cause the loss of the required components shall be identified. The concern is that the effects of a fire can extend outside of the immediate fire area due to fire-induced electrical faults on inadequately protected cables or via inadequately sealed fire area boundaries. *(See Appendix B for considerations when analyzing common enclosure concerns.)*	Document the results and any exceptions/clarifications.
2.4.2.3* Nuclear Safety Equipment and Cable Location. Physical location of equipment and cables shall be identified. *(See Appendix B for considerations when identifying locations.)*	Review the methodology of the current Equipment and Cable Location analysis against the methodology outlined in NEI 00-01 or NFPA 805 Appendix B. If the selection criteria and methodology are consistent, then no further analysis or evaluation is required. If the current criteria and methodology are not consistent with the referenced documents, modify and perform the additional analysis needed. Document the results and any exceptions/clarifications.
2.4.2.4 Fire Area Assessment. An engineering analysis shall be performed in accordance with the requirements of Section 2.3 for each fire area to determine the effects of fire or fire suppression activities on the ability to achieve the nuclear safety performance criteria of Section 1.5. *[See Chapter 4 for methods of achieving these performance criteria (performance-based or deterministic). (See Appendix B for considerations when performing the fire area assessments.)*	Review the methodology of the current Equipment and Cable Location analysis against the methodology outlined in NEI 00-01 or NFPA 805 Appendix B. If the selection criteria and methodology are consistent, then no further analysis or evaluation is required. If the current criteria and methodology are not consistent with the referenced documents, modify and perform the additional analysis needed. Document the results and any exceptions/clarifications. See Table B- 3 for a suggested format for documenting the Fire Area Transition.

Table B-3

NFPA 805 Chapter 2 – Nuclear Safety Transition - Fire Area Assessment Table (Sample)

Fire Area	Fire Area Description	Appendix R Compliance Methods	Exemption / Deviation	Nuclear Safety Performance Criteria	Evaluations	Outstanding CLB Issues
1	Containment	III.G.1, III.G.2.	Exemption 7, RCP Lube Oil Bases for Acceptability: ▪ Type of oil ▪ Seismic zone ▪ Deluge system ▪ Detection Exemption 14, intervening combustibles Bases for Acceptability: ▪ Detection ▪ Admin. Controls. ▪ Fire stops. ▪ Deluge system for RCPs.	The nuclear Safety Criteria are met as follows: ▪ Reactivity control – Charging (Tr. A & B) ▪ Inventory and pressure control – Charging (Tr. A & B), Aux. Spray or PORV B ▪ Decay heat removal (AFW A, B, or C, RHR A & B) ▪ Vital auxiliaries (CCW A&B), (SW A&B) ▪ Process monitoring (dependant on location)	▪ Eval 89-05, Unrated containment penetrations ▪ Eval. 88-05, Manual Action Feasibility	▪ RCPLOC CR 02-0221 ▪ Radiant energy shield rating CR 99-0233 ▪ NRC IR 02-01 URI 02-01-04
2	Aux. Bldg. 50' Elev.	III.G.2	Exemption 4, Lack of automatic suppression. Bases for Acceptability: ▪ Detection in pump rooms ▪ Low combustible loading ▪ Separation of redundant circuitry (> 50 ft.)	The nuclear Safety Criteria are met as follows: ▪ Reactivity control – Charging (Tr. A) ▪ Inventory and pressure control – Charging (Tr. A), Aux. Spray ▪ Decay heat removal (AFW A, B, RHR A) ▪ Vital auxiliaries (CCW A), (SW A) ▪ Process monitoring (Channels I, III)	▪ Eval 89-07, unrated hatch ▪ Eval 95-07, fire dampers fire area 2 – fire area 14 ▪ Eval 92-13, partial detection evaluation ▪ Eval 84-3, NFPA 72 code deviations ▪ Eval. 88-05, Manual Action Feasibility	None

Appendix B-2: Transition of Nuclear Safety Performance Criteria

Table B-3

NFPA 805 Chapter 2 – Nuclear Safety Transition - Fire Area Assessment Table (Sample)

Fire Area	Fire Area Description	Appendix R Compliance Methods	Exemption / Deviation	Nuclear Safety Performance Criteria	Evaluations	Outstanding CLB Issues
3	DG 1 Room	III.G.1	None	The nuclear Safety Criteria are met as follows: ▪ Reactivity control – Charging (Tr. A) ▪ Inventory and pressure control – Charging (Tr. A), Aux. Spray ▪ Decay heat removal (AFW A, B, RHR A) ▪ Vital auxiliaries (CCW A), (SW A) ▪ Process monitoring (Channels I, III)	▪ Eval. 92-03, barrier between fire area 3 – fire area 18 ▪ Eval. 88-02, fire dampers (generic) ▪ Eval. 84-3, NFPA 13 code deviation	▪ Circuit Isolation CR 01-0121 ▪ NRC IR 02-01 URI 02-01-05
4	Div. B Swgr. Room	III.G.1	None	The nuclear Safety Criteria are met as follows: ▪ Reactivity control – Charging (Tr. B) ▪ Inventory and pressure control – Charging (Tr. B), PORV B ▪ Decay heat removal (AFW C, RHR B) ▪ Vital auxiliaries (CCW B), (SW B) ▪ Process monitoring (Channels II, IV)	▪ Eval. 95-04, barrier between fire area 4 – fire area 7 ▪ Eval. 88-02, fire dampers (generic) ▪ Eval 84-3, NFPA 72 code deviations ▪ Eval. 88-05, Manual Action Feasibility	▪ Fire Wrap rating CR 00-0141 ▪ NRC IR 01-01 URI 01-01-02 ▪ NRC GL 04-05 Response

Appendix B-2: Transition of Nuclear Safety Performance Criteria

Table B-3

NFPA 805 Chapter 2 – Nuclear Safety Transition - Fire Area Assessment Table (Sample)

Fire Area	Fire Area Description	Appendix R Compliance Methods	Exemption / Deviation	Nuclear Safety Performance Criteria	Evaluations	Outstanding CLB Issues
5	Cable Spreading Room	III.G.3	None	The nuclear Safety Criteria are met as follows: ▪ Reactivity control – Charging (Tr. A @ HSDP) ▪ Inventory and pressure control – Charging (Tr. A @ HSDP), PORV B @ HSDP ▪ Decay heat removal (AFW A @HSDP, RHR A @ swgr.) ▪ Vital auxiliaries (CCW A @ swgr.), (SW A @ swgr.) ▪ Process monitoring (Channel I @ HSDP)	▪ Eval. 97-06, barrier between fire area 5 – fire area 13 ▪ Eval. 84-3, NFPA 12A code deviation ▪ Eval. 97-05, Manual Action Feasibility ▪ Eval. 87-43, Changing Halon system – auto to manual	None
All	Generic Issues	N/A	▪ 3 – hour rated fire barrier exemption 18	N/A	▪ Associated circuits SER dated 11/21/84 ▪ High-low pressure interface SER dated 4/11/86	▪ NRC Manual Action Rulemaking ▪ NRC Associated Circuits Implementation ▪ NRC Generic Letter 05-02 response (sample only)

Appendix C – FHA Transition

The traditional Fire Hazard Analysis will require some revision as a result of the transition to the new NFPA 805 licensing basis. The outline below identifies those sections that will require revision and guidance as to what that revision would entail.

1. Identification of Performance Criteria

The identification of criteria in NFPA 805 is straightforward, however they are different then the current performance criteria and therefore need to be revised

- Nuclear Safety
- Traditional
- Non-Power Operational Modes
- Radioactive Release

2. Identification of Fire Hazards

The identification of fire hazards in NFPA 805 is straightforward and comprehensive. However, the traditional method of identifying fire hazards within a fire area will need to be modified for those fire areas that employ a risk-informed, performance-based compliance strategy. The following items should be revised for those areas:

- Level of detail commensurate with the evaluation performed (rigorous detail regarding combustibles, fire hazards, propagation,).
- Items to consider when identifying fire hazards, given that information may/will be used in fire modeling and may be subject to additional configuration controls (i.e., monitoring) if explicitly modeled.

3. Identification of Applicable SSCs

For those areas that employ a risk-informed, performance-based analysis, the identification of SSCs in the area should be revised. The revised FHA should focus on the identification of "targets" that were evaluated against the nuclear safety and radioactive release performance criteria. It encompasses:

4. Radioactive Release

A new section should be added to the FHA for Radioactive Release. This section should address the results of the evaluation performed during the transition.

5. Other modes of operation

A new section should be added to the FHA for Other Mode of Operation. This section should address the results of the evaluation performed during the transition.

Appendix D Fire Modeling

TABLE OF CONTENTS

Page

Appendix D – Fire Modeling

1.0 Introduction

The purpose of this Appendix is to provide additional guidance on the use of fire models. Fire modeling is the application of any type of mathematical analysis to quantify the effects of a fire. This is accomplished by presenting the various types/classes of models that may be useful when implementing NFPA 805. It is not the intent of the guide to recommend or endorse any specific fire model or calculation methodology. Rather, the goal is to summarize the strengths and weaknesses of a given model type/class, identify possible applications for fire models, and provide some guidance on limitations. When discussing fire models, specific models may be cited as examples, especially those most commonly encountered in the fire protection community. The use of any model should be verified for the particular application. The NRC is currently in the process of verifying and validating several fire models and plans to develop a pool of acceptable fire models and acceptable applications of these fire models using the ASTM E-1355 (1997) Standard (Dey, 2002). In the absence of such a pool, adequate documentation will be necessary that demonstrates the appropriateness of the model, the application of the model, and the overall approach to evaluating the problem. The use of fire models is discussed in Section 2.4.1 (Engineering Analyses) and Appendix C of NFPA 805.

Fire modeling often involves the use of a combination of engineering calculations and computer-based modeling. Rarely can the desired analysis be performed through the application of any one method. The selection of a single model is therefore not nearly as important as utilizing the range of appropriate engineering tools and data available. In the context of NFPA 805, fire models take three broad forms, namely engineering calculations, zone type computer models and field type/computational fluid dynamic (CFD) computer models.

The type of model necessary to perform a given analysis depends on the important physical processes in the problem, the capabilities of the particular model and, to a lesser extent, the degree of accuracy required of a specific analysis. Another factor that must be considered when selecting a model is whether or not the model has been validated for a particular application by the Nuclear Regulatory Commission (NRC) or in the fire protection community in general. Use of a model that is not validated may require extensive documentation and sensitivity analyses to demonstrate acceptability.

There are certain types of problems where the use of engineering calculations in the form of correlations, closed form solutions, *etc.*, may be more appropriate and more accurate than even the most sophisticated computer-based models available. This condition would be driven largely by the uncertainty in the problem, either inherent or introduced by the model itself. If there is a large uncertainty in the heat release rate, for instance, the use of a highly sophisticated CFD model would not necessary result in a more accurate prediction than a simple correlation. In some cases, correlated data may yield quick results that are more accurate for the particular application than the most sophisticated CFD model because the configuration at hand resembles the tested data very closely. In this case, the uncertainty introduced by the assumptions necessary to run a CFD model exceed the uncertainty in a correlation applied to a configuration that has actually been tested.

Appendix D – Fire Modeling

This appendix is organized into five major sections. Section 2 introduces the process of engineering analysis as applied to fire protection issues addressed using fire modeling tools. It describes the modeling approach used in NFPA 805 and provides some specific guidance on each process element. One of the key elements is the description of the maximum expected fire scenario (MEFS). Section 3 of the Appendix deals specifically with information and guidance on developing the MEFS for various source fires including fires involving flammable and combustible liquids, electrical cables, electronics cabinets, and transient combustibles. Section 4 of the Appendix addresses quantifying the MEFS source terms. Section 5 deals with different calculation methods that are available for evaluating the various impacts of the MEFS. These include flame radiation and plume calculations, target damage, detector actuation, flashover, etc. Section 5 provides a brief overview of the issue of validation. This Appendix attempts to summarize the state of the art for fire modeling and provides adequate references and guidance for a user to apply fire-modeling techniques in a nuclear power plant in accordance with NFPA 805. Substantial additional material is available in the references provided in Section 6. A useful primer on the subject with specific sample problems is contained in the Electric Power Research Institute (EPRI) Fire Modeling Guide for Nuclear Power Plant Applications (EPRI, 2002a). Note that this guide has not yet been reviewed by the NRC and is therefore not endorsed by the NRC.

It should also be noted that while this Appendix and many of the references herein propose specific methods and/or sources of data, neither should be construed as an indication that the method or data source referenced excludes the use of other calculation methods, assumptions, or sources of data for any particular purpose or application.

2.0 Engineering Analysis Using Fire Models

This section describes the process of engineering analysis for fire related problems, with specific reference to the requirements of NFPA 805.

2.1 Introduction

The use of fire models arises in many different contexts, ranging from simple calculations, such as determining whether flashover can occur given the ventilation and fuel load in a compartment, to a detailed transient calculation such as determining the temperature and velocity field for a large turbine hall fire. The purpose of the calculation has an important bearing on the type of modeling and the approach used. For example, to estimate the heat flux required to damage two targets separated by a specified distance (assuming a large room with limited combustibles), a simple flame radiation/plume calculation may be the most appropriate approach. Such a calculation may be computed by hand or by using software, examples of which include the Fire Induced Vulnerability Evaluation (FIVE) methodology (EPRI, 1992), the updated spreadsheet versions of these calculations (EPRI, 2002a), or NRC spreadsheet calculations (Iqbal et al., 2002; 2003), the latter which are derived in large part from the Society of Fire Protection Engineers (SFPE) Handbook of Fire Protection Engineering (DiNenno, 2002). If software is used, the user is required to understand the potential uncertainty in the results and adhere to the limitations of the method. If the resulting fire size exceeds any fixed or transient fire load expected and uncertainties in the approach are adequately addressed and bounded, then that is normally the only calculation that is required.

For this type of calculation, there are multiple simple methods available. The use of bounding assumptions and adequate safety margins enables one to quickly answer the question or determine the need for additional analysis. This is termed a screening analysis.

At the opposite extreme are the problems that involve complex geometries, significant mechanical ventilation, unusual fire scenarios, and other factors that are not readily evaluated using simplified screening methods. Using fire models to address issues under these circumstances may require calculations with limited data and may involve multiple, strongly interacting phenomena. These problems are often highly sensitive to changes in input data or fire growth assumptions. An example of this type of problem is a fire involving multiple layers of electrical cable trays within a relatively small room. In this case, a space is termed small if the energy release rates result in substantial (over 150°C, for instance) temperature rise in the hot gas layer. Suppose that the problem involves calculation of the damage to a target located near the ceiling but at some radial distance from the source fire. In addition, assume that cables in a tray are ignited. The desired calculation result assesses whether or not the target is damaged, and if so, when would it be. This example involves predicting the flame spread rate along the cable trays, the ignition of adjacent or proximate cables in trays, the effect of an increasing fire size on the hot gas layer temperature in the compartment, the effect of that hot gas layer temperature on the growth rate of the cable fire and the effects of the combination of the hot layer and ceiling jet temperature on the target being assessed. This type of problem is at the limits of the current capability in fire modeling, primarily because there are no methods available that adequately address flame spread and fire growth along contiguous irregularly shaped combustible surfaces. Such an analysis would require the use of, at minimum, a zone model in conjunction with other calculations to make it even tractable.

These two examples are taken from both ends of the spectrum in terms of level of detail, difficulty, and uncertainty, and illustrate the difference between simple screening calculations and detailed calculations requiring the use of detailed computer-based fire models.

The qualifications necessary for personnel involved in the fire modeling projects depends to a great extent on their role and the nature of the analysis. In most cases, the individual responsible for conducting quantitative engineering analysis related to fire hazard quantification should be an experienced engineer with formal training in fire dynamics and use of the methods or models being used. The user should also have knowledge of available data sources and validation studies for the method being used. In addition to modeling and analysis expertise, the successful application of modeling will involve an individual or a team with experience in Nuclear Power Plant (NPP) systems and plant operations, the relevant regulations, plant configurations and Quality Assurance (QA)/Quality Control (QC) programs. For simple screening calculations where well defined and isolated fuel arrays are being evaluated, and less expertise is required, an engineer with training in the calculation methods being used should be adequately qualified.

2.2 Screening Calculations

Screening calculations may involve the use of hand or spreadsheet calculations or the use of zone-type computer fire models. They are intended to be done quickly, and yield results that either demonstrates with substantial safety margin that the situation under analysis is acceptable or demonstrates the need for additional analysis or some alternative solution. An acceptable safety margin depends on the problem evaluated, the uncertainty in the input parameters, and the conservatism of the approach. There is no clear definition of an adequate safety margin; however, it should be sufficiently large so as to bound the uncertainty within a particular calculation or application. The exact nature of the uncertainty varies from problem to problem but generally includes consideration of the source fire heat release rate, the failure criteria, and the mechanism by which the source fire impacts the element of concern (*i.e.*, smoke layer, thermal radiation, immersion in plume, *etc.*).

Screening calculations share one or more of the following attributes.

1. Well-defined simple geometry using materials with well-defined thermal properties.
2. Time scale is not important.
3. Well-defined source fires with bounding assumptions on fire size.
4. Constant fire size, no compartment effects on fire size.
5. No fire or flame spread.
6. Calculated results exceed thresholds by substantial margins.
7. Calculated results not necessarily sensitive to input parameters across the range of uncertainty.

Screening calculations are often done in support of Probability Risk Assessments (PRA) analyses. Screening calculation methods, examples of which include FIVE (EPRI, 1992; 2002a), those developed by the Nuclear Regulatory Commission (NRC) (Iqbal et al., 2002; 2003), and FASTLITE (Portier et al., 1996), are based on simple correlations and underlying methodologies. In order for the screening process to work properly, input assumptions should be conservative. When selecting a screening tool, consideration should be given of the degree to which they have been validated and verified by the NRC. Application of screening calculations is discussed in Section 8.3 of this guidance document under Plant Change Evaluations.

2.3 Detailed Analysis

Detailed engineering calculations and analyses require substantial additional resources to successfully complete in contrast to a screening evaluation. The attributes of problems requiring detailed calculations may include one or more of the following:

1. Complex geometry/use of materials with complex or uncertain thermal properties within geometry.
2 Time dependent problem.
3. Time dependent fire growth.
4. Flame spread along contiguous combustibles with irregular surfaces.
5. Interaction between compartment effects and fire size/growth.
6. Multiple target heating mechanisms (e.g., connection from plume or ceiling jet and hot layer and radiation from hot layer and/or flame.
7. Mechanical ventilation.
8. Screening analysis result with an unacceptable safety margin (problem specific).

Detailed analysis is generally conducted using some combination of screening tools, engineering calculations, zone fire models, and computational fluid dynamic models. Screening tools are useful for reducing the number of parameters or scenarios that are evaluated using a detailed analysis. Engineering calculations sometimes provide reasonable and satisfactory results, however in many cases they are used to provide various input values for zone and CFD models. The successful use of fire modeling is highly sensitive to the problem under evaluation, the approach/model used, and the assumptions necessary for evaluating the problem.

Zone models, examples of which are CFAST (Jones et al., 2000), MAGIC (Gautier, 2002; EPRI, 2002b), and COMPBRN IIIE (Ho et al., 1988), are compartment fire models that are widely used to estimate compartment temperature, smoke conditions, and other information. CFD models simulate the three dimensional flow and temperature fields within the model domain and often require a significantly more detailed input data as compared to a zone model. Examples of CFD models that have been used to simulate fire and smoke conditions in various types of spaces include the Fire Dynamics Simulator (FDS) (McGrattan et al., 2002), JASMINE (Cox et al., 1986), and Kameleon (Vembe et al., 1999). Currently, the models cited above have not been completely validated and verified for use in nuclear power plant applications and may require substantial validation exercises or a sensitivity analysis if used.

2.4 Engineering Analysis Process

This section describes a generic process for performing engineering analysis consistent with the requirements of NFPA 805. It involves the following steps, illustrated in Figure 2-1.

1. Describe the problem.
2. Select an approach to evaluate the problem.
3. Select the appropriate model(s)/calculation procedure(s).
4. Define the Maximum Expected Fire Scenario(s).
5. Perform the calculations.
6. Evaluate the results.
7. Define the range of limiting fire scenarios.
8. Assess safety margins.
9. Documentation the analysis.

Each of the nine process components is discussed in detail in the following subsections.

2.4.1 Problem Description

This first step in this problem requires describing the problem in enough detail to enable decisions regarding the approach to the problem. The following information should be addressed at this stage:

1. Define the Objective. Then objective should include the performance or regulatory issue(s) that are applicable; the probabilistic elements, if any; identify the requirements that form the basis of an equivalency if the analysis an equivalency evaluation; and an indication that the evaluation is part of a PRA assessment, if applicable (See Section 8.3 of this guidance document).
2. Identify the performance criteria. Based on the objective(s) of the analysis, this step requires establishing the desired performance objective(s). The objective(s) should be stated in a quantitative form so that comparison with the analysis results can be made.

For example, in evaluating damage potential to a redundant circuit, the performance objective may be that the heat flux at that target location cannot exceed some critical value.

3. Identify the important physical and environmental variables such as those associated with the source fire parameters and the compartment. Source fire parameters typically include assessing whether the postulated fire is steady state or growing; whether the fuel is a pool fire or a Class A combustible; the location and potential impact of multiple combustible fuel packages or contiguous combustibles, etc. Compartment effects usually refer to the temperature and position of the smoke layer temperature, the potential impact of the smoke layer on nearby targets or fuel packages; the ventilation conditions (mechanical or natural); the compartment dimensions; the enclosure construction, etc.

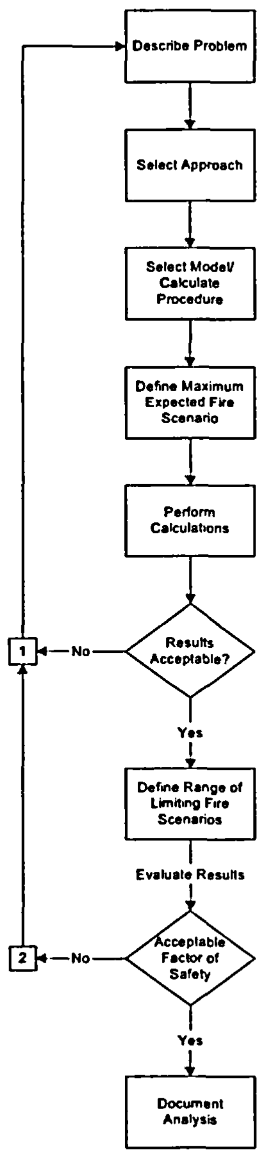


Figure 2-1. Simplified Engineering Analysis Process

2.4.2 Select Approach

The goal of this step is identify the technical approach (engineering calculations, zone fire modeling, CFD modeling, or some combination thereof) that is to be used in the analysis.

Defining the Problem

In order to select the approach, various aspects of the problem need to be identified. There are four key elements to defining the problem determining the nature of the problem, the source term variables, the impact of the compartment, and the key environmental variables. Each is described in greater detail below.

1. <u>The Nature of the Problem</u>

This relates the problem to the type of information desired from the evaluation. Common types of evaluations are:

a. Target damage or ignition potential.
b. Detector/sprinkler activation.
c. Flashover potential.
d. Human tenability conditions.
e. Fire resistance, such as a structural element, a fire barrier, or a fire stop.

Target damage often refers to cables or equipment. Redundant cables or equipment that are too close may be impacted by the same fire event; in this case the goal may be to demonstrate that a fire that damages one set or train necessarily would not damage the other. Target damage/ignition also includes ignition of multiple fuel packages. If combustible controls limit the placement of fuel packages, a calculation may be necessary to determine a safe distance such that two distinct fuel packages are not involved.

Sprinkler and/or detector activation is typically determined to verify that a fire would not damage a target or spread beyond the initial fire area prior to suppression or alarm. In some cases, sprinklers may be obstructed and a detailed fire model is necessary to demonstrate that they would or would not actuation given the assumed fire. Detector actuation may be useful for developing time lines for various fire scenarios and may be used as a basis for initiating manual response.

Flashover potential is considered in spaces where temperatures from a fire may exceed 500°C. Flashover is a transition where it is usually assumed that all contents of a space are damaged, the space is entirely untenable, and fire spread across unrated boundaries is possible.

Human tenability evaluations quantify the impact of a fire to occupants. In nuclear power plants, occupants are usually engaged in one of three generalized activities in the event of a fire: leaving the area (a life safety concern), performing a required function (i.e., an operator action), or suppressing the fire (fire brigade, fire department). The appropriate tenability conditions depend on the activity the occupants are engaged in. Occupants that are in the process of exiting the structure may be exposed to greater levels of toxic products or higher temperatures than those that are required to remain and perform a function for a designated time period. The fire brigade and fire department personnel may be equipped with breathing apparatus and protective clothing such that a greater temperature or toxic threshold may be assumed. This type of evaluation assesses the tenability conditions and uses this information to make a determination as to whether the occupants are successful at their task.

Fire resistance calculations may be used to determine if a fire spreads across a boundary and may be used as the basis for limiting combustible fuel loads and their placement. In some cases, structural issues may be considered, such as localized fires exposing unprotected steel or compartment temperatures that may heat beams or columns to their failure temperature.

Evaluations could involve multiple elements. For instance, it may be necessary to determine if flashover is possible in a space, and if so would sprinklers actuate before flashover occurred. Another example may involve flashover and fire resistance.

2. <u>Source Fire Variables</u>

These describe the types of fire scenarios that are to be modeled and may be characterized as:

a. Physically separated, discrete steady state fire sources.
b. Fire involving time dependent heat release rates or fire spread.
c. Fire spread across contiguous combustible

Physically separated steady state source fires involve fuel packages where the heat release rate is expected to be constant and multiple fuel packages are not expected to become involved (unless subsequent calculations show otherwise). A good example of this type of fire scenario would be a fire involving combustible liquid in a contained area. A variant of this type of scenario would be an unconfined combustible liquid spill with an assumed area. In this case, multiple areas should be assumed to bracket the results. A conservative steady state fire may be assumed for fuel packages with transient heat release rate profiles as measured in a full scale test. In this case, the peak heat release rate may be assumed for the duration of the scenario as a conservative input to a fire model.

Transient source fires or fires involving fire spread may be used in lieu of a steady state source fire if there is sufficient information available. Examples include fire spread across a cable tray or along a combustible vertical surface or a fuel package that has a 't^2' heat release rate profile as measured in a full scale test. A 't^2' heat release rate profile is a common expression for evaluating fire growth in combustible materials and refers to the proportionality between the heat release rate and the time from ignition squared. Heat release rate data as obtained from a test may also be used as direct input into an analysis. Such data may fluctuate considerably about a mean and may exhibit multiple peaks and troughs. Refer to Section 6.1 for a list of references that contain heat release rate data.

The most complex source fire involves multiple fuel packages and transient heat release rate profiles. Fuel packages that are closely spaced or are at risk of igniting via thermal radiation or the smoke layer may lead to this type of scenario. This may ultimately lead to a flashover condition and/or ventilation limited burning if there is a sufficient quantity of combustible material present. In the latter cases, the source fire term is no longer driven by the physical description of the fuel package.

3. Compartment Effects

These variables determine whether or not compartment effects are an important aspect to the problem. They primarily consist of:

a. The fire size.

b. The room volume.

c. The room height.

d. The ventilation rate.

e. The enclosure construction

The fire size in relation to the compartment refers to a ventilation controlled scenario. In this case, the fire size is no longer a function of the fuel package geometry but rather the ventilation conditions within the compartment. Post-flashover fires are often ventilation limited; however flashover is not a requirement for a fire to become ventilation limited. Small spaces with little ventilation may not be able to support a flashover fire and would be ventilation limited. The most severe fire exposure in terms of a temperature versus time profile typically occurs when the fire size is optimized for the ventilation conditions. This condition supports that largest fire size without significant excess pyrolysis products for the longest duration.

The room volume, height, ventilation rate, and construction collectively define the compartment and are used directly in various calculations and fire models. These parameters directly influence the type of fire that may be support in a compartment, the potential for flame impingement to structural elements or overhead targets and the potential for environmental variables to be significant. Depending on the type of analysis performed, simplification of the room geometry may be necessary. Many screening methods and zone models require only the height, width, and length of a space. In this case, the volume and compartment height should be conserved and the floor plan adjusted accordingly. The ventilation rate includes natural (doors, louvers, penetrations, etc.) as well as forced. Forced ventilation includes a variety of systems such as supply, exhaust, supply and exhaust, and re-circulation. Depending on the location of the supply and exhaust points, consideration should be given to a one-zone environment where re-circulation systems are present and are expected to remain functional. Compartment construction includes both the actual materials that form the boundaries and the leakage through or leakiness of the boundaries. Guidance on boundary leakage is available in Klote (2002) and Klote et al. (1992).

A room temperature calculation or a zone model is typically used to establish whether or not compartment effects are significant. If the temperature increase in the space, the oxygen depletion (as it pertains to ventilation controlled burning conditions), or any other critical parameter is such that the evaluation results would not be impacted, then the compartment effects may be neglected.

4. Environmental Variables

These include compartment aspects that may be influence the scenario and the impact the problem. They include:

a. Elevated ambient temperature.
b. Thermal stratification as it pertains to detector activation.
c. High localized ventilation such as wind.

An elevated ambient temperature includes normal operating temperatures that are greater than a typically assumed ambient (20 – 30°C) or ambient temperatures generated by the source fire. A greater ambient temperature will reduce the temperature increase necessary to ignite other combustible materials or damage a target provided they have fixed critical temperatures. This condition may arise when evaluating the exposure from a thermal plume to an overhead cable tray or combustible item. If a smoke layer forms, then the ambient temperature surrounding the thermal plume increases. This reduces the amount of cool air entrained by the thermal plume and results in a more severe exposure to a target. Likewise, if estimating the radiant heat flux to a target in the presence of a hot gas layer, the ambient temperature is greater effectively reducing the critical heat flux necessary to raise the target to a predetermined temperature.

In some cases, detector activation in large spaces may be hindered by stratification of smoke. Stratification effects are a function of the fire size, room geometry, and ambient temperature. When predicting detector activation, it should be verified that a stratified environment does not form.

Ventilation from external sources may also be a significant aspect to a problem, especially when considering smoke movement or maximum fire sizes. Wind load may generate sizeable pressure differentials between the building exterior and interior and between internal compartments in the structure. These pressure differentials may lead to increased air supply or may force smoke into other areas of the building that would not normally be considered. Some fire models include parameters that address this, such as CONTAM and CFAST. Guidance on wind effects is available in Klote (2002) and Klote et al. (1992).

Selecting the Approach Given the Problem

Once the problem has been defined, then the process of selecting the approach involves comparing the requirements of the analysis and the nature of the problem to the capability of the model or calculation procedure. If a model is employed, then an important consideration is the degree to which it has been validated and verified for the application at hand. The ideal approach should provide sufficient resolution and capacity to address the important phenomena and interactions expected and yield reasonable results for the type of problem modeled.

In many cases a combination of calculation methods is required, for example, using a zone model to calculate hot gas layer temperatures and a flame radiation model to calculate the total heat flux incident on a target.

An example of the combination of these variables in selecting the most appropriate approach is shown in Table 2-1 for a target heating/damage assessment problem. In this case, if there are no compartment effects in a problem involving a complex geometry, hand or spreadsheet calculations may be used. For cases where the hot layer temperature or oxygen depletion (compartment effects) are significant, a zone model or a CFD model should be considered. For complex geometries with compartment effects, a combination of zone modeling and engineering calculations may be appropriate.

Table 2-1. Comparison of Calculation Approaches for a Target Damage Problem

Parameter	Calculation	Zone Model	CFD
Source Fire Term	• Obtain from correlations	• Input data from correlations • May calculate interaction	• Input data (from correlations)
Compartment Effects	• Limited use for screening calculations	• Used to calculate the smoke layer position and temperature and oxygen concentration	• Can yield detailed spatial resolution of the temperature field in a compartment
Problem Geometry	• Can be used for complex geometries	• Simple or simplified geometries	• May be used for complex geometries. Thermal radiation calculations may be limited.
Environmental Effects	• Can be used to estimate the impact of wind and smoke stratification	• Limited use	• Effective

This table only applies to a target-heating problem. Other types of problems, such as detector or suppression system activation, will yield different combinations of approaches.

2.4.3 Select the Model/Calculation Procedure

The purpose of this step is to identify the appropriate calculation procedure or fire model. In many cases, some combination of engineering calculations and zone or CFD fire modeling is necessary. Examples include using engineering calculations to determine the most severe location that will be evaluated in greater depth; using engineering calculations to develop input (heat release rate information) for a zone or CFD model; using a zone of CFD model to evaluate the room wide effects and engineering calculations to quantify a localized exposure; or using a zone model for calculating the far field (areas beyond room of origin) effects and a CFD model to calculate near field (room of origin) effects. Selecting the calculation procedure is therefore a matter of determining what calculations and/or models will be used to calculate which variables. It is the responsibility of the user to have sufficient understanding of the scenario, the variables needed from the evaluation, and limitations of the models involved in order to select the most appropriate approach.

2.4.3.1 Engineering Calculations

This type of calculation involves the use of correlations, closed form approximations or exact solutions that can be done by hand or in a spreadsheet. Typical examples include:

- Heat release rate of pool fires;
- Temperature and velocity in an unconfined plume or a ceiling jet in a simple geometry;
- Thermal radiation heat transfer between a flame and/or hot smoke/gas layer and a target; and
- Thermal detector response in unconfined space.

These types of calculations are given in many reference texts, including handbooks (DiNenno, 2002; Cote, 2003) and reference books (Quintiere, 1998; Drysdale, 1999). NRC recently released a series of spreadsheet calculations (Iqbal et al., 2002; 2003) based largely on the methods described in the SFPE Handbook (DiNenno, 2002). Simplified screening versions of these correlations are the basis of the FIVE methodology (EPRI, 1992; 2002a). FPETools is another collection of simple correlations that is available at the National Institute of Standards and Technology (NIST) (Portier et al., 1996). A significant consideration when selecting the appropriate calculation procedure is the degree to which is has been previously accepted by the NRC. An unverified model or approach may require a sensitivity analysis and validation cases.

The NRC spreadsheet calculations provide a good example of the range of capacity of screening calculations. The following calculation procedures are contained in the NRC spreadsheet analysis software (Iqbal et al., 2003):

- Hot gas layer temperature and smoke layer height in a room with natural or forced ventilation.
- Heat release rate, flame height, and burning duration of a liquid pool fires and other fuel packages.
- Flame height correlations for line fires, fires adjacent to walls, fires in corners, and burning vertical surfaces.
- Radiant heat flux from a source fire to a target.
- Ignition of a combustible target exposed to a constant radiant heat flux.
- Cable tray heat release rate (full-scale).
- Burning duration of solid combustible fuel packages.
- Centerline temperature in a buoyant fire plume.
- Sprinkler response time.
- Smoke detector response time.
- Heat detector response time.

- Flashover potential in a compartment.
- Fire-induced pressure rise in a closed compartment.
- Explosion-generated overpressures.
- Hydrogen gas generation in battery rooms.
- Structural fire resistance of steel elements.
- Visibility through smoke.

There are usually multiple approaches for any particular type of calculation. Calculations contained in the SFPE Handbook of Fire Protection Engineering are generally acceptable provided they are used within a valid range.

2.4.3.2 Zone Models

There are as many as twenty different zone models in use in some form. The most widely used zone models include CFAST, which was developed and is currently maintained by NIST (Jones et al., 2000), COMPBURN IIIE, a combined probabilistic and zone type single compartment fire model that has been widely used in nuclear power applications (Ho et al., 1988), MAGIC, available through EPRI and also widely used in the nuclear power industry (Gautier, 2002; EPRI, 2002b), and OZone, a model developed and maintained by University of Liege (Cadorin et al., 2001). Note that COMPBURN IIIE has not been maintained and is not likely to be included in the NRC verification and validation program.

Each zone model has strengths, weaknesses, and features that should be considered when selecting the most appropriate one to use. For example, CFAST is widely use within the fire protection community because it is in the public domain and has been extensively verified against full-scale test data for a number of configurations and applications (Peacock et al., 1993; Jones et al., 2000). COMPBRN IIIE has been used extensively in PRA applications for NPP applications, however at this time it is not being maintained. MAGIC, which is similar to CFAST but with somewhat less capability, has specialized features that are designed to aid calculations related to NPP applications (Gautier, 2002; EPRI, 2002b). A list of various zone models and some of their features is given in Appendix C of NFPA 805. EPRI (2002a) provides a good introduction to zone modeling and provides specific details on four fire models (FIVE, COMPBRN IIIE, CFAST, and MAGIC). Note that NRC is currently in the process of developing a group of models acceptable for use in nuclear power stations. In the absence of such a list, if a model is used within its limitations and acceptable verification and validation documentation is provided, the application should be suitable.

<u>Zone Model Features</u>

CFAST provide a good example of a generic zone model. Listed below are notable features of CFAST that are generally common to other zone models:

1. The model calculates a single hot gas layer temperature, layer height, and layer composition in each room modeled. One model may contain multiple rooms.

2. The model does not predict fire growth rates, heat release rates, or generation of smoke and other products of combustion. This type of information is required as input or is generated using engineering calculations. No effect of temperature or thermal radiation on the fire growth is directly calculated. Ignition of combustible objects (fuel packages) can occur based on user specified criteria (incident heat flux, surface temperature, smoke layer temperature, etc.).
3. The effect of hot gas layer temperature on the fire growth history and the heat release rate is not calculated. Such effects must be accounted for in the specification of the source fire. This often involves an iterative process.
4. The model may include Natural and forced/mechanical ventilation.
5. Heat losses through walls are calculated via a simple transient heat conduction approximation that assumes convection and thermal radiation boundary conditions.
6. The effects of oxygen depletion are accounted for by reducing the user specified heat release rate using a predefined function of the oxygen concentration. The energy release rate is reduced zero when a user specified limiting oxygen concentration is reached.

Selection of Zone Model

Selecting one zone model over another is largely a matter of balancing the validation and acceptability against particular features that a particular model may possess. Specific features, such as target heating sub-models, that may exist in one code versus another can generally be incorporated or integrated with any other code by combining the results with independent engineering calculations. A significant consideration when selecting the appropriate zone model is the degree to which is has been previously accepted by the NRC. An unverified model or approach may require a sensitivity analysis and validation cases. Validation efforts for several zone models are currently underway (Dey, 2002).

2.4.3.3 Field or Computational Fluid Dynamics (CFD) Models

Field or CFD models solve mass, energy, and equation of motion for each volume cell in a calculation grid. The grid size is determined by balancing the accuracy requirements of the analysis against the cost and computational time required to assess a finer grid. As a general rule, a finer grid yields a more resolved solution and presumably because of this there is a greater accuracy for the given the input parameters. There are studies indicating that this may not always be the case (Petterson, 2002). One possible reason that a finer grid results could result in less accurate results under certain circumstances is that various sub-models (combustion, radiation, flame height corrections, etc.) are valid only over a range of cell volumes.

Note that NRC is currently in the process of developing a group of models acceptable for use in nuclear power stations. In the absence of such a list, if a model is used within its limitations and acceptable verification and validation documentation is provided, the application should be suitable.

CFD Model Features

There are a number of CFD codes used in a wide variety of energy/fluid flow applications. A few have been modified to deal more effectively with fire-related phenomena (plume entrainment, radiative transfer, etc.). Examples of CFD models that have been used to simulate fire and smoke conditions in various types of spaces include the Fire Dynamics Simulator (FDS) (McGrattan et al., 2002), JASMINE (Cox et al., 1986), and Kameleon (Vembe et al., 1999). These codes have generally been validated for some types of problems that may or may not be related to NPP applications [McGrattan et al., 1998a; 1998b; Floyd, 2002; Zhang et al., 2001; Cox et al., 1986). Currently, none of the models cited above have been completely validated and verified for use in NPP applications by the NRC and thus may require substantial validation exercises or sensitivity analysis if selected.

The primary advantage of CFD models is their ability to handle the flow and mixing characteristics of fire–induced flows in complex geometries *and* their ability to spatially resolve the temperature and concentration fields throughout a compartment. This means that they do not have the inherent limitation of a two-zone/two temperature compartment environment description that a zone model has.

Like zone models, CFD models require that the fire source be provided as input, usually in the form of a gas evolution rate or a heat release rate per unit area, which is analogous to mass loss rate of a fire, a heat release rate per unit area. Some CFD models contains a solid fuel pyrolysis sub-model that couples the heat transfer from the flames and heated compartment with the surface burning characteristics. The use of this type of sub-model will increase the uncertainty in the results.

CFD codes do not predict fire growth or spread across a fuel surface. Using a gas evolution rate, the models predict the oxygen mixed with the fuel and calculate the energy release rate in that particular cell, based on a prescribed fuel release rate.

The primary disadvantage of CFD codes is the level of effort required for computation. Most NPP applications require multiple calculations or computer simulations to evaluate sensitivity and limiting cases, which is a serious drawback when considering CFD modeling codes in conjunction with other methods. However, CFD modeling can be highly effective where used to evaluate details or cases that are not adequately assessed by with other methods.

Selection of a CFD Code

The range and complexity of CFD codes makes selection of a specific code problematic. For most typical fire modeling applications, FDS (Fire Dynamics Simulator) or an equivalent code will possess many of the features necessary for successful application because of the way in which they were developed. Some types of highly specialized problems may require features that are unavailable in the CFD codes currently in use by the fire protection community and will require seeking specialized CFD models that are not normally available or used for fire modeling. These types of applications may include simulating deflagrations, detonations, boiling liquid vapor cloud explosions (BLEVEs), high velocity flows (jet fires), complex thermal radiation exchanges, etc. As noted above, none of the CFD codes currently available for use have been fully validated and verified by the NRC.

2.4.4 Develop Maximum Expected Fire Scenarios

A key concept of NFPA 805 as it relates to application of fire modeling is the maximum expected fire scenario (MEFS). The MEFS is intended to describe the most challenging fire scenarios that can reasonably be expected to occur. It is not intended to describe the worst case or limiting conditions nor does it define a mere average condition. The terms *reasonably be anticipated* and *realistic and conservative* are used in Appendix C of NFPA 805 to describe the characteristics of an MEFS. An introductory discussion of fire scenarios with examples for six important plant areas is given in the EPRI Fire Modeling Guide (EPRI, 2002a).

The MEFS is expected to capture the variables that are relevant to or important to the particular analysis. For any given problem, there may be several fire scenarios that require evaluation before an MEFS can be determined. In some cases, there may be more than one MEFS. Establishing the scenario involves defining the problem in sufficient detail to perform calculations and to ensure that the input parameter set represents conditions that are *reasonable and conservative.*

The process of developing fire scenarios for a specific problem is also intended to capture some probabilistic elements. For example, a self-ignited non-power cable fire may not be considered a fire scenario because of an extremely low probability of occurrence. The integration of the fire scenario development and probabilistic methods is a useful means to objectively develop the range of fire scenarios that are to be considered for a given problem. Section 8.3 of this guidance document discusses the use of fire modeling in PRA based evaluations. PRA assessments can also be used to screen potential fire scenarios, depending on the objective or purpose of the modeling.

The fire scenarios that are selected for further evaluation will to some extent depend on the problem under consideration. The MEFS that is developed to evaluate detector or sprinkler response may be different from one that is developed to evaluate redundant shutdown circuit spacing. This is partially due to the fact that conservative assumptions for one analysis purpose are not necessarily conservative for another.

The MEFS(s) should address the following input parameters as described in NFPA 805:

1. Combustible materials – type, quantity, etc.
2. Ignition sources.
3. Plant area configuration – dimensions of spaces involved, target location, etc.
4. Fire protection systems and features.
5. Ventilation – mechanical and natural.
6. Personnel – specifically those likely to be impacted by the fire scenario.

The combination of items 1 and 2 will define the fire sources on which the MEFS is based. The plant configuration will establish the geometry of the problem, including the compartment size, the relative position of the fire sources and/or targets, and possible fire/smoke spread paths. If the objective of the analysis includes the evaluation of detection or suppression, the details of fire protection systems in the area are required. Ventilation effects include mechanical and natural ventilation.

Parameters associated with mechanical ventilation, if present, include the supply, exhaust, and re-circulation air flow rates, the position of thermal or detector activated fire dampers, the location of the detectors which actuate the dampers, the location of any fans (in order to evaluate thermal effects), the position of supply and exhaust duct openings, and the fan performance curves. Fan shutdown due to automatic or manual means, the actuation of fire suppression systems or as a result of excessively high temperatures in the flow path may need to be addressed in the analysis. Parameters associated with natural ventilation (openings) include the size and location of each opening in the area(s) considered, the compartments to which they are connected, and the ambient pressure differentials between these compartments. Also, any changes in the configuration that may occur over the course of the scenario should be identified. These include doors opening or closing, fire dampers activating (closure), fan shutdown criteria, and other ventilation system reconfigurations.

If personnel exposure to combustion products is a consideration, as would be the case if personnel actions are necessary in an area where a fire is postulated, then the number persons and their relative position would be required as input.

2.4.4.1 Fire Source Variables

One of the most critical tasks in defining a fire scenario is the description of the fire source term. Most fire models require the user to specify the fire source term or use empirically derived data or correlations. This requires that the user specify a priori all of the details of the fire as a function of time. This involves specifying one or more of the following:

1. The heat release rate or mass loss rate as a function of time.
2. The spatial position of the fire(s) within the compartment in which they are modeled relative to some reference point or an origin.
3. The yield of soot and various gas products from the fuel source.
4. Fuel stoichiometry and limiting oxygen values.

All of these values may not be required, as different types of evaluations and approaches will use different combinations of parameters.

The fire source variables must be considered in the context of the maximum expected conditions or the most severe result given the evaluation goal. The selection of maximum expected source term parameters is sensitive to the type of analysis being performed. For example, maximizing a radiation fraction may pessimize the heat flux to a target in the lower layer but reduce the hot layer gas temperature. If the calculation is intended to evaluate detector response, the selection of a slower rate of fire growth or a smaller fire would be a more appropriate MEFS in that the actuation time will be maximized. Since there are often multiple objectives of a modeling assessment, multiple MEFS specifications may be needed to pessimize each objective for the intended initiating fire scenario.

Often it is not possible to identify the most reasonable and conservative set of parameters. This often occurs when evaluating scenarios where oxygen depletion and mechanical ventilation are involved. Since the balance between fire size or fire growth rate and the ventilation rate are important, use of the largest expected fire size or fastest growth rate does not always result in the most severe conditions. In such cases, it is often necessary to perform multiple iterations to determine the maximum expected conditions for a given fire scenario.

Compartment effects on the fire source variables, if not treated adequately by the model used, must be accounted for by other calculations or demonstrated to be unimportant. Also, fire spread paths between objects must be evaluated prior to performing the calculation to ensure that either a) the model or calculation accounts for ignition, spread and subsequent contribution of additional combustible fuel packages or that b) the input fire source term contains the heat release rate contribution of remotely ignited or contiguous combustible materials.

Specific guidance on fire source terms is given in Section 3 of this appendix.

2.4.5 Perform Calculations and Evaluate Results

The next step the analysis is to perform the calculations using the MEFS and the methods previously selected. The most important aspect of this step is to provide all necessary input data in the correct form for the model or calculation being used.

Once the results are obtained, they are checked against the performance criteria identified by the problem description. This can be as simple as comparing the calculated incident heat flux to a critical flux or it may involve determining what type of approach is should be used when performing additional calculations.

If the calculated results are show that performance criteria is not met or if the safety margin is outside an acceptable range for the type of problem considered, then the use of a more refined model or a less conservative calculation procedure should be considered.

2.4.6 Limiting Fire Scenarios

NFPA 805 requires that the conditions under which failure (exceeding the established performance criteria) occurs be identified. The set of input variables that result in a failure condition is termed the limiting fire scenario (LFS). The development of the LFS(s) is essentially a sensitivity analysis performed to identify which combinations of input parameters or variables are critical to the analysis.

The particular variables to be evaluated depend entirely on the problem being evaluated. At a minimum one would expect to vary the following until a failure condition results:

1. The heat release rate per unit area and/or the total heat release rate.
2. The fire growth rate or the flame spread rate
3. The flame radiative fraction or the radiative power.
4. The location of fuel package relative to target (if variable).

In some cases, calculating the LFS will necessitate postulating large fire sources. Depending on the problem, many other input parameters may require evaluation. Once the range of limiting fire scenarios has been established and calculated, one can evaluate whether an adequate safety margin exists. Note that the term "safety margin" has a specific meaning in risk-informed applications and is discussed in Section 4.4.2.2 of the main body of the guide. Fire modeling safety margin is typically characterized as the difference between MEFS and LFS. The term "safety factor" also is used in the engineering and fire protection professional community to address uncertainty (including Appendix C of NFPA 805). The concept of a safety factor is that values are multiplied by the safety factor and the results are checked at the different value (the product of the original value and the safety factor). In the overall assessment of safety margin, different parameters can be varied using a safety factor, as discussed in Section 2.4.7.

2.4.7 Safety Margin

At this point in the analysis, the MEFS(s) and the LFS(s) have been established. An evaluation and assessment of the safety margin of the analysis can now be performed. The safety margin is normally based on one or two key scenario elements, such as the heat release rate or the critical heat flux. In some cases, the heat release growth rate may be important. For example, in calculating the time to flashover in a compartment fire, the growth rate of the fire may determine when or if flashover conditions will be reached. Depending on what the time to flashover result will be used for, a safety factor calculated on the basis of the time to flashover or the fire size at the time to flashover may be appropriate.

The safety factor is intended to ensure that the analysis reflects uncertainty in the MEFS, the evaluation method(s) used, and the performance criteria. There is no single recommended safety factor or method for its evaluation. A reasonable or appropriate safety factor depends entirely on the situation under evaluation. Where very conservative assumptions are embedded in simple screening calculations, the safety factor may be less than one that is associated with very detailed calculation or a scenario with a significant degree of uncertainty. This is highlighted by example in Section 4.1 of this appendix. For cases where the screening analyses are used in support of a Fire PRA, a safety factor of at least two relative to expected fire size is recommended (see Section 8.4 of this guidance document). A larger safety factor may be warranted, depending on the uncertainty in the input parameters and the conservatism of the calculation.

One design method that provides a recommended factor based on comparisons of predicted versus measured data is summarized by the SFPE (1999). This guide presents simplified methods for calculating thermal radiation from a flame to an external target. The design guide recommends a safety factor of two when using the screening methods described therein. That is, the calculated heat flux should be at fifty percent or less than the critical heat flux for the target to meet the performance criteria, if based on heat flux. This safety factor is based entirely on a comparison between various calculation methods and full-scale data and adequately captures the uncertainty in the incident heat flux given a source fire. If there is additional uncertainty in the source fire, then an additional safety factor may be required.

In most fire engineering calculations the primary uncertainty is in the specification of the heat release rate of the fire. The uncertainty associated with the calculations can vary widely. Some simple calculations, such as the temperature in a thermal plume, are effectively correlations of data and are reasonably accurate, within twenty percent or so given the heat release rate. For these types of calculations, the primary source of uncertainty is the source fire heat release rate. Some types of fires are better characterized than others. For example, the heat release rate of a liquid pool fire in a curbed may be calculated with a relatively small uncertainty. The heat release rate from a complicated three-dimensional arrangement of Class A and Class B combustible materials may be estimated from test data of similar items (individually or collectively), but the estimate will also pronounced uncertainty associated with it. If a reasonably well-defined fuel package is identified, a safety factor of two on the critical heat release rate versus expected heat release rate is often adequate may even be unnecessarily high depending on the uncertainty in the fire size. The appropriateness of this safety factor depends entirely on the specific situation considered.

The required safety factor may also depend on the failure condition or performance criteria established for the problem considered. For example, the use of a steady state critical heat flux value for establishing cable failure is inherently conservative because heat loss terms are ignored and it is assumed that the exposure duration is long relative to the transient response of the target. For short duration fire exposures (less than ten minute), an acceptable safety factor will be less than that for a longer duration fire if failure criterion is based on steady state conditions. The analysis could be modified to take into account other important processes to yield a more realistic result. In this case, an even larger safety factor may be preferred because some inherent conservatism has been removed from the evaluation.

The appropriate safety factor is a function of the problem being evaluated, the uncertainty in the calculation method used, the uncertainty in the definitions of the MEFS and the definition of the failure conditions or performance requirements. As a minimum, the safety factor should bound the uncertainty in the evaluation in terms of the source fire, critical value, and any other significant parameter. Thus an evaluation with little uncertainty requires a smaller safety factor than one in which there are several parameters with a significant uncertainty associated with each.

In the event that the calculated safety factor is deemed inadequate, there are two options available. The first involves using a more accurate calculation procedure and more representative failure criteria (e.g., cable temperature versus critical steady state heat flux). This approach removes embedded conservatism from the analysis and generally requires more sophisticated calculation methods than those methods initially selected. For example, it may involve the use of a more realistic representation of the fire source as input for radiative heat transfer calculations in lieu of a simplified equivalent point source assumption. The second path involves evaluating the initial conditions and input parameters to ensure that they represent a maximum expected versus worse case limiting conditions. Alternatively, the MEFS may be revised to reflect more restrictive conditions of operation or hardware solutions, such as thermal radiation shields or additional insulation, or removal of a combustible fuel source.

Since it is not unusual to initially perform screening or bounding calculations, subsequent refinement of both the calculation method /model selected and the input parameters used to determine the MEFS is a normal part of the evaluation process.

2.4.8 Documentation

The assumptions, methods, input data, and the results should be documented in sufficient detail to permit a reviewer to reconstruct the analysis and check all relevant calculations and results.

At a minimum the documentation should include the following elements:

1. Description of Problem
   a. Objective of the analysis
   b. Regulatory basis
   c. Plant area or compartment
   d. Plant configuration assumptions
   e. Performance objectives
2. Calculation Method(s)
   a. Description of the calculation approach
   b. Reference to applicable equations used in analysis
   c. Model(s) name and version number
   d. Model validation/applicability references or information
   e. Assumptions and assumption bases
3. Maximum Expected Fire Scenario Description
   a. Scenario selection
   b. Scenario description
   c. Compartment/fire area physical description as related to scenario
   d. Ventilation configuration and size/flow rates
   e. Ambient environmental conditions
   f. Source fire location, Rate of heat release as a function of time ($\dot{Q}(t)$), and related parameters
   g. Failure criteria
   h. Data sources
4. Input Data
   a. Complete set of input data used for all calculations
   b. Copies of input files used for computer models
5. Results
   a. Complete set of all calculation results
   b. Copies of output files from computer models
   c. Relevant validation data if required

6. Limiting Fire Scenarios
    a. Set of input conditions resulting in failure/exceeding the performance criteria
    b. Range of variables evaluated
    c. Calculated safety margins
    d. Discussion of uncertainty in the analysis
7. Conclusion/Summary/Recommendations (if applicable)

All documentation should meet the relevant quality assurance provisions. In some cases it will be advisable and/or necessary to include the model assumptions, data and results into the plant fire protection program.

3.0 Fire Source Terms for Maximum Expected Fire Scenarios

This section describes methods for developing the MEFS(s) for selected fuel packages. Additional information and guidance is available in Appendix E of the EPRI Fire PRA Implementation Guide (EPRI, 1995; 2000), the EPRI Fire Modeling Guide (EPRI, 2002a), the SFPE Handbook (DiNenno, 2002), and many of the references listed in Section 6 of this Appendix. Guidance presented in this section is not intended to be a complete discussion of a specific topic, nor is it intended to preclude the use of any other methods.

3.1 Pool Fires

MEFS that involve liquid pool fires can be developed using the following guidance:

Pool Fire Size

1. For confined spills, where curbs or equipment enclosures form the boundaries of a pool spill, the enclosed area is the maximum spill area.
2. For unconfined spills, a steady state pool size can be calculated using data given by Gottuk et al. (2002). Unconfined spills have fuel depths in the range of 1 – 3 mm and the burning rates are typically about one-fifth those for confined spills having the same area.
3. For unconfined spills where the fuel continues to flow, it is reasonable to derive an equivalent steady state pool size that results in a burning rate equal to the spill flow rate.

Specific data and calculation methods on liquid fuel fires can be found in Gottuk et al. (2002).

Spray Fires

The effect of pressurized liquid spray fires cannot presently be modeled using readily available tools. The overall impact of spray fires in a compartment can be approximate by treating the spray as a heat release rate source term. This is a reasonable assumption if the spray is of sufficiently low momentum such that entrainment of air into the spray is not significant and the size of the liquid jet is not a large fraction of the compartment floor area. Limited data on spray fires is given in Appendix E of the EPRI Fire PRA Implementation Guide (EPRI, 1995; 2000). Note that in many actual spray fires, energy is contributed from both the spray fire and a pool fire that forms under the spray. CFD methods are available for calculating the details of a spray flame, but these are not available for general design or analysis. Limited data on radiation calculations from spray and jet flames is given by Beyler (2002). Target exposure calculations involving spray flame exposures require significant additional care.

3.2 Transient Combustibles

In most plant areas, it is necessary to postulate a transient fuel fire source given the transient fuel loads. Transient fuel loads arise from normal operating conditions as well as maintenance or testing activities. Depending on the location in the plant and the general area use, transient combustibles will comprise at a minimum, of one or more trash or refuse bags. Large refuse bags may have heat release rates in the range of 150 – 350 kW, depending on the nature of the contents, packaging density, size and weight. Other transient loads, including lubricating oil, packaging material, and furniture items should be included as appropriate. Transient combustible materials should take into consideration transient loads allowed within the plant Fire Hazard Analysis and the combustible control program. Data on heat release rate characteristics of transient fuel loads is given in Babrauskas (2002), Babrauskas et al., 1992; and Grayson et al. (2000). The EPRI Fire PRA Implementation Guide also contains specific guidance for transient fuel loads in Appendix E (EPRI, 1995; 2000).

Transient loads are included in the MEFS and LFS as appropriate by postulating transient loads in addition to normal fuel loads.

3.3 Cabinet Fires

Heat release rates for electronics cabinets can be developed using data from large-scale cabinet fire tests using equipment similar ventilation and fuel loading. Two cabinet heat release rate values measured by Chavez (1987) are in widespread use for fire PRA evaluations. In these evaluations, a lower heat release rate (65 kW) is used when the cables are IEEE-383 qualified *and* only one small cable bundle is expected to be involved. For other cases involving IEEE-383 qualified cables, 200 kW is assumed (EPRI, 1995; 2000).

The heat release rate from electronics cabinets is a function of the cabinet ventilation, the combustible fuel load in the cabinet, and the fuel distribution within the cabinet. Fire testing conducted by Chavez (1987) and Mangs et al. (1994, 1996) attempted to evaluate the impact of these variables on the cabinet fire heat release rate. A summary of the test conditions is provided in Table 3-1. Transient heat release rate profiles for various cabinet fires are shown in Figure 3-1. Additional data is available in the EPRI Fire PRA Implementation Guide (EPRI, 1995; 2000). This guide gives energy release rate data for cabinet fires as a function of cabinet fuel loading, cable type and ventilation opening.

Table 3-1. Electronic Cabinet Fire Test Conditions

Test No.	Ref.	Ventilation Area (m^2)			Fuel Load (MJ)	Peak HRR (kW)	Fire Duration (min)
		Type	Lower	Upper			
VTT-I 1	[1]	Vent Grills, Door Ajar	0.050	0.11	925	385 at 40 min.	105
VTT-I 2	[1]	Vent Grills	0.040	0.079	455	50 at 14 min	45
VTT-I 3-2	[1]	Vent Grills	0.040	0.079	1,400	180 at 15 min	125
VTT-II 1	[2]	Vent Grills	0.0097	0.054	1,500	175 at 36 min	105
VTT-II 2	[2]	Vent Grills	0.0097	0.054	1,600	110 at 32 min	120
VTT-II 3	[2]	Vent Grills	0.0097	0.054	1,500	100 at 13 min	120
ST #10	[3]	Vent Grills	0.14	0.14	600	280 at 11 min	50
PCT #1	[3]	Vent Grills	0.14	0.14	780	185 at 12 min	60
PCT #2	[3]	Open door	1.30	1.30	1,000	950 at 11 min	40

1. Mangs et al. (1994) 2. Mangs et al. (1996) 3. Chavez (1987)

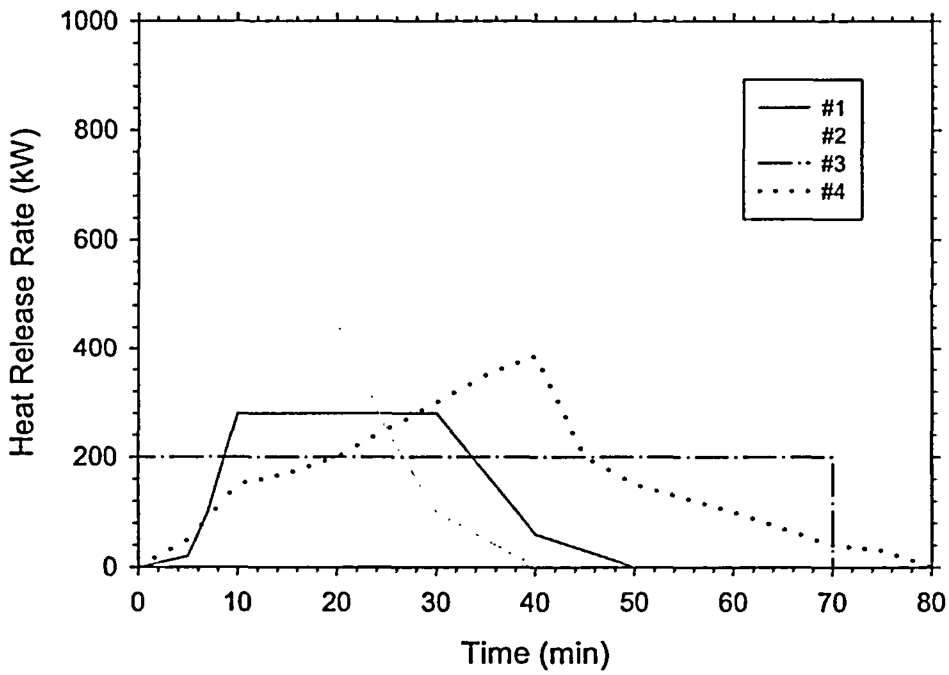


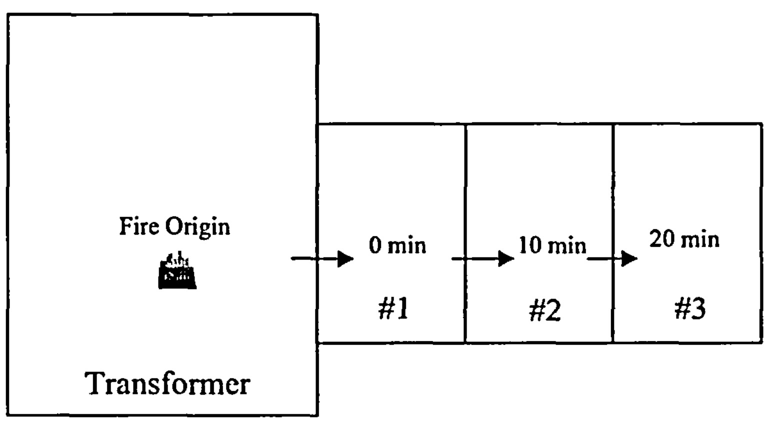
Figure 3-1. Heat release rate of individual electronic cabinets in the cable spreading room. Curve #1 from ST#2 and PCT#1 (Chavez, 1987), Curve #2 from PCT#2 (Chavez, 1987), Curve #3 (Najafi et al., 1999), and Curve #4 from Test 1 (Mangs et al., 1994).

Often, cabinets are located adjacent to or close to other cabinets. The potential for fire spread between adjacent cabinets can be estimated using experimental data from tests conducted by Chavez (1987) and Mangs et al., (1994, 1996). Chavez (1987) found that electronic cabinets that are not separated by an air gap may transmit sufficient heat to allow auto-ignition of cables in the adjacent cabinet. Wall temperature data obtained from by Mangs et al., (1994, 1996) indicates that fires will spread to adjacent cabinets approximately ten minutes after ignition of the initial burning cabinet.

A heat release rate curve that combines the heat release rate contribution of individual cabinets with the expected ignition delay between cabinets is shown in Figure 3-2. In this example, fire spreads from a transformer to three adjacent electronics cabinets.

High Voltage Faults

None of the electronic cabinet fire data currently available are relevant to the case of a high voltage arcing failure (NRC, 2002). No existing fire modeling calculation method can deal directly with these types of events. An approach to treating such scenarios would be to account for the initial electrical energy release as a zero oxygen consumption heat release rate and then assume ignition of all combustibles within a certain radius (1 – 2 m). Fire spread beyond this initial ignition zone could then be treated by existing methods as appropriate. Since the energy release rate for all models is given as input data, such an approach would enable the user to evaluate compartment-wide effects of such initiating events.



Top view showing fire spread to adjacent cabinets.

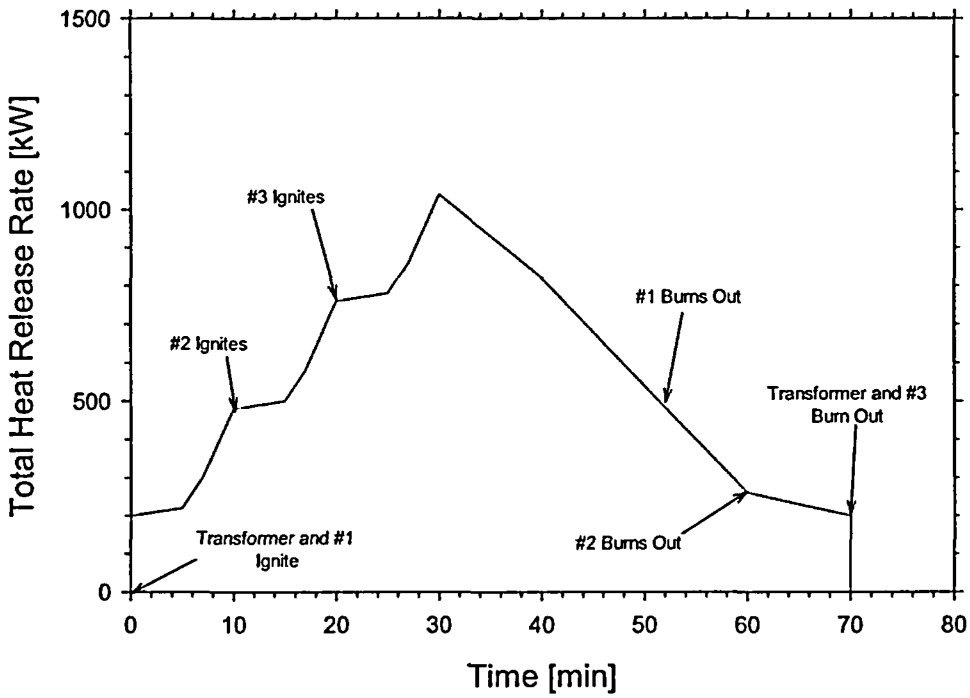


Figure 3-2. Heat Release Rate Profile and Depiction of Fire Spread from a Transformer to Adjacent Cabinets.

3.4 Cable Fires

Cable fire growth rates may be approximated by empirical correlations relating bench scale heat release rate data to full scale fire spread and heat release rate data. The heat release rate and fire spread characteristics are strongly dependent on the following variables:

1. The cable jacket and insulation material.
2. The number and size of the cable conductors.
3. The cable construction.
4. The density and arrangement of cables in the tray, bundle, etc.
5. The cable orientation (vertical/horizontal).
6. The presence of fire retardant material on the cables.

The range of heat release rate data for a given type of insulation and jacket material varies widely. For example, heat release rate data for PE/PVC cable construction can vary between 200 kW/m^2 and 600 kW/m^2 for IEEE 383 qualified cables. Empirical data is available only for a small fraction of all cables current in use, so approximations are necessary when evaluating cable tray fire scenarios. A sample method that treats a cable tray fire a line fire that spreads in two directions is provided below. Other approaches may be used as appropriate.

The heat release rate per unit length of the cable tray system is a function of the plan area of the cables as follows:

$$\dot{q}'_{tot} = \dot{q}''_{fs} \cdot W_{p,c} \qquad (1)$$

where $\dot{q}''_{fs}$ is the full-scale single cable tray heat release rate (kW/m^2) and $W_{p,c}$ is the maximum plan width of the cables (m). The plan width is equal to the sum of all individual cable outer diameters or the actual cable tray width, which ever is smaller. If there are multiple trays, the total plan width includes the plan width on each cable tray within the array.

The full-scale heat release rate per unit area is determined using the equation (Lee, 1985):

$$\dot{q}''_{fs} = 0.45 \cdot \dot{q}''_{bs} \qquad (2)$$

where $\dot{q}''_{bs}$ is the heat release rate per unit area measured at an incident heat flux of 60 kW/m^2 in a bench-scale (cone calorimeter) apparatus.

Burning Duration

The burning duration at a single point is in direct proportion to the quantity of combustible material available and the burning rate. The following equation is used to determine the burning duration:

$$t_d = \frac{Q'}{\dot{q}'_{tot}} \qquad (3)$$

where t_d is the fire duration at a specific location (s), and Q' is the energy load of the cable tray system (kJ/m).

Spread Rate

Evidence suggests the spread rate in cable tray fires is a function of the bench-scale heat release rate (Lee, 1985). Lee (1985) correlated bench-scale data to moderate-scale tests in terms of an *area* spread rate for a single cable tray *array*. The cable tray array contained six tiers or two cable trays. Each individual tray within the array was 0.5 m wide (Sumitra, 1982).
As noted by Lee (1985), the correlated area spread rate is valid "...only to [for] cable tray arrangements, cable packing densities, and exposure fires similar to those tested by Sumitra."

The arrangement of the cable tray system is typically smaller than those that were tested. Consequently, some modification to the Lee (1985) methods is required before the test results can be applied to the configuration at hand.

The correlation derived by Lee can be modified using the actual test observations by Sumitra (1982). Sumitra noted the number of trays involved before the onset of suppression for each test. This information, along with the burn area at the time suppression as determined by Lee (1985) was used to calculate the actual flame spread rate. Figure 3-3 shows the flame-spread rate versus bench-scale heat release rate along with a linear curve fit. The following correlation is obtained from the linear curve fit of the data:

$$v_s = (7.55E-3)\cdot \dot{q}''_{bs} - 1.25 \qquad (4)$$

where v_s is the flame spread rate (mm/s) in one direction on horizontal cable tray.

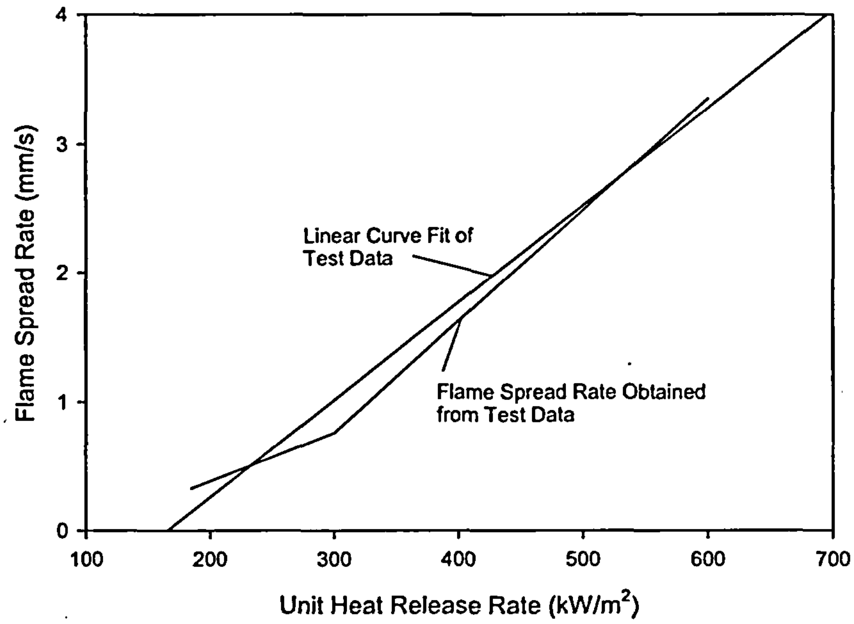


Figure 3-3. Horizontal Flame Spread Rate as a Function of the Unit Heat Release Rate

The flame spread velocity as calculated using Equation 4 may be compared to other test data on cable trays and cable fires for validity. Tewarson et al. (1993) observed that the horizontal flame spread velocity in communications cables is about 0.6 mm/s for a three-tiered cable tray arrangement. Investigations of a power cable fault fire (FTIC, 1989) concluded that the spread velocity in these cables was about 2 mm/s. Vertical cable trays with various types of cables have been shown to have a flame spread rate between 2 mm/s and 7 mm/s and presumably represent an upper bound spread rate (Tewarson et al., 1988). Thus, the horizontal cable tray flame-spread rate is expected to lie between 0.6 – 7-mm/s, which is nearly the case for Equation 4 over the expected range of unit heat release rates for cables.

Another consideration when estimating the cable tray flame spread rate is the packing density. Test data on vertical cable tray tests indicates that the flame-spread rate in cables is sensitive to the packing density (Hasegawa et al., 1983). Hasegawa et al. (1983) found that cable trays with a packing density of twenty-five percent had a fifty percent or greater reduction in the peak flame spread rate. Cable trays with a packing density approaching one-hundred percent also exhibited a flame spread rate reduction.

Alternative (and lower) flame spread rates for cable arrays are given in the FIVE method documentation (EPRI, 1992), and discussed in the EPRI Fire Modeling Guide for Nuclear Power Plant Application (EPRI, 2002a).

Spread Distance

The maximum flame spread distance from the point of origin in one direction is

$$X_s = t_d v_s \tag{5}$$

where X_s is the distance the flame spreads from the origin before the onset of burnout (m). Note that the total spread distance is *twice* this value because it is assumed that flame spread occurs in two directions.

The method described above is applicable for single horizontal cable tray arrays. Vertical arrays spread flame much more quickly as noted above. No generic method exists for calculating or estimating this spread rate. For many problems vertical flame spread may be assumed to happen instantaneously.

For complex horizontal cable array geometries (such as those which typically occur in cable spreading areas), a bench to full-scale spread correlation (viz., Equation 2) may be used to estimate the amount of cable involved if a slow or medium 't^2' growth rate fire is assumed. Note that none of those methods account for the change to flame spread rates that occur as the compartment heats up. As cables become immersed in hot gases and their surfaces preheated, the flame spread rate will increase. Methods for approximating the increase in flame spread rate can be derived from methods used to calculate flame spread on combustible surfaces (Quintiere, 2002).

It is not presently possible to directly account for the effects of coatings on electrical cables without additional full or bench-scale data. Reference to full-scale cable tray test data may provide some guidance in establishing source fire characteristics of coated cables (Klamerus, 1978). At a minimum, coated cables passing IEEE-383 can be reasonably expected to equal the performance of IEEE-383 qualified cables from the standpoint of damageability.

4.0 Guidance on Application of Engineering Methods

This section provides guidance and reference material on the use of engineering methods and models for specific applications.

4.1 Damage or Ignition of a Target

This category of problems is widely encountered in NPPs due to its relationship with prescribed minimum separation distance requirements between certain systems and circuits. The general problem can be subdivided into two cases, one where the room size is large and the source fire relatively small such that compartment effects are negligible, and the other where compartment heating and/or oxygen depletion effects are expected to be significant.

4.1.1 Target Exposure: Negligible Compartment Effects

Plumes and Ceiling Jet Exposure

This case is illustrated schematically in Figure 4-1. Three sample target positions, T1, T2, and T3, are shown in Figure 4-1. Location T1 represents a target tat is immersed in the plume at some elevation above the flame. The axis-symmetric plume temperature may be calculated using methods found in Iqbal et al. (2002; 2003), FIVE, (EPRI, 1992; 2002a), Lattimer (2002) or Heskestad (2002). For line type flames and plumes or fires against walls or in corners, different correlations may be required (Iqbal et al., 2003). Location T2 represents a target within the ceiling jet zone. Correlations for estimating the temperature and velocity in a ceiling jet are available in Iqbal et al. (2002; 2003), Alpert (2002), Lattimer (2002), or FIVE (EPRI, 1992). These cases can also be evaluated using computer codes used for detector/sprinkler activation, for example, DETACT-QS/T2 (Portier et al., 1996; Evans et al., 1985; 1986) and LAVENT (Cooper, 1990).

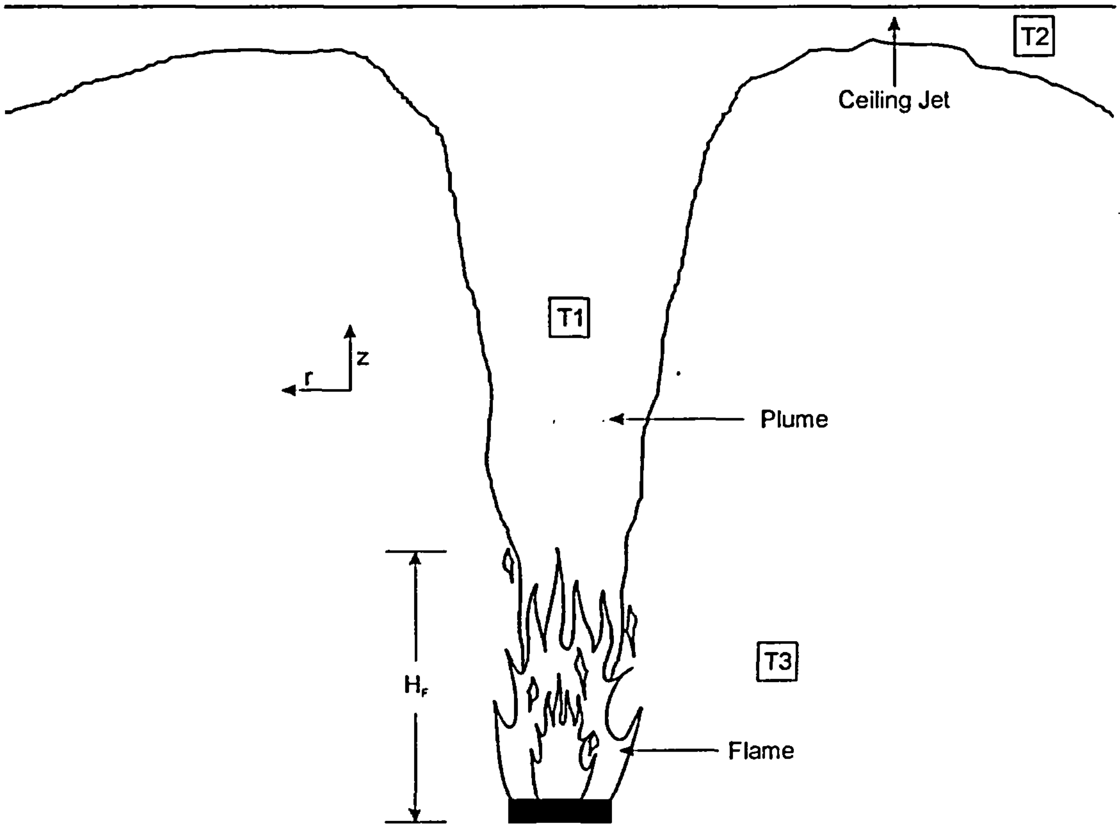


Figure 4-1. Schematic of Target Exposure, No Compartment Effects

Where plumes or ceiling jets may flow through highly obstructed paths, as would be the case near the ceiling of a cable spreading room, the use of the methods described above could over-predict temperatures. Also, a target that is located outside of the flow path in an unobstructed configuration may become immersed in obstructed configuration. If such considerations are critical to the evaluation, then detailed calculations (such as a CFD analysis) should be pursued.

The temperatures calculated for both plume and ceiling jet exposures are typically maximum values and occur along centerline of a thermal plume and near the ceiling for ceiling jets. If the target is not on the centerline, there are correlations for the temperature variation as a function of the distance from the maximum value that may be used. Heskestad (2002) gives the necessary correlations to perform this calculation for thermal plumes. In most applications (particularly for low ceiling heights), the use of maximum plume or ceiling jet temperature is most appropriate and recommended.

Flame Radiation

In the situation noted by the target location T3 in Figure 4-1, the primary exposure is flame radiation. This problem can be readily evaluated if the flame is approximated as a circular source with a simple target-flame geometry. Techniques are summarized in Beyler (2002), SFPE (1999), and Iqbal et al. (2002; 2003).
Geometries that involve non-circular fire source (e.g. line fires), or irregular flame-target positions, intervening flame shields, etc., require a more complex calculation method. Beyler (2002) and Heskestad (2002) summarize several methods that address complex configurations.

For complex geometries, the general process for calculating flame radiation effects is as follows.

1. Estimate the fire heat release rate.
2. Establish the dimensions of the flame base.
3. Calculate the flame height.
4. Estimate the emissive power at flame:
   a. Use the radiative fraction of the total heat release rate divided by the flame surface area; or
   b. Use the average flame temperature and emissivity; or
   c. Use an empirical correlation based on the fire diameter and other parameters.
5. Calculate view factor from flame to the target, accounting for flame shields and other obstructions.
6. Apply any corrections for the transmissivity through boundaries and absorption by intervening gas (can be neglected for most cases).
7. Calculate the radiant flux at target.

This procedure described above may be used for most flame and flame/target geometries. Summarized below is the application of four different flame radiation calculation methods of variable complexity. The examples illustrate the relationship between methods used and the appropriate safety margin.

Comparison of Flame Reduction Calculation Methods

An example of applying various calculation procedures and the effect it has on the appropriate safety margin is given in this section. Four methods for calculating flame radiation are described and compared with experimental data. The basis for comparison between the methods is calculated heat flux for the data set used to validate the point source model.

Classical Point Source Method

The classical point source model was used in this analysis because it is simple to apply and it is the only method that does not require a determination of the diameter of the fire. The point source model assumes that the radiant energy is released at a point located at the center of the fire. The heat flux is inversely related to the separation from a source fire the following equation (Drysdale, 1999):

$$\dot{q}'' = \frac{\chi_r \dot{Q}_p}{4\pi R^2} \tag{6}$$

where $\dot{q}''$ is the heat flux (kW/m²) at a distance R (m) from the center of the flame, Π_r is the is the energy fraction released as thermal radiation, $\dot{Q}_p$ is the peak heat release rate (kW). As can be seen in Equation 6, only the peak heat release rate and the separation distance are required to calculate the heat flux to a target.

In most instances, the fraction of energy released as radiation varies between 0.03 and 0.45 (SFPE, 1999; Tewarson, 2002) with most data falling between 0.1 and 0.3. A value of 0.35 is initially assumed in the following example analysis and based on comparison with the available test data an appropriate safety margin is determined. Note that assuming a different value would result in a different safety margin but not a different conclusion. It is also assumed that the separation distance R is equal to the horizontal distance between the edge of the source fire and the edge of the target. Because the horizontal separation distance will always be less than the distance to the center of the flame, the heat flux values predicted by Equation 6 will be more conservative using the horizontal separation distance. Equation 6 has been compared to actual test data from pool fires with diameters of less than 3 m because it is expected that the assumptions described above would not apply to large diameter source fires. Table 4-1 summarizes the experimental data sets that were used in this comparison. Figure 4-2 shows a plot of the measured versus predicted heat flux values Equation 6 using an assumed radiative fraction of 0.35 as described above and a separation equal to the horizontal distance from the edge of the source fire.

Although most of the target heat fluxes are conservatively over-predicted, there are still enough data points that are under-predicted to warrant the use of a safety margin.

Table 4-1. Summary of Experimental Data Compared with Point Source Model Predictions

Data Reference	Type of Fuel	Fire Diameter (m)	Number of Data Points
Seeger (1974)	Fuel Oil	1.6	4
Yumoto (1977)	Gasoline	1.0 to 1.5	11
Dayan et al. (1974)	JP-4	1.2	4
Dayan et al. (1974)	JP-5	2.4 to 3.1	8
Hagglund et al. (1976)	JP-4	1.1 to 2.3	11
Koseki et al. (1991)	Crude Oil	1.0 to 3.1	5
Koseki et al. (1988)	Heptane	1.0 to 2.0	2
Koseki et al. (1989)	Heptane	3.1	1

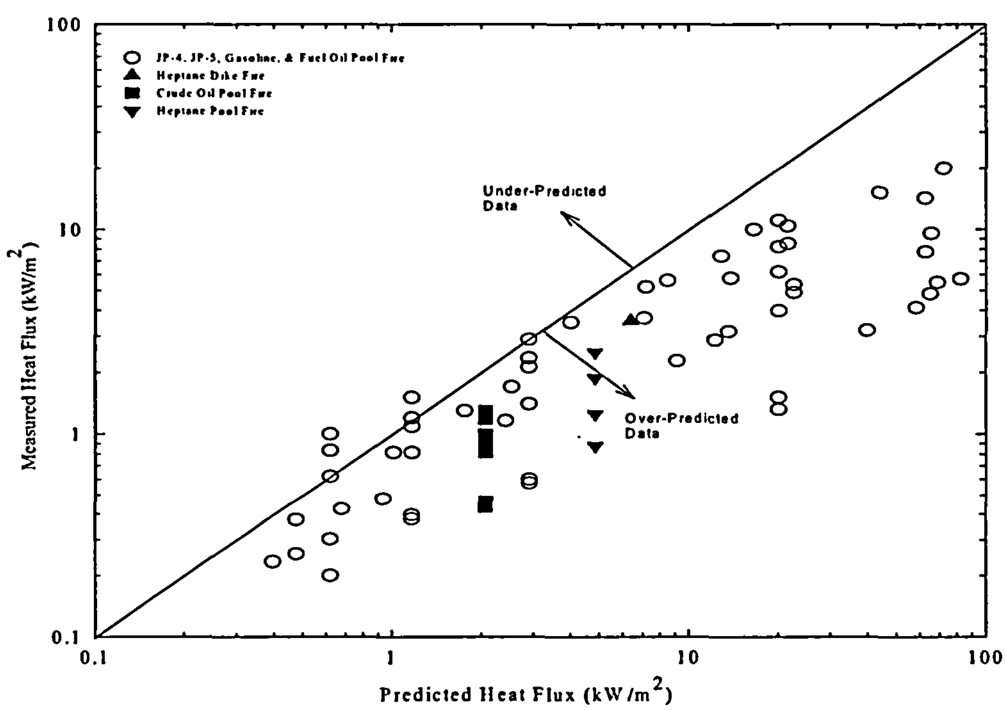
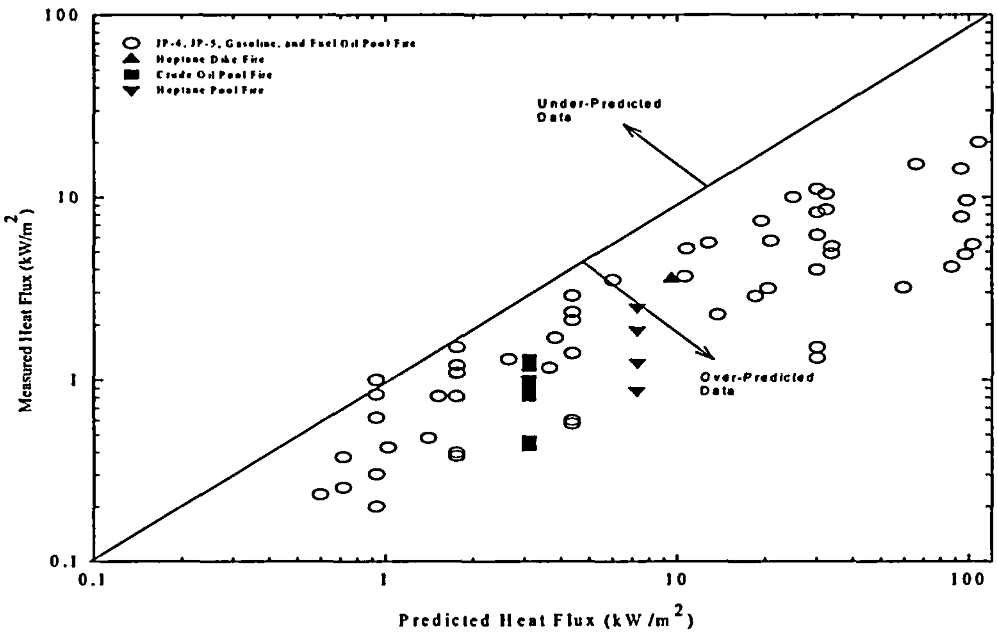


Figure 4-2. Predicted Versus Measured Target Heat Fluxes Using the Classical Point Source Model

Figure 4-3 shows point source model predictions using a safety margin of 1.5, an assumed radiative fraction of 0.35 as described above, and a separation distance equal to the horizontal distance from the edge of the source fire. As can be seen, all of the data is either accurately predicted or conservatively over-predicted. In some instances the heat flux is over-predicted by a considerable amount. Nevertheless, Figure 4-3 shows that with some relatively moderate assumptions to the initial model, the calculation can be shown conservative for a wide range of fuels and fire sizes without the need for evaluating fire specific parameters such as the diameter and flame height.

Figure 4-3. Predicted Versus Measured Target Heat Fluxes Using the Classical Point Source Model



with a Safety margin of 1.5

Shokri and Beyler Correlation

The Shokri and Beyler correlation requires the determination of the fire diameter. The following equation is used in this method to calculate the heat flux to a target (Shokri et al., 1989):

$$\dot{q}'' = 15.4\left(\frac{R}{D}\right)^{-1.57} \tag{7}$$

where D is the source fire diameter (m). The radial separation R is the distance between the center of the source fire and the edge of the target. Figure 4-4 shows the predicted heat flux versus the measured heat flux at a target for the same data set used to validate the point source model. Figure 4-4 shows that the Shokri and Beyler correlation under estimates about half of the data points and over estimates the other half. This is the basis for a recommended factor of safety of two in the SFPE Engineering Guide (SFPE, 1999).

Detailed Method of Shokri and Beyler

Shokri et al. (1989) present a more detailed method than the Shokri and Beyler correlation summarized above and the results are improved. The heat flux to a target is calculated using the following equation:

$$\dot{q}'' = EF \tag{8}$$

where E is the emissive power of the fire flame (kW/m²) and F is the radiation view factor between the target and the flame. The emissive power of the flame is determined using the following equation (Shokri et al., 1989):

$$E = 58 \cdot 10^{-0.00823 D} \quad (9)$$

where E is in kW/m² and D is in meters. The configuration factor between the target and the flame is a function of the flame height, the fire diameter, the shape of the flame, and the orientation of the target. Shokri and Beyler assume that the flame can be approximated as a cylinder with a diameter equal to the diameter of the source fire and a height equal to that of the flame. The equations for this radiation configuration factor geometry are summarized in Shokri et al., (1989). Figure 4-5 shows the predicted versus measured target heat fluxes for the same data set used to validate the point source model. The figure indicates that this method is much better than the Shokri and Beyler correlation, though some data is still underestimated, hence a lower factor of safety may be warranted.

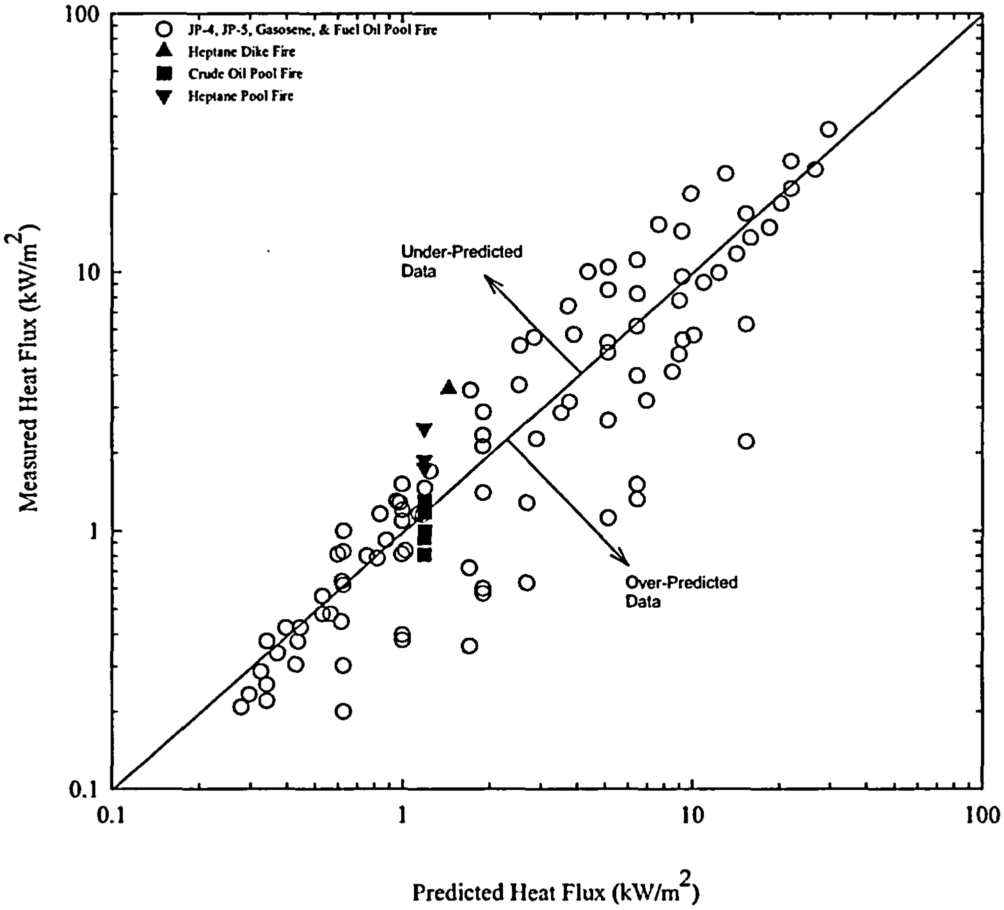


Figure 4-4. Predicted Versus Measured Target Heat Fluxes Using the Shokri and Beyler Correlation

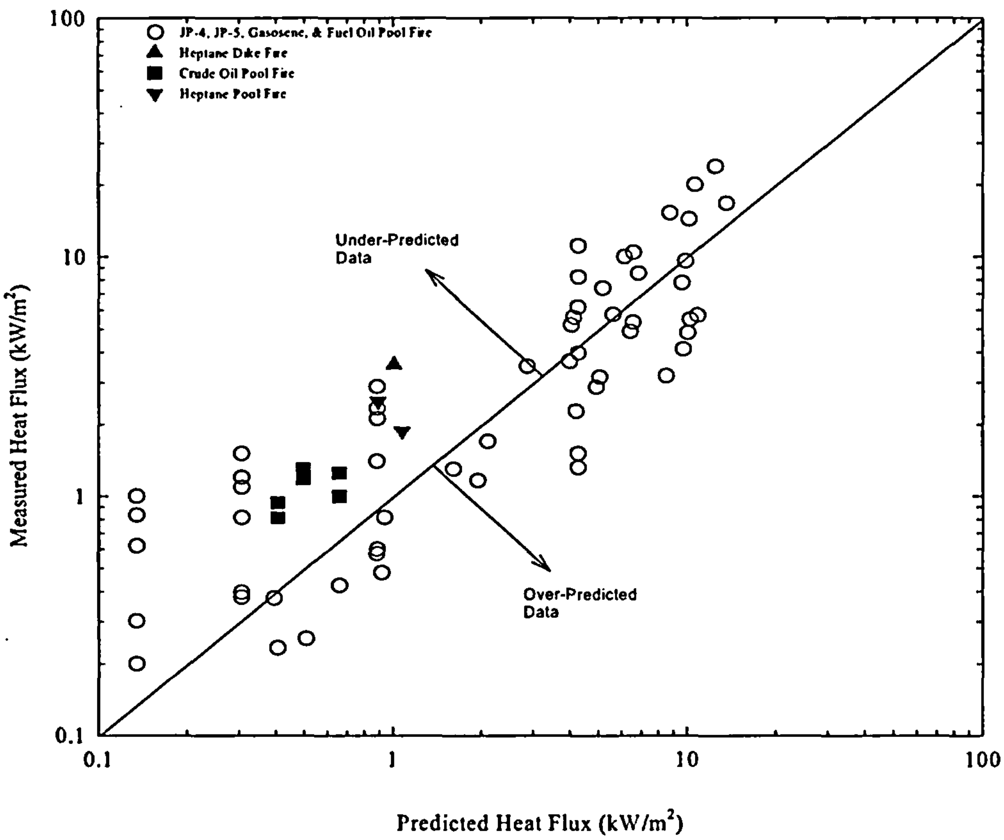


Figure 4-5. Predicted versus Measured Target Heat Fluxes Using the Shokri and Beyler Procedure

Method of Mudan and Croce

The method of Mudan and Croce is similar to the detailed Shokri and Beyler method, however different correlations for the flame height, flame emissive power, and the shape factor are employed. This method is summarized in Beyler (2002) and by SFPE (1999).

<u>Sample Application Comparing the Four Heat Flux Models</u>

This section presents an application that compares the calculated predictions of each heat flux model. The sample fuel package is a 1.5 m diameter combustible material fire. The assumed heat release rate per unit area is 400 kW/m². The incident target heat flux at several distances was calculated using each of the four methods discussed above. Table 4-2 summarizes the predictions of each method. The point source model and the Shokri and Beyler correlations, both of which are screening methods, yield the most conservative results near the source fire and is the next most conservative method at distances away from the fire. It should be noted that all correlations are conservatively applied in this case in so far as the fuel package is treated as a pool fire. The results in Table 4-2 suggest that the safety margin is generally greater for the screening methods near the source fire, where the greatest error would be expected, and approaches the more detailed methods at distances away from the source fire.

Table 4-2. Comparison of Heat Flux Predictions for Miscellaneous Fire Example

Method	Heat Flux (kW/m²) at				
	0.5 m	*1.0 m*	*1.5 m*	*2.0 m*	*2.5 m*
Point Source Model[1]	117	29	13	7.3	4.7
Shokri/Beyler Correlation	86	29	15	10	7
Detailed Shokri/Beyler	31	17	10	6.9	4.9
Mudan/Croce Method	67	39	25	17	12

[1]Point source model with a safety margin of 1.5 and a radiant fraction of 0.35.

4.1.2 Target Exposure: Significant Compartment Effects

Compartment effects are critically important to fire engineering calculations. These effects manifest themselves in several ways. It is important to ensure that any analysis captures these effects where important. They include:

1. The formation of a hot gas layer that thermally exposes all elements located within that layer. At relatively low temperatures, this exposure is primarily convective, and as this temperature approaches 500°C, thermal radiation heat transfer begins to dominate. In many cases both heat transfer mechanisms should be accounted for.
2. The hot gas layer causes an increase in plume and ceiling jet temperatures since the plume and jet are entraining heated air. Any calculations involving direct exposure from a plume or ceiling jet that entrains heated air must account for this effect.
3. The hot gas layer has a reduced oxygen concentration. This has two primary effects. The first is that when the flame zone is immersed in the hot gas layer, the flame entrains gases and air at reduced oxygen concentrations. This results in lengthening of the flame and a decrease in heat release rate/unit length of the flame (energy release rate). This same effect will cause an increase in soot production and in the yield of carbon monoxide (CO).
4. At elevated hot gas layer temperatures, radiation from the hot gas layer will cause an increase in the burning rate of objects located within the layer and eventually radiation from the hot gas layer will increase the burning rate of objects located below it. In the limiting case (flashover), objects below the hot layer will ignite and the compartment fire will transition to a post-flashover, and often ventilation limited, state.

In any given analysis, some or all of the above effects may not be significant or they may be readily accounted for. A small fire in a large space is an ideal example of such a case. Nevertheless, compartment effects should always be considered, and if they are found to be insignificant, appropriate documentation should be provided.

A typical case where compartment effects are or may be important is depicted in Figure 4-6. There are two basic approaches to these types of problems. The first involves using engineering calculations to calculate plume and ceiling jet exposures (T1, T2) as if there were no hot layer. Then estimate the hot gas layer temperature using either engineering calculations such as Iqbal et al. (2002), Walton et al., (2002), zone models such as CFAST (Jones et al., 2000) or MAGIC

(Gautier, 2002; EPRI, 2002b), or field models such as FDS (McGrattan et al., 2002) or JASMINE (Cox et al., 1986). The average hot gas layer temperature rise due to compartment heating is then added to the temperature increase due to the plume or ceiling jet. Although this will result in slightly over-predicted exposure temperatures if the thermal plume is not fully immersed in the hot gas layer (as assumed), the approach has the advantage of exploiting a range of conditions for plumes and ceiling jets and allows easy calculations of a range of target positions.

For targets located outside of the plume or ceiling jet, the exposure temperature can be calculated directly from the hot gas layer temperature. An alternative approach is to use a zone model to calculate the heating of a target in the hot gas layer and exposed to flame and hot gas layer radiation.

A third approach is to use a CFD model, such as FDS or JASMINE, to calculate the temperature and velocity field at a target location. CFD codes can be used to great advantage where resolution in a complex flow field or geometry is required. One disadvantage that CFD models in general and LES CFD models in particular have is in calculating radiant heat fluxes from flames to targets. Much of the thermal radiation characteristics of the flame occur at sub-grid scales in an LES simulation and thus can not be resolved. Furthermore, radiation calculations are tune consuming for CFD codes in general. To compensate for this, CFD models incorporate various approximate thermal radiation sub-models as necessary. These models often have not been verified and the results may be highly sensitive to the actual grid scale used. In this case of FDS, there is little published data on the validation of its flame radiation sub-model.

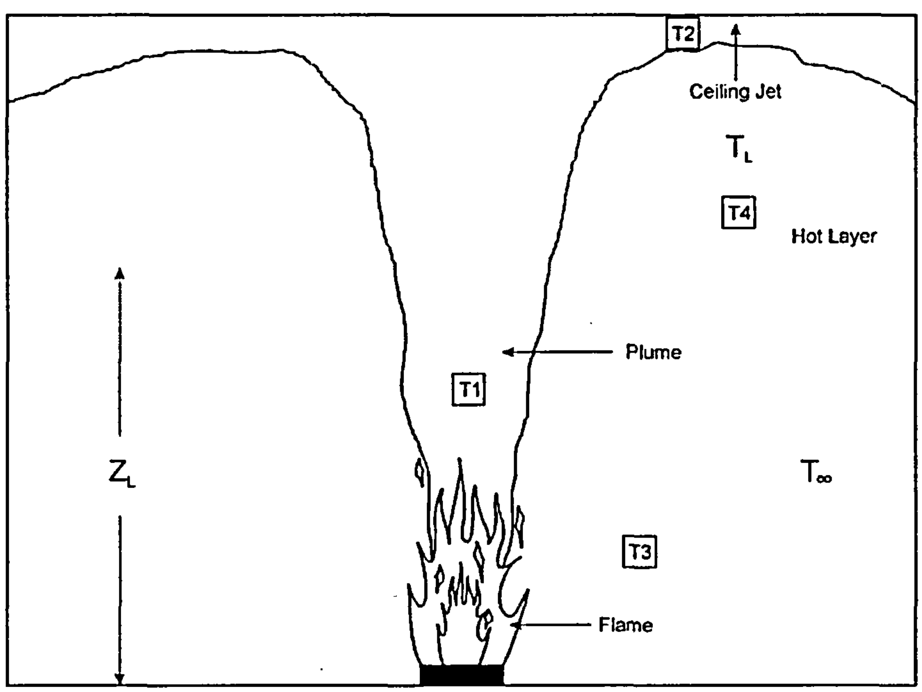


Figure 4-6. Schematic of Target Exposure Problem with Compartment Effects

4.1.3 Target Response Calculations

Damage to or ignition of target items is generally handled in two ways. In the simplest case a threshold gas temperature or critical heat flux value is used that is based on some empirical data. For example, IEEE 383 qualified cables are often assumed to fail when the heat flux exceeds 10 kW/m^2 (EPRI, 1992). Similar gas temperature criteria are also available. The second approach involves calculating the heat transfer to the target and subsequent transient heating of the target until some failure criteria is met.

The use of steady state heat flux or gas temperature failure criteria is conservative and simple. Depending on the problem under evaluation, such methods may result in excessively conservative values. The calculation of the transient heating of the target will normally result in longer predicted failure times and in many cases may be used to show that failure does not occur despite an exposure temperature that exceeds a threshold temperature value. These transient calculations are, however, subject to increasing uncertainty.

For cases where a threshold gas temperature or critical flux are used and the calculated factor of safety is not considered adequate, additional calculations involving transient heating of the target will provide a quantitative improvement in the factor of safety.

Target heating calculations can be performed using several methods. The first broad category involves exact solutions of thermally thin and semi-infinite solid surface heating problems. These are standard engineering calculations that can be applied in special cases. These calculations are embedded as target heating models in some zone models, notably MAGIC and to a lesser extent, CFAST. The second type of heating calculation involves the use of finite difference or finite element heat transfer computer codes. There are many such codes available for this application. HEATING (Childs, 1998), as an example, has been used for target heating calculations.

4.2 Fire Spread on Contiguous Combustibles

This class of problems relates to fire between fuel packages that are continuous or close enough that direct flame spread mechanisms are important. No validated model exists to calculate flame spread directly, with the possible exception of combustible wall and ceiling surfaces. Therefore, any problem involving direct flame spread must be estimated using some combination of empirical data and calculations. Flame spread on cable fires is an example of this class of problem. Methods for estimating fire growth and flame spread rate for cables are given in Section 3.4 of this Appendix.

Typically, ignition of other fuel packages may be estimated using ignition criteria (immersion temperature, surface temperature, and/or incident heat flux), and one or more of the calculation methods described in Section. If the ignition criteria are met, then it is reasonable to assume the object would ignite. If room temperatures exceed critical flashover temperatures (500°C – 600°C), then it is reasonable to assume combustible materials below the smoke layer, or in the smoke layer if there is sufficient oxygen, would ignite.

A related issue often arises when modeling electronic cabinet fires. For cases where more fire-stopped exposed cables penetrate the top of the cabinet a direct contiguous flame spread path to cable trays located above the cabinet exists and must be calculated. Any modeling or calculations done to evaluate the impact of cabinet fires should include as part of the source fire term flame spread to the cables above.

4.3 Thermal Detector Activation Time

This problem, in effect, is a calculation of the thermal response of a lumped heat capacity thermal element to a temperature and velocity field within a thermal plume or a ceiling jet. It is analogous to the target damage problem, except in this case the target has very high conductivity and low mass (e.g., a sprinkler fusible link).

The calculation of sprinkler or heat detector response time requires two steps.

1. Calculate the temperature and velocity at the detector position in the plume or ceiling jet.
2. Solve the transient heating equation for the thermal link or detector using the Response Time Index (RTI) of the thermal element.

Evaluation of the plume and ceiling jet temperatures and velocities as a function of position are done using correlations. The transient heating of the thermal element is performed using a lumped heat capacity model. The RTI is a sprinkler specific constant that is generally determined by the manufacturers. The lower the RTI value, the quicker the sprinkler will respond to a temperature increase. Generally, standard response sprinklers have RTI values that are between 80 – 110 $m^{0.5}$-$s^{0.5}$ (Budnick, 1984; Puchovsky, 1996). Quick response sprinklers can have RTI values between 40 and 60 $ft^{0.5}$-$s^{0.5}$ (Budnick, 1984; Puchovsky, 1996). The actuation temperature for ordinary sprinklers is normally between 68°C (155°F) and 74°C (165°F). Sprinkler models are available with ratings as low as 57°C (135°F) and greater than 149°C (300°F). Only ordinary sprinklers are considered in this analysis. Closed form approximations for fires with a heat release rate growth that is proportional to time squared are given by Schifiliti et al. (2002).

Sprinkler and thermal detector actuation models are for flat open ceiling configurations, a notable example of which is DETACT-QS (Evans et al., 1985; 1986; Portier et al., 1996). DETACT-QS calculations have been compared to experimental data in several studies. These studies include Madryzykowski (1993) and Walton et al. (1993). In general, the DETACT-QS model performs well considering the inherent uncertainty in the some of the input parameters, such as the sprinkler RTI value and the actual source fire heat release rate. In some instances, the effects of a hot layer were found to be significant and should be included in the evaluation (Madrzykowski, 1993).

The activation of smoke detectors can be treated in an analogous way. There are two basis methods: the Temperature Rise Method and the Optical Density Method (Schifiliti et al., 2002; NFPA 72, 1999). The Temperature Rise Method assumes that the optical density to temperature rise ration remains constant for a given fuel and combustion mode (Heskestad et al., 1977). The latter part of this definition is often ignored and a temperature rise of 10°C – 15°C are used as the alarm thresholds for all detectors and fires (Schifiliti et al., 2002). The assumed relationship has little or not basis (Beyler et al., 1991; Schifiliti at al., 1996) and there is data suggesting that detectors may alarm at temperature rises as low as 1°C (Mowrer et al, 1998; Gottuk et al., 1999; Wakelin, 1997).

The Optical Density Method involves calculating the smoke concentration at the detector and comparing the smoke level to an alarm threshold for the detector. Using the mass loss of the fuel, the volume into which the smoke accumulates, and an empirically derived fuel constant, an optical density may be computed. Typically, a zone model or a CFD model is used for this type of calculation. Alarm thresholds vary much as RTI values vary with a sprinkler. Data is available for average and bounding values (Gottuk et al., 1999; Ross-Phersson et al., 2000; Wong et al., 2000). Uncertainty in this calculation arises from the source fire mass loss and smoke yield and the sensitivity of the detection device.

4.4 Tenability Calculations

These calculations refer to calculating the conditions under which personnel would be threatened. They arise from these primary effects, reduction in visibility due to smoke, effects of temperature or heat flux and the effects of toxic gases.

Visibility is a function of the optical density of the smoke in a hot layer, which in turn is a function of the mass of material burned, the soot properties of the material, and the volume of material occupying the area of concern. It is either directly calculated in the model or can be readily calculated from the results of either zone or modeling. It requires the specification of accurate soot yield and soot optical properties as input data. Methods for calculating visibility are given by Mulholland (2002) and Jin (2002).

Temperature effects are based on time/temperature relationships for human exposure. Data on limiting thermal radiation and temperature conditions for human exposure can be found in Beyler (2002) and Purser (2002). These data indicate tolerance levels of 110°C for between 10-25 minutes in dry air.

Toxicity assessments are normally not required in NPP applications. Calculation methods are available to estimate time to incapacitation for combination of fire products including CO, CO_2, HCl, acrolein and formaldehyde, using a Fractional Effective Dose, or FED approach. These methods can be readily applied using the results of zone and CFD models. Purser (2002) provides a methodology for estimating time to incapacitation.

4.5 Suppression Effects

The effects of fire suppression systems on fire growth rate, room temperature conditions, etc. can only be crudely accounted for using existing zone and CFD models. CFAST uses completely empirical measured room temperature and heat release rate reductions values based on a limited set of sprinkler tests (Jones et al., 2000). This method cannot be used in general. CFD codes have been used in special applications to calculate the effects of sprinkler and water spray systems. The use of models for routine design or analysis purposes is currently not possible.

To account for suppression effects one is forced to rely on full-scale test data from tests that approximate the conditions being evaluated. A very crude but conservative approximation would be to hold the heat release rate constant at the time of sprinkler operation. Alternatively, one could specify a cooling rate based on relevant full-scale test data.

4.6 Flashover Calculations

The potential for flashover to occur is of interest when assessing whether of not room contents are damaged or lost and fire spread across rated and unrated boundaries is possible. These types of calculations may be used in combination with other assessments, such as estimating if automatic suppression occurs prior to flashover or when preparing a time line for a fire scenario.

These calculations are used to quickly determine the minimum heat release rate necessary to cause flashover. Flashover typically occurs when the hot layer temperature exceeds 500-600°C, and effectively marks the location in a fire development history where the fire becomes ventilation limited. Flashover is characterized by rapid ignition of available fuel surfaces, primarily due to exposure to thermal radiation (Walton et al., 2002).

There are several methods available for estimating the potential for flashover. There are several screening methods that perform an energy balance between the compartment volume, the energy loss through the boundaries and openings, and the source fire heat release rate (Walton et al., 2002). These methods generally do not consider ventilation aspects other than as a source of energy loss. These methods may be used to determine a minimum fire size necessary to reach a flashover condition. More detailed screening methods provide a fire size and time to flashover at the particular fire size (Walton et al., 2002). A determination as to whether or not the minimum flashover fire size is possible based on the existing combustible fuel packages is then made. Section 6.1 provides references for evaluating fire sizes. If the minimum flashover fire size is possible, an assessment of the duration in combination with the minimum fire size is then necessary, namely is there a sufficient quantity of fuel available to sustain the fire long enough to cause flashover. Flashover screening calculations may be computed from correlations (Walton et al., 2002) or from software such as FASTLite (Portier et al., 1996) and Iqbal (2002; 2003). Note that these types of software calculations are not currently validated for applications in nuclear power plants, however used within the proper limitations and with adequate documentation and validation they should be satisfactory.

The potential for flashover may also be evaluated using zone and CFD computer models. Zone models essentially perform the same type of energy balance as the screening calculations but typically include more detailed source fire, boundary heat loss, and volume terms. One significant improvement that zone and CFD models have over the screening correlations is that they will determine whether or not a particular fire size is possible given the ventilation conditions. Thus, if a flashover correlation identifies a minimum fire size necessary to cause flashover, and it is concluded that a fuel package is present that would have such a heat release rate, a zone or CFD model may be used to ascertain whether or not this heat release rate can be sustained given the ventilation.

4.7 Post-Flashover Temperature Calculations

These calculations are a special case of compartment fire temperature calculations. They normally used in cases where flashover is assumed/predicted and the primary variable of interest is the room temperature. This temperature is usually used to evaluate the fire resistance of structural elements or a fire barrier. Most post-flashover calculations assume that the energy release rate of these fires is limited by the air inflow available (ventilation limited burning). While zone and CFD models can be used for calculating post-flashover temperatures, time/temperature relationships have already been calculated and are available in table and graphical form (Milke, 2002). In addition, zone models often significantly over-predict layer temperatures in post flashover conditions.

In addition to those data, post-flashover temperature calculations may also be estimated using methods given by Walton et al., (2002) and Iqbal et al. (2002; 2003). An example of a post-flashover fire model is COMPF2 (Babrauskas, 1985), which was developed for evaluating the compartment temperature under these circumstances.

4.8 Compartment to Compartment Fire Spread

The potential for compartment to compartment fire spread may be used estimate impacts of a fire in areas beyond the initial fire area. Compartment to compartment fire spread may occur through a number of means:

- Fire spread across unrated construction.
- Compromising a fire barrier.
- Compromising a penetration seal.
- Thermal radiation.
- Smoke products.

Fire spread across boundaries may be the result of a flashover condition in the room of origin or the development of a hot spot on the unexposed side due to a localized fire exposure. There are several approaches available for estimating the likelihood and time lag for inter-compartment fire spread.

Fire spread across unrated construction generally should be assumed if the room of origin reaches flashover conditions. In some cases, a time lag may be assigned based on test data. An example of this would be 5/8 inch gypsum on steel stud construction, which typically provides about 20 minutes fire resistance per layer. An alternate approach, if the construction is well sealed, would be to evaluate the transient temperature profile through the material/assembly using a conduction model. The exposure could be determined from a fire model (zone, CFD) or from estimates based on the fuel load and ventilation conditions. If a localized exposure is expected, correlations based on the fire size may be used in lieu of compartment temperature data. Fire spread is assumed when the unexposed side of the boundary exceeds an ignition threshold, typically 325°F for Class A combustible material [ASTM E119, 1999].

Fire spread across fire barriers and rated penetration seals is normally assumed if a post-flashover fire exposure exceeds the rating of the fire barriers or seals. Thus, if a 4 hour fire post-flashover fire is postulated in a space, then fire spread across a 3 hour fire barrier is likely. Unfortunately, the exposure fire rarely corresponds to the ASTM E119 Standard Time-Temperature Curve, such that fire spread across the boundary does not necessarily correspond to the listed rating. In many cases, the ASTM E119 temperature profile is more severe, but this is not always so. The most practical means of predicting the time fire spreads across a boundary in the absence of a specific test is to perform a thermal analysis given the exposure temperature/heat flux. Once the unexposed temperature of the boundary or the seal exceeds the critical ignition temperature, typically 325°F (but greater in some cases if the combustibles are cables in a penetration seal), the fire spread should be assumed. Consideration should be given for a localized exposure in combination with a room wide post-flashover exposure.

Other means by which compartment to compartment fire spread could occur is thermal radiation from a source fire or hot combustion products entering an area and igniting combustible materials. These types of fire spread would occur only under specialized circumstances. For example, large external fire separated from a building by a fixed distance may radiate sufficient energy so as to spread into the structure either through window or door openings or unrated construction. Fire spread by a hot smoke layer could occur if a space that is open to a corridor or other type of intervening space normally free of combustibles reaches flashover conditions. The smoke products spread into the corridor and other areas adjacent to this corridor. If the smoke is sufficiently hot, it may ignite combustible materials either directly or via thermal radiation. These types of scenarios generally require radiation calculations and/or computer fire models to adequately assess.

5.0 Validation of Engineering Methods

The limits of the various types of models have been described in a broad sense throughout this Appendix, particularly in the context of the applications discussed in Section 4. This section identifies additional limits and considerations as well as model validation.

There are no fire-related engineering methods or models that have been validated over the entire range of applications for which they might reasonably be used by the NRC or within the fire protection community in general. There have been and are substantial and ongoing efforts directed at performing validation studies on various calculation methods and models (Beall, 1997; Dey, 2002). ASTM E-1355 (1997) gives general guidance on evaluating the predictive capability of fire models.

NRC is currently in the process of verifying and validating several fire models and plans to develop a pool of acceptable fire models and acceptable applications of these fire models using the ASTM E-1355 (1997) Standard (Dey, 2002). In the absence of such a pool, adequate documentation will be necessary that demonstrates the appropriateness of the model, the application of the model, and the overall approach to evaluating the problem.

<u>Engineering Calculations</u>

Most calculation procedures are based on correlations of experimental data. These include relationships for determining the flame radiation, plume and ceiling jet temperature and velocity, flashover calculations, and so on (DiNenno, 2002; Drysdale, 1999). These correlations are based on full-scale test data and are expected to give reasonable results within the limits of the mathematical model on which they are based. When using correlations, it should be verified that application is within the proper limitations. It is reasonable to use these correlations for most NPP applications and they are primarily limited by uncertainty beyond the range of the data set on which they are correlated. In NPP applications, this is often occurs when dealing with spaces that have a very large ceiling heights (over 30 to 40 ft), highly obstructed flow paths, or very large fires in large spaces (e.g. turbine halls).

Zone Models

Zone type fire models have been extensively compared to experimental data for a range of applications, including those associated with NPPs (Floyd, 2002; Dey, 2002; Jones et al., 2000; Peacock et al., 1993; Nelson et al., 1991; and Dembsey et al., 1995). An ongoing project supported by the NRC has conducted an international set of validation studies for a range of zone and CFD codes for typical NPP applications (Dey, 2002). These validation data sets include room sizes up to 1,300 m^3, fire sizes between 100 kW to 2.5 MW, and a range of fire sources. Thus far, the project has found that many of the models evaluated, including CFAST and MAGIC, give reasonable results for the applications considered.

CFD Models

CFD models have been subjected to many validation studies, primarily for non-nuclear applications (Cox et al., 2002; Floyd, 2002; Cox et al., 1986; McGrattan et al., 1998a, Miles et al., 1999). As noted above, there is currently an effort to study the predictions of both zone and CFD models in NPP related applications being performed under an NRC-supported international model evaluation project (Dey, 2002). Preliminary results indicate that CFD models such as FDS, JASMINE, and VULCAN provide reasonable temperature profiles for some types of fire and spaces that are typical of NPPs. Much of the variation in the model results was noted to be a direct result of the manner in which the user applied the model to the scenario (Dey, 2002). The major advantage of CFD codes relative to validation is that they, as a group, are inherently less dependent on empirical data or approximations. The codes utilizing large eddy simulation (LES) methods to predict the turbulent flow behavior of fire-induced flows do so without the need for direct manipulation of the turbulence characteristics and are thus readily adapted for simulating smoke conditions. CFD codes that use other types of turbulence sub-models, such as the *k*-, method, may require correlated turbulence parameters and may require additional validation for a particular application. The implementation of certain physical phenomena or sub-models, notably thermal radiation, is a weak point in these types of models, especially for flame radiation.

Summary

Calculation methods and models have been validated to an adequate level for most NPP-related problems subject to the overall caveat that the fire source term can be specified a priori. Cases of interest where there is insufficient validation and substantial uncertainty are primarily associated with large spaces (over 2,000 m^3) and large fire sources (over 10 MW). There have been no validation studies that would approximate a large multi-level fire in a turbine hall. There is no theoretical reason that models should not adequately treat these cases, and larger scale validation tests may be necessary. Adequate validation of calculation methods and models largely remains one of balancing the uncertainty in the calculations with adequate factors of safety applied to the results.

Appendix D – Fire Modeling

6.0 Sources of Input Data

Summarized below are particularly useful references for input data sources related to heat release rate, thermal property data and methods, ignition and damage criteria and flame spread.

6.1 Data Sources for Input Data for Heat Release Rates

Heat release rate data may be based on full or small-scale experiments or it may be deduced using methods or models previously described. Sources of data, including experimental heat release rate measurement and parameters used to calculate the heat release rate, are provided below.

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6.2 Data Sources for Thermal Property Input

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6.3 Input Sources for Ignition/Damage Thresholds

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Appendix E – Monitoring

As discussed in Sections 4.5.3 and 5.2, it is expected that a monitoring program for a risk-informed, performance-based fire protection program would be established in phases, with elements added as more of the program relies upon risk-informed, performance-based techniques. For example, during the transition to a new licensing basis, a plant may only truly employ risk-informed, performance-based techniques to address a few fire areas or fire protection features/elements. It is important to identify parts of the program that may require additional attention during the transition and change evaluation process. Likely candidates would include monitoring of nuclear safety equipment that is not part of the traditional 10 CFR 50, Appendix R post-fire safe shutdown analysis and whose availability is an important component of limiting fire risk. Other attributes may include features that are integral to successful fire modeling in an area, but may not have been considered important in a compliance-based approach.

A suggested methodology is outlined below:

1. Identify all of the fire protection systems and features and "nuclear safety equipment" relied on to demonstrate compliance with NFPA 805. Start from the current systems and features relied on to demonstrate compliance with the CLB and make the additions and deletions necessary as derived from the analysis conducted for the transition to the NFPA 805 licensing basis.

2. Establish the performance criteria for the availability and reliability of fire protection systems and features relied on to demonstrate compliance. In fire areas for which compliance is based on previous NRC approval of compliance with deterministic requirements, the concepts of availability and reliability do not necessarily apply, e.g., suppression systems are always assumed to operate. In these areas, existing surveillance and testing may be assumed to be adequate.

   In fire areas for which compliance is established by applying risk-informed techniques, use the assumptions in the risk analyses to establish these criteria. Where criteria already have been established for other purposes, such as compliance with the Maintenance Rule or the Technical Specifications, review those criteria for acceptability. If any differences between the existing criteria and the assumptions in risk calculations do not materially affect a demonstration of compliance with NFPA 805, adopt the existing criteria and document the basis for that adoption. If the differences do materially affect compliance with NFPA 805, either adopt different criteria or modify the fire protection program, whichever is easier.

3. Use the methods established for monitoring compliance with the Maintenance Rule and/or Technical Specifications to monitor the availability, reliability and performance of fire protection systems and features. In particular, use the Maintenance Rule methods for considering plant operating experience and industry operating experience.

4. Establish a catalog of the engineering assumptions made to demonstrate that systems and features provide compliance with NFPA 805. Include the review of these assumptions in the established process for reviewing changes made to the plant or its programs. Where a review shows that an assumption will no longer be valid, determine whether the result materially affects compliance with NFPA 805. If not, document that conclusion. If so, modify either the proposed change or the fire protection program.

5. Review the corrective action program to determine whether the current spectrum of deficiencies and corrective actions is appropriate for the risk-informed, performance-based fire protection program. Use risk analyses to determine appropriateness of the existing program elements. Include in that analysis the impact of deficiencies on the engineering assumptions. Where the range of deficiencies and/or timing and nature of the corrective actions is insufficient, modify the corrective action program accordingly, as it will be applied to fire protection findings of deficiencies. Perform the same process for the program used to determine effectiveness of the corrective action program.

Appendix F – Considerations for Non-Power Operational Modes

To begin the process of assessing the fire protection requirements for non-power modes of operation discussions should be held between the Probabilistic Risk Assessment (PRA), the Fire Protection, and the Outage Management staffs to determine the best way to integrate NFPA 805 fire protection aspects into existing Outage Management Processes.

The current industry approaches for evaluating risk during shutdown conditions involves both quantitative and qualitative assessments and is based on NEI 93-01 and NUMARC 91-06. To transition to the NFPA 805 Licensing Basis, the licensee must demonstrate that the nuclear safety performance criteria are met for High Risk Evolutions (HREs as defined by NUMARC 91-06) during non-power operational modes. To accomplish this the following tasks need to be accomplished. These should be documented using Table F-1.

- Review existing plant outage processes (outage management and outage risk assessments) to determine equipment relied upon to provide Key Safety Functions (KSF) including support functions. Each outage evolution identifies the diverse methods of achieving the KSF. For example to achieve the Decay Heat Removal KSF a plant may credit DHR Train A, DHR Train B, HPI Train A, HPI Train B, and Gravity Feed and Chemical and Volume Control.

- Identify locations where 1) fires may cause damage to the equipment (and cabling) credited above, or 2) recovery actions credited for the KSF are performed (for those KFSs that are achieved soley by recovery action i.e., alignment of gravity feed).

- Identify fire areas where a single fire may damage all the credited paths for a KSF. This may include fire modeling to determine if a postulated fire (MEFS – LFS) would be expected to damage equipment required.

- For those areas consider one or more of the following options to mitigate potential fire damage depending upon the significance of the potential damage:
  - Prohibition or limitation of hot work in fire areas during periods of increased vulnerability
  - Verification of operable detection and /or suppression in the vulnerable areas.
  - Prohibition or limitation of combustible materials in fire areas during periods of increased vulnerability
  - Provision of additional fire patrols at periodic intervals or other appropriate compensatory measures (such as surveillance cameras) during increased vulnerability
  - Use of recovery actions to mitigate potential losses
  - Identification and monitoring insitu ignition sources for "fire precursers" (e.g., equipment temperatures).

It is important to note the evaluation of the plant during non-operational modes is qualitatively risk-informed at this time pending the development of shutdown PRAs.

Table F-1

NFPA 805 Chapter 1 – Non-Power Operational Guidance

NFPA 805 Requirements	Implementing Guidance	Results
Radiation release to any unrestricted area due to the direct effects of fire suppression activities (but not involving fuel damage) shall be as low as reasonably achievable and shall not exceed applicable 10 CFR Part 20, limits.	▪ Review existing plant outage processes (outage management and outage risk assessments) to determine equipment relied upon to provide Key Safety Functions (KSF) including support functions. Each outage evolution identifies the diverse methods of achieving the KSF. For example to achieve the Decay Heat Removal KSF a plant may credit DHR Train A, DHR Train B, HPI Train A, HPI Train B, and Gravity Feed and Chemical and Volume Control..	▪ List the KSFs and the systems / components required to support those function. ▪ Identify those systems / components that require additional analyses. For example, a KFS may rely on instrumentation that is currently not part of the "Safe Shutdown Analysis", or a component may have been modeled in one position (closed, off, etc.) but to support the KFS it would need to be evaluated in an additional positions (open, on, etc.) ▪ For those additional components, perform circuit analysis, location tasks described in Appendix B. Document the results.
	▪ Identify locations where 1) fires may cause damage to the equipment (and cabling) credited above, or 2) recovery actions credited for the KSF are performed (for those KFSs that are achieved soley by recovery action i.e., alignment of gravity feed).	▪ Evaluate on a fire area basis the loss of KSFs. Document those areas
	▪ Identify fire areas where a single fire may damage all the credited paths for a KSF. This may include fire modeling to determine if a postulated fire (MEFS – LFS) would be expected to damage equipment required.	▪ For the areas identified above, determine if a single fire in the area can cause a loss of all credited paths for a KFS. ▪ Conservatively, assume the entire contents of a fire area are lost. If this does not result in the loss of all credited paths for a KFS, document success. ▪ If fire modeling is used to limit the damage in a fire area, document that fire modeling is credited and ensure the basis for acceptability of that model (location, type, and quantity of

Table F-1 NFPA 805 Chapter 1 – Non-Power Operational Guidance		
NFPA 805 Requirements	**Implementing Guidance**	**Results**
		combustible, etc.) is documented. These critical design inputs are required to be maintained during outage modes. See next step below.
	▪ For those areas consider one or more of the following options to mitigate potential fire damage depending upon the significance of the potential damage: o Prohibition or limitation of hot work in fire areas during periods of increased vulnerability o Verification of operable detection and /or suppression in the vulnerable areas. o Prohibition or limitation of combustible materials in fire areas during periods of increased vulnerability o Provision of additional fire patrols at periodic intervals or other appropriate compensatory measures (such as surveillance cameras) during increased vulnerability o Use of recovery actions to mitigate potential losses o Identification and monitoring insitu ignition sources for "fire precursers" (e.g., equipment temperatures).	▪ Integrate the results of the analysis performed above into the plant's outage management process. ▪ To the extent practical pre-plan the options for achieving the KFS. See list to the left.

Appendix G – Considerations for Radioactive Release

The treatment of radiological release to any unrestricted area due to fire is focused on potential radioactive release due to potential fuel damage and fire fighting activities:

- The Nuclear Safety Goal, Objectives, and Performance Criteria all require the prevention of fuel cladding damage. As such, radiological release due to fuel damage should not require a separate examination since no such damage is assumed to occur without violating the basic requirements of NFPA 805. This effectively limits the source of radiation (release source term). Therefore, containment integrity should not require specific examination. This means the scope of the fire protection analyses do not need to be expanded to include all containment isolation valves. No additional analyses are needed.
- The potential for radiological release due to fire fighting activities shall be addressed via fire pre-plans. The objective is to address the potential for the loss of boundary control for contaminated spaces

Evaluation of the Potential for Radiological Release Due to Fire Fighting Activities

- **Review pre-fire plans.** Ensure for locations that have the potential for contamination that specific steps are included for containment and monitoring of potentially contaminated fire suppression water. Update pre-fire plans as necessary.
- **Review fire brigade training materials.** Ensure that training materials deal specifically with the containment and monitoring of potentially contaminated fire suppression water. Update training materials as necessary.
- **Document results in Transition Table G-1.**

Table G-1 NFPA 805 Chapter 1 – Radioactive Release Transition Review Guidance		
NFPA 805 Requirements	**Implementing Guidance**	**Results**
Radiation release to any unrestricted area due to the direct effects of fire suppression activities (but not involving fuel damage) shall be as low as reasonably achievable and shall not exceed applicable 10 CFR Part 20 limits.	**Review pre-fire plans.** Ensure for locations that have the potential for contamination that specific steps are included for containment and monitoring of potentially contaminated fire suppression water. Update pre-fire plans as necessary.	Describe how the pre-fire plans do (or will) provide guidelines for the containment and monitoring for potentially contaminated fire suppression water.
	Review fire brigade training materials. Ensure that training materials deal specifically with the containment and monitoring of potentially contaminated fire suppression water. Update training materials as necessary.	Describe how the fire brigade training materials do (or will) provide instruction for the containment and monitoring for potentially contaminated fire suppression water.

Appendix H-1 - Template: Letter of Intent to Adopt NFPA 805 as a Risk-Informed, Performance-Based Alternative for Fire Protection Requirements

[Date]

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Document Control Desk

Subject: [Facility Name]
[Facility Docket numbers]
Adoption of NFPA 805 (Performance-Based Standard for
Fire Protection for Light Water Reactor Generating
Plants, 2001 Edition)

This letter serves to inform you of [Facility Name] intent to adopt NFPA 805 (Performance-Based Standard for Fire Protection for Light Water Reactor Generating Plants, 2001 Edition)in accordance with 10 CFR 50.48(c).

The transition to the performance-based standard for fire protection is expected to commence in [month/quarter, year] and take [total estimated time (in months)] to fully implement. The activities that need to be performed in order to support this transition includes [Outline the activities that are needed to support the transition. Also include a timetable with the anticipated completion date for transition milestones and implementation phase activities.] This schedule is subject to change depending on the extent to which the plant determines that it needs to make either physical modifications or changes to the fire protection program to comply with NFPA 805. An updated schedule will accompany the license amendment request required under 10 CFR 50.48(c)(3)(i).

{*Optional statement regarding enforcement discretion. This statement may not be needed if the NRC issues an Enforcement Guidance Memorandum (EGM) which would provide such discretion.*

It is our understanding that this letter of intent initiates a period of enforcement discretion during which no enforcement actions will be taken for non-compliances discovered as a result of evaluations conducted to support this licensing basis transition process.}

Appendix H-2 - Template: License Amendment Request to Authorize Adoption of NFPA 805 with Optional Provision for Alternative Methods and Analytical Approaches

[Date]

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Document Control Desk

Subject: [Facility Name]
[Facility Docket numbers]
License Amendment Request to Adopt NFPA 805, Performance-Based Standard for Fire Protection for Light Water Reactor Generating Plants, 2001 Edition)

Pursuant to Title, Code of Federal Regulations (CFR), Part 50, Section 90 (10 CFR 50.90), [Facility Name] proposes to amend Appendix A, Technical Specifications (Tech Specs), for Facility Operating Licenses [License Numbers] for [Facility Name]. [Identify the Technical Specifications that need to be amended (including changes to the bases).] This amendment is needed to support the adoption of NFPA 805 Performance-Based Standard for Fire Protection, 2001 Edition in accordance with 10 CFR 50.48(c). The proposed License Amendment Request (LAR) revises the licensing basis associated with the Fire Protection Program.

The following process was used to determine that these are the only Technical Specifications that require amendment. [Describe the process.]

In addition, [Facility Name] also requests that the license be amended to remove the following superseded license conditions [identify license conditions to be superseded] and replace them with the following suggested license condition authorizing the use of NFPA 805. The following process was used to identify all of the license conditions that are required to be removed. [Describe the process used to ensure completeness of the set of license conditions that are required to be removed.]

As a separate but related matter, [Facility Name] has identified the following unnecessary or superseded orders and exemptions that are required to be revoked. [Identify orders and exemptions]. The following process was conducted to identify all of the orders and exemptions that are required to be revoked. [Describe the process used to ensure completeness of the set of orders and exemptions that are required to be revoked.]

[Optional provisions for alternative methods and analytical approaches.] Alternative methods and analytical approaches have been used to demonstrate compliance with certain requirements in NFPA 805. The following table lists those requirements and the alternative method and analytical approach applied to each. A detailed analyses demonstrating how an alternative method and analytical approach demonstrates compliance for each such requirement is provided in the attachments.

Implementation of this amendment to the [Facility Name] operating license and Tech Specs will impact the [Facility Name] UFSAR. As a result of implementing this LAR, it will be necessary to revise various sections of the [Facility Name] UFSAR. Necessary changes will be made in accordance with 10 CFR 50.71(e).

Plant modifications are/are not necessary to support the adoption of NFPA 805. [Provide a brief description of the modifications].

[Facility Name] plans to implement this/these modification(s) by the dates shown in the following updated transition schedule. [Insert update of schedule provided in letter of intent] Approval of this proposed LAR is requested by [month, day, year] to support this transition schedule.

Implementation of these changes will not result in an undue risk to the health and safety of the public.

Attachments:

Detailed Analyses of Compliance Using Alternative Methods and Analytical Approaches
No Significant Hazards Consideration
Environmental Impact Assessment

Optional Attachment

Detailed Analysis Demonstrating Compliance with
[Identify NFPA 805 Requirement]

Using the Alternative Method and Analytical Approach [Describe]

NFPA 805 [cite to requirement] requires [describe requirement]. Compliance with this requirement is demonstrated below using the following alternative method and analytical approach [describe the alternative method and analytical approach]. Compliance with the nuclear safety performance criteria, performance objectives and goal are achieved as follows:

Nuclear Safety Performance Criteria

- 1.5.1(a) Reactivity Control. [Explain basis for compliance or why not applicable.]
- 1.5.1(b) Inventory and Pressure Control. [Explain basis for compliance or why not applicable.]
- 1.5.1(c) Decay Heat Removal. [Explain basis for compliance or why not applicable.]
- 1.5.1(d). Vital Auxiliaries. [Explain basis for compliance or why not applicable]
- 1.5.5(e) Process Monitoring [Explain basis for compliance or why not applicable.]

Nuclear Safety Objectives

- 1.4.1(1) Reactivity Control. [Explain basis for compliance or why not applicable.]
- 1.4.1(2) Fuel Cooling. [Explain basis for compliance or why not applicable.]
- 1.4.1.(3) Fission Product Boundary [Explain basis for compliance or why not applicable.]

Nuclear Safety Goal

- 1.3.1 Nuclear Safety Goal. [Explain basis for compliance or why not applicable.]

Compliance with the radioactive release performance criterion, performance objective, and goal are achieved as follows. [Explain basis for compliance or why not applicable.]

Maintenance of safety margins is achieved as follows. [Explain].

Fire protection defense in depth is maintained as follows. [Explain for fire prevention, fire suppression, and post-fire safe shutdown capability, as appropriate.]

Attachment

No Significant Hazards Consideration Finding

Pursuant to 10 CFR 50.91, [company name] has made the determination that, based on the following NRC statements in the Statements of Consideration accompanying the adoption of alternative fire protection requirements, and other considerations, this amendment request involves No Significant Hazards Consideration under the standards established by the NRC in 10 CFR 50.92. This ensures that, the operation of the facility in accordance with the proposed amendment would not:

To the extent that these conclusions apply to compliance with the requirements in NFPA 805, these conclusions are based on the following NRC statements in the Statements of Consideration accompanying the adoption of alternative fire protection requirements based on NFPA 805. The NRC stated that:

1. Involve a significant increase in the probability or consequences of an accident previously evaluated
   NFPA 805, taken as a whole, provides an acceptable alternative for satisfying General Design Criterion 3 (GDC 3) of Appendix A to 10 CFR Part 50, meets the underlying intent of the NRC's existing fire protection regulations and guidance, and achieves defense-in-depth and the goals, performance objectives, and performance criteria specified in Chapter 1 of the standard and, if there are any increases in core damage frequency (CDF) or risk, the increase will be small and consistent with the intent of the Commission's Safety Goal Policy. [cite]

2. Create the possibility of a new or different kind of accident from any kind of accident previously evaluated

   The requirements in NFPA 805 address only fire protection and the impacts of fire on the plant have already been evaluated.

3. Involve a significant reduction in the margin of safety.
   NFPA 805 continues to protect public health and safety and the common defense and security because the overall approach of NFPA 805 is consistent with the key principles for evaluating license basis changes, as described in Regulatory Guide 1.1.74, is consistent with the defense-in-depth philosophy, and maintains sufficient safety margins and [cite]

To the extent that the conclusions regarding no significant hazards considerations apply to demonstrations of compliance based on the use of alternative methods and analytical approaches, these conclusions are supported by the following demonstrations that the regulatory criteria are met:

Use of [name the alternative method and analytical approach used] to demonstrate compliance with the requirement in [cite to the requirement] does not involve a significant increase in the probability or consequences of an accident previously evaluated because [explain why not].

Use of [name the alternative method and analytical approach used] to demonstrate compliance with the requirement in [cite to the requirement] does not create the possibility of a new or different kind of accident from any kind of accident previously evaluated because [explain why not].

Use of [name the alternative method and analytical approach used] to demonstrate compliance with the requirement in [cite to the requirement] does not involve a significant reduction in the margin of safety because [explain why not].

Accordingly, Licensee/Station's adoption of the new fire protection rule based on NFPA 805 does not present a significant hazards consideration.

Attachment

Environmental Assessment

Pursuant to 10 CFR 51.22(b), an evaluation of the license amendment request (LAR) has been performed to determine whether it meets the criteria for categorical exclusion set forth in 10 CFR 51.22(c). The LAR does not involve:

1) A significant hazards consideration.

   This conclusion is supported by the determination of no significant hazards consideration.

2) A significant change in the types or significant increase in the amounts of any effluents that may be released offsite.

   Compliance with NFPA 805 explicitly requires the attainment of performance criteria, objectives, and goals for radioactive releases to the environment. Therefore, this LAR will not change the types or amounts of any effluents that may be released offsite.

3) A significant increase in the individual or cumulative occupational radiation exposure.

   Compliance with NFPA 805 explicitly requires the attainment of performance criteria, objectives, and goals for occupational exposures. Therefore, this LAR will not change the types or amounts of occupational exposures.

In summary, this LAR meets the criteria set forth in 10 CFR 51.22(c)(9) for categorical exclusion from the need for an environmental impact statement.

Appendix H-3 - Template: Transition Report Outline

The following is a sample outline for the licensee transition report:

1.0 Introduction

The Nuclear Regulatory Commission (NRC) has adopted a voluntary alternative rule for fire protection requirements at nuclear power plants, 10 CFR 50.48(c). [Licensee/Station] has conducted the process for transitioning from its current fire protection licensing basis to compliance with the new requirements. This document describes the transition process applied by Licensee/Station and the results that demonstrate compliance with the new voluntary requirements.

1.1 Background

In 2001, the National Fire Protection Association (NFPA) adopted NFPA 805, Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants. On [date], the NRC promulgated 10 CFR 50.48(c) as voluntary, alternative performance-based fire protection requirements based on NFPA 805. subsequently, on [date], the NRC endorsed the Nuclear Energy Institute's (NEI) *Guidance for Implementing A Risk-Informed, Performance-Based Fire protection Program Under 10 CFR 50.48(c, NEI-0402 [date].*

Licensee/Station determined to transition its fire protection licensing basis to the performance-based alternative in 10 CFR 50.48(c). A letter of Intent was submitted to the NRC on [date]. Thereafter, work began on the transition. A License Amendment Request was submitted on [date]. The NRC granted the license amendment on [date]. Since then, Licensee/Station completed its implementation of the methodology in Chapter 2 of NFPA 805 (including all required evaluations and analyses) and modified the fire protection plan required by 10 CFR 50.48(a) to comply with NFPA 805. Accordingly, Licensee/Station transitioned to the new fire protection licensing basis on [date]. This report documents the transition process and new fire protection licensing basis.

1.2 Purpose and Scope

The purposes of this report are to: (1) describe the process implemented by Licensee/Station to transition its fire protection program to demonstrate compliance with the requirements in 10 CFR 50.48(c); (2) summarize the results of Licensee/Station's transition process; (3) explain the bases for Licensee/Station's conclusions that its current fire protection program, with certain modifications, comply with those requirements; and (4) to describe the new fire protection licensing basis. Licensee/Station's transition process was based on NEI's implementing guidance.

2.0 Overview of Existing Fire Protection Program

2.1 Current Fire Protection Licensing Basis

Licensee/Station was licensed to operate [date]. As a result, Licensee/Station's fire protection licensing basis is based on compliance with [state regulatory basis for regulatory requirements, i.e., Appendix R, or SRP (NUREG-0800), and license condition]. Licensee/Station's current fire protection licensing basis was approved by the NRC in a Safety Evaluation Report dated [date] as supplemented by [citations to any SER supplements. Licensee/Station also received the following exemptions from fire protection requirements [list exemptions].

2.2 Applicable Regulatory Requirements

[Insert a list of applicable regulatory requirements]

3.0 Transition Process

The process for transitioning from compliance with the current fire protection licensing basis to the new requirements is described in general in Section 4.0 of the implementing guidance. It contains the following steps: (1) licensee determination to transition the licensing basis and devote the necessary resources to it; (2) Letter of Intent to the NRC stating the licensee's intention to transition the licensing basis in accordance with a tentative schedule; (3) licensee conduct of the transition process to determine the extent to which the current fire protection licensing basis supports compliance with the new requirements and the extent to which additional analyses, plant and program changes, and alternative methods and analytical approaches are needed; (4) filing of License Amendment Request (LAR); and (5) completion of transition activities and adoption of the new licensing basis consistent with the NRC's grant of the license amendment.

Licensee/Station followed this transition process. The Letter of Intent is not discussed because it was superseded by implementation of the transition process. Analyses and plant and program changes that did not require license amendments were made as described in the appropriate sections below.

3.1 License Amendment Request and License Amendment

The LAR identified all orders, license conditions, Technical Specifications and their bases that were required to be revised or superseded to permit the Licensee/Station to comply with the new fire protection requirements.

The following orders, license conditions and Technical Specifications were superseded. [list]

The following orders and license conditions were revised as follows. [insert table of original orders and license conditions with revisions side-by-side].

The following Technical Specifications and their bases were revised as follows. [insert table of original Technical Specifications and their bases with revisions side-by-side].

[Optional] The LAR included requests to use the following alternative methods and analytical approaches to demonstrate compliance with certain requirements in NFPA 805. [List the alternative methods and analytical approaches for which license amendments were requested and their associated requirements.]

On [date], the NRC issued a license amendment which authorized Licensee/Station to use the alternative methods and analytical approaches described in the LAR, approved the proposed changes to the Technical Specifications, made all necessary revisions to orders and license conditions, and approved the use of NFPA 805 as the fire protection licensing basis for Licensee/Station.

3.2 Implementation of NFPA 805, Section 2.2: General Approach

Section 2.2 of NFPA 805 establishes the general process for demonstrating compliance with NFPA 805. The process is illustrated in Figure 2.2 of NFPA 805. It shows that except for the fundamental fire protection requirements, compliance can be achieved on a fire area basis either by deterministic or performance-based methods. (The NRC permits licensees to use performance-based methods to comply with the fundamental fire protection requirements but those applications must be approved through the NRC's license amendment process, as discussed above.) Licensee/Station implemented this process by first determining the extent to which its current fire protection program supported findings of deterministic compliance with the requirements in NFPA 805. Risk-informed, performance-based methods were then applied to the requirements for which deterministic compliance could not be shown.

3.2.1 Implementing Guidance, Section 4.0

Section 4.0 of the implementing guidance describes the detailed process for assessing a fire protection program for the extent to which it supports a showing of compliance with NFPA 805. Licensee/Station conducted the detailed evaluation processes by establishing teams comprised of knowledgeable plant personnel and outside experts who were members of the Implementing Guidance drafting team. The assessment processes used by these teams and the results of their assessments are discussed in detail below.

4.0 Demonstrations of Compliance with NFPA 805 Requirements

4.1 Fundamental Fire Protection Program Elements and Minimum Design Requirements

The Fundamental Fire Protection Program and Design Elements are established in Chapter 3 of NFPA 805. Section 4.31 of the Implementing Guidance sets out a systematic process for determining the extent to which the current licensing basis meets these criteria and for identifying the fire protection program changes that would be necessary for complete compliance with these criteria.

4.1.1 Overview of Implementing Guidance Appendix B-1 Process for Mapping Current Licensing Basis to Requirements in Chapter 3 of NFPA 805

Appendix B-1 of the Implementing Guidance provides a mapping of the Fire Protection Program Fundamentals of Chapter 3 to NFPA 805 to the appropriate NRC Guidance Documents (BTP9.5-1, NUREG 0800, etc.). Each section and subsection of Chapter 3 is a "Fundamental Fire Protection Program Attribute" defining the fundamental program elements and minimum design requirements of a nuclear fire protection program. The cross-reference table(s) included as Appendix B-1 serves as a starting point for determining "previously acceptable" methods of compliance with that particular fire protection program attribute.

4.1.2 Results of application of the Implementing Guidance Appendix B-1 mapping process

4.1.2.1 NFPA 805 Chapter 3 Requirements Previously Approved by the NRC

Requirements in NFPA 805 Chapter 3 for which the NRC previously approved alternatives are included in the Implementing Guidance Appendix B-1 Table. Licensee/Station should include the complete mapping table as an attachment to the Transition Report.

4.1.2.2 NFPA 805 Chapter 3 Requirements not Previously Approved by NRC

[Optional] For the following items in Chapter 3, no previous NRC approvals of alternatives were discovered. [list]

Compliance for these requirements was demonstrated in some cases by showing deterministically that the requirement could be met by the plant as currently configured. [list with explanations]

For the cases where compliance could not be demonstrated deterministically, performance-based alternatives were used to demonstrate compliance. [list each requirement and briefly describe the performance-based method used to demonstrate compliance]

The NRC approved these uses of performance-based methods in the transition license amendment [optional-any changes made by the NRC as conditions of approval of use of the methods]

4.2 Nuclear Safety Performance Criteria

Five nuclear safety performance criteria are established in Section 1.5.1 of NFPA 805. Section 4.3.2 of the Implementing Guidance sets out a systematic process for determining the extent to which the current fire protection licensing basis meets these criteria and for identifying the changes to the current fire protection program that would be necessary for demonstrating compliance with these criteria.

4.2.1 Overview of Appendix B-2 Transition Review Process for Demonstrating Compliance with Chapters 2 and 4 of NFPA 805

Appendix B-2 of the Implementing Guidance identifies five program elements that are to be evaluated for compliance with the requirements in NFPA 805. They are:

- Nuclear safety capability system and equipment selection
- Nuclear safety capability circuit analysis
- Circuits required in nuclear safety functions
- Other required circuits (associated circuits)
- Nuclear safety equipment and cable location
- Fire area assessments

For all but the fire area assessments, the compliance determination strategy used was to: (1) compare the methodology used to establish the current licensing basis with the corresponding methodology provided in either NFPA 805 or NEI 00-01; (2) identify inconsistencies; and (3) perform any needed modifications and analyses. For the fire area assessments, a detailed fire area by fire area review was conducted to identify the equipment that implements compliance with the nuclear safety performance criteria.

4.2.2 Comparison of Methodology Used to Develop Current Safe Shutdown Equipment List with Applicable New Methodology

Licensee/Station's methodology for developing its current Safe Shutdown Equipment List is contained in [identify document]. The methodology in that document was compared in detail to the methodology in Section B.2 of Appendix B of NFPA 805 (Nuclear Safety Systems and Equipment). For each methodology element of Section B.2 the corresponding methodology element was identified in the DBD. Each pair of corresponding elements was compared for assumptions and factors considered.

4.2.2.1 Determination of Extent of Consistency of Methods

[Describe the extent of correlation between the methods in the License/Station document and Section B.2. Details of the comparison are contained as an Appendix to the report. Where there are differences between the details in some pairs of methodology elements, either show that the differences were determined not to result in safety significant differences in the lists of safe shutdown equipment that would be generated by both methods or modify the list of safe shutdown equipment, as necessary]

4.2.2.2 Modifications and Additional Analyses for Compliance

[State either that no modifications or additional analyses were required to establish compliance with the methodology elements in Section B.2. or describe the modifications and analyses conducted to demonstrate compliance]

4.2.3 Comparison of Methodology Used for Current Circuit Analysis with Applicable New Methodology

Licensee/Station's methodology for conducting circuit analyses is contained in [identify document]. The methodology in that document was compared in detail to the methodology in Section B.3 of Appendix B of NFPA 805 (Nuclear Safety Circuit Analysis). For each methodology element of Section B.3 the corresponding methodology element was identified in the document. Each pair of corresponding elements was compared for assumptions and factors considered.

4.2.3.1 Determination of Extent of Consistency of Methods

[Describe the extent of correlation between the methods in the License/Station document and Section B.3. Details of the comparison are contained in an Appendix. Where there are differences between the details in some pairs of methodology elements, either show that the differences were determined not to result in safety significant differences in the lists of safe shutdown equipment that would be generated by both methods or modify the circuit analysis, as necessary]

4.2.3.2 Modifications and Additional Analyses for Compliance

[State either that no modifications or additional analyses were required to establish compliance with the methodology elements in Section B.3.4. or describe the modifications and analyses conducted to demonstrate compliance]

4.2.4 Comparison of Methodology Used for Current Associated Circuit Analysis with Applicable New Methodology

Licensee/Station's methodology for analyzing associated circuits is contained in [identify document]. The methodology in that document was compared in detail to the methodology in Section B.3.4 of Appendix B of NFPA 805 (Other Required Circuits). For each methodology element of Section B.3.4 the corresponding methodology element was identified in the document. Each pair of corresponding elements was compared for assumptions and factors considered.

4.2.4.1 Determination of Extent of Consistency of Methods

[Describe the extent of correlation between the methods in the License/Station document and Section B.3.4. Details of the comparison are contained an in Appendix. Where there are differences between the details in some pairs of methodology elements, either show that the differences were determined not to result in safety significant or modify the analysis, as necessary.]

4.2.4.2 Modifications and Additional Analyses for Compliance

[State either that no modifications or additional analyses were required to establish compliance with the methodology elements in Section B.3.4. or describe the modifications and analyses conducted to demonstrate compliance]

4.2.5 Comparison of Methodology Used for Equipment and Cable Location Analysis with Applicable New Methodology

Licensee/Station's methodology for equipment cable and location analysis is contained in [identify document]. That methodology was compared, in general, against the methodology in Section B.4 of NFPA 805 Appendix B. For each methodology element of Section B.4 the corresponding methodology element was identified in the document. Each pair of corresponding elements was compared for assumptions and factors considered.

4.2.5.1 Determination of Extent of Consistency of Methods

[Describe the extent of correlation between the methods in the License/Station document and Section B.4. Details of the comparison are contained in Appendix. Where there are differences between the details in some pairs of methodology elements, either show that the differences were determined not to result in safety significant or modify the analysis, as necessary.]

4.2.5.2 Modifications and Additional Analyses for Compliance

[State either that no modifications or additional analyses were required to establish compliance with the methodology elements in Section B.4. or describe the modifications and analyses conducted to demonstrate compliance]

4.2.6 Overview of Table B-3 Process for Making Fire Area Assessments to Determine Effects of Fire or Fire Suppression on Compliance with Nuclear Safety Performance Criteria

The current fire protection licensing basis for each fire area has been summarized by completing the templates provided in the NEI 04-02 Implementing Guidance, Appendix B-2 (Table B-3). The completed templates are in an Appendix. Among the program elements addressed are:

- The current fire protection licensing basis (i.e., compliance with Sections III.G.2, III.G.3 of 10 CFR 50, Appendix R, etc.) including approved exemptions/deviations
- Detection – Licensing and design basis references for detection system (exemptions/deviations, SERs, Generic Letter 86-10 evaluations/code compliance evaluations, etc.). Requirements for detection systems used to meet the nuclear safety performance criteria require assessment in accordance with Chapter 3 of NFPA 805.
- Suppression – Licensing and design basis references for detection system (exemptions/deviations, SERs, Generic Letter 86-10 evaluations/NFPA code compliance evaluations, etc.). Requirements for suppression systems used to meet the nuclear safety performance criteria require assessment in accordance with Chapter 3 of NFPA 805.

- Emergency Lighting – Licensing and design basis references such as exemptions/deviations, SERs, calculations)
- Manual Actions – Manual action information for the fire area including: 1) whether or not manual actions are relied upon for the fire area, 2) whether or not the manual actions are previously approved by the NRC, 3) whether or not the manual actions are relied upon for post-fire safe shutdown.
- Outstanding Current Licensing Basis Issues – References to items that have been identified as being outside of the current licensing basis (such as corrective action documents, inspection findings and violations, and generic industry issues).

Table B-3 is included as an attachment.

4.2.6.1 Deterministic Methods

[List those fire areas that are transitioning under the "grandfathered" deterministic option.]

4.2.6.2 Risk-Informed, Performance-Based Methods

[List the fire areas that are transitioning using the risk-informed, performance-based techniques contained in NFPA 805. For each area, include a summary of the basis for acceptability of that change. References should be given to the detailed analyses performed as part of the transition.]

4.2.6.3 Modifications to Achieve Compliance

A licensee will list any modifications necessary to bring the plant into compliance with either the deterministic or performance-based acceptance criteria. The schedule for these modifications should be included in the License Amendment Request.

4.2.7 Nuclear Safety Performance Criteria in Non-Power Modes

Licensee/Station has used the templates provided in the NEI 04-02 Implementing Guidance, to summarize the current licensing basis associated with non-power modes. The information includes:

- Current outage management procedures
- Current fire protection insights that had been incorporated into outage management practices
- The safe shutdown analysis for compliance with 10 CFR 50, Appendix R, to determine the extent that equipment used to achieve and maintain cold shutdown (i.e., the residual heat removal system) had been identified and analyzed.

Details are provided in the completed templates in an Appendix.

4.2.7.1 Overview of Qualitative Risk-Informed, Performance-Based Evaluation Process

Discussions were held between the Probabilistic Risk Assessment (PRA) and Fire Protection staffs to determine the best way to integrate NFPA 805 fire protection aspects into existing

Outage Management Processes. Licensee/Station had previously conducted a low power and shutdown operations analysis based on NUREG 1449. Licensee/Station also has a [identify document] that contains a defense in depth checklist for each train alignment and evolution for outage management.

4.2.7.2 Results from Risk-Informed Evaluation Process

The following procedures and processes are used/modified to meet the low power operations criteria. [Identify and summarize procedures and processes. Among other things, describe the revisions to the current NUREG 1449 analysis to include additional components and circuits and how they were integrated with the current defense in depth checklist.]

4.3 Radioactive Release Performance Criteria

4.3.1 Overview of Evaluation Process

Licensee/Station updated the current NUREG 1449 analysis to include the additional components and circuits necessary for compliance with NFPA 805 and integrated those results with the current defense in depth checklist. Licensee/Station has used the templates provided in the NEI 04-02 Implementing Guidance to summarize the current information associated with control of radioactive release due to fire fighting. Information about fire pre-plans and training materials for Fire Brigade members has been included. [Copies of the completed templates are in an Appendix.]

4.3.2 Results from Evaluation Process

The following procedures and processes will be used either as is or as modified to meet the low power operations criteria. [Summarize procedures, processes and any changes. Among the changes that may be required are revisions to pre-fire to give more specific guidance with respect to controlling potentially contaminated smoke and fire fighting water and updating of training for Fire Brigade leaders on Part 20 limits.]

4.4 Monitoring Program

In order to assess the impact of a transition on the current monitoring program, the Licensee/Station fire protection program documentation hierarchy, maintenance program process / procedures and plant change processes were reviewed. Sections 4.5.3 and 5.2of the NEI 04-02 Implementing Guidance were used during the review. The results of those reviews follow.

4.4.1 Compliance with Section 2.6 of NFPA 805

4.4.1.1 Extent of Reliance on Current Programs

[Summarize the extent to which current programs/processes have been relied on.]

4.4.1.2 Overview of Additional Program Elements

The monitoring program has been upgraded in the following ways. [Describe upgrades. Describe a decision process for determining the appropriate responsibility for monitoring that should be included for fire protection equipment (i.e., does it go in the Maintenance program or the fire protection equipment operability control process).] It is envisioned that a Licensee will summarize the necessary upgrades to the monitoring program.

4.4.1.3 Phased Process for Expanding Monitoring Program

The monitoring program will be expanded on the following schedule. [Provide schedule]

4.5 Program Documentation, Configuration Control, and Quality Assurance

4.5.1 Compliance with Documentation Requirements in Section 2.7.1 of NFPA 805

Licensee/Station has developed a hierarchy document which explains how fire protection program procedures and documentation fit together. [This document should be included in this section.]

4.5.2 Compliance with Configuration Control Requirements in Section 2.7.2 of NFPA 805

4.5.2.1 Extent of Reliance on Current Programs

[Summarize the extent to which current programs/processes have been relied on. The summary may be brief, as shown in the following example.

The existing fire protection quality assurance program is sufficient for a risk-informed, performance-based program transition. The scope of fire protection features that fall under the umbrella of the fire protection quality assurance program may change based upon whether the feature(s) will continue to be credited (directly or via defense in depth analyses) under the new risk-informed, performance-based program.]

4.5.2.2 Overview of Additional Program Elements

[Describe the necessary upgrades to the fire protection/configuration control/quality assurance programs. These may include, but are not limited to,

- Guidance similar to NEI 02-03 for assessing changes
- A procedure for the change process if the change does not pass a screening process.]

Appendix I - Plant Change Evaluations

This Appendix supplements information contained in Section 4.4. Refer to Figure 4-4.

I.1 Overall Change Evaluation Process

The overall Change Evaluation process involves a graded and potentially iterative process. The intent of the graded approach is to provide analysis flexibility to address a wide range of issues and conditions. It also provides the mechanism to recognize and incorporate the diverse set of plant fire risk analyses in the industry. In general, the Change Evaluation process focuses on performing those Engineering Analyses needed to establish the acceptability of the change. As such the methods described herein will typically provide conservative (bounding) results.

I.2 Change Definition

A concise statement of the change should be developed. The change is defined as the altering or modification of a state or condition that is consistent and compliant with the Licensing Basis (CLB pre-transition or NFPA 805 Licensing Basis post-transition) to some other state or condition not specifically recognized or addressed by the Licensing Basis. The statement of the change should describe the condition requiring examination and focus on the key inconsistencies with the requirements of the Licensing Basis as they relate to satisfying the Performance Criteria described in Section 1.5 of NFPA 805. These inconsistencies will become the focus of the Change Evaluation process.

Note that the initial assessments discussed in Section I.4 are directed at complex changes that would require engineering analysis for resolution. It is expected that minor, routine changes would be dispositioned in a qualitative manner using processes similar to the design review and work control processes that exist at nuclear plants under a traditional regulatory framework and not be considered as "changes" to the Licensing Basis. Examples of minor routine changes, that are typically reviewed for impact by fire protection staff, but would not be considered a "change" to the Licensing Basis, are:

- Addition of minor amounts of cable to a cable tray, where margin is provided in combustible control programs.
- Changing a handwheel on a valve to a similar type.
- Relocating a fire extinguisher several feet due to planned modifications.
- Sealing a wall penetration with an approved rated material.
- Changing the type of fire hoses used at hose stations.
- Changing a fire protection feature (i.e., barrier, detection, or suppression system) in an area with no potential for impact on nuclear safety or radioactive release)
- Changing a protective device setting on a power supply credited for post-fire nuclear safety, within the limits for acceptable coordination.
- Rewiring a circuit for a component credited for ensuring nuclear safety. The rewiring does not result in any new failure modes due to fire in any plant fire area.

- Discovery of an unrated penetration in a barrier that has been previously evaluated as "adequate for the hazard" under a Generic Letter 86-10 fire area boundary evaluation. The particular penetration is bounded by the evaluation.

The statement of change may involve multiple plant features. In some instances, the resultant altered condition may be inconsistent with the Licensing Basis, but otherwise meets the criteria associated with the deterministic approach.

Example:

Prior to the transition to NFPA 805, an exemption or deviation may be applicable to an area that otherwise satisfies the deterministic criteria. Following transition to NFPA 805, the post-transition licensing basis (NFPA 805 Licensing Basis) would recognize this "approved" configuration. For this example, let us assume that redundant circuits for credited safe shutdown equipment are present in a fire area and the NFPA 805 Licensing Basis acknowledges the lack of raceway fire barriers and automatic suppression. The acceptability of this configuration is based on the lack of in-situ ignition sources and limited combustibles.

A discrepancy is identified where a plant modification resulted in the introduction of an oil lubricated pump and associated cabling. As a result, the configuration of the area is no longer consistent with the NFPA 805 Licensing Basis. Therefore, it cannot be assumed that one safe shutdown path will be available given a postulated fire event. The unavailability of a safe shutdown path results in the inability to meet the performance criteria of NFPA 805, Section 1.5. However, the scope of plant safe shutdown systems under consideration could be expanded such that a redundant or diverse means becomes available using equipment and circuits outside the fire area. The addition of this new safe shutdown system feature to the fire protection program would result in the area now meeting the deterministic requirements of Section 4.2.3 of NFPA 805. Therefore, the change statement would address the current NFPA 805 Licensing Basis requirements for no fire ignition sources and no combustibles, the impacted plant system feature(s), the new system to be considered in the fire protection program, and the fact that this new system meets the criteria for the deterministic approach. In this case, the application of the deterministic criteria is deemed to satisfy the performance criteria and no further analysis is required.

In this example, the change evaluation would document the assessment, the "new" feature(s) being credited, and indicate the applicable deterministic criteria that form the basis for acceptance. In this case, detailed engineering analyses using fire modeling and/or PRA would not be required.

I.3 Fundamental Program Elements and Minimum Design Requirements

The Change Evaluation process is an integral part of the risk-informed, performance-based option provided by NFPA 805 for meeting the performance criteria as described in NFPA 805, Section 1.5. A License Amendment Request will be required for changes to fundamental program elements or minimum design requirements required by Chapter 3 of NFPA 805. Therefore, the Change Evaluation process begins with a confirmation that the change under consideration does not involve a specific requirement of Chapter 3 or the related NFPA 805 Licensing Basis for satisfying the Chapter 3 requirements.

I.4 Initial Assessment

The Change Evaluation process may involve the application of fire modeling and risk assessment techniques. Before either technique is applied a preliminary assessment of the change should be performed. The purpose of this preliminary assessment is to gain insights as to whether simplified treatment (referred to as an initial assessment) would be sufficient to demonstrate the acceptability of the change. Otherwise, a detailed integrated analysis should be performed. NFPA 805 requires that engineering analyses be performed to judge acceptability. This may include traditional engineering analyses, fire modeling, and risk assessment. The goal of the initial assessment is to structure either the fire modeling analysis OR the risk assessment such that the need for the other is eliminated by the bounding treatment of results.

I.4.1 Preliminary Assessment

The preliminary assessment involves the examination of the parameters that would be used as input to the fire modeling analysis and risk assessment. If it can be discerned that one approach would be successful and less burdensome as compared to the other, then that path should be chosen. Otherwise, it would be appropriate to undertake both paths in parallel until the advantages of one over the other can be determined. Regardless of the path taken, the degree of analysis refinement applied in the initial assessment is limited since the objective is to bias the analysis in the conservative direction so that only one analysis type is required to demonstrate acceptability of the proposed change – either fire modeling or risk assessment. In other words, if a large fire would result in a very low consequence event, then a risk analysis may be the most effective method of evaluation. On the other hand, if the likelihood of a significant fire is very low due to lack of ignition sources, combustible loading, and detection and suppression systems, a fire modeling approach may be the most effective method.

The objective of the preliminary assessment is to determine if one of the following outcomes is reasonably likely to occur. If both are judged to be possible, then the path involving the least effort should be taken. If neither is judged to be possible, then the initial assessment should not be performed and the detailed integrated analysis should be pursued.

1. The fire modeling analysis can demonstrate that target damage does not occur given a postulated Maximum Expected Fire Scenario (MEFS) AND the Limiting Fire Scenario (LFS) involves an incredible event. An example of an incredible LFS is one that involves an oil volume greater than that available. If this can be achieved, the translation of these results into a risk assessment would result in no change in calculated core damage frequency (CDF) and Large Early Release Frequency (LERF). This conclusion can be reached without performing a risk assessment since only the incredible fire scenario would result in target damage.

2. The risk assessment can demonstrate that there is either no, or negligible, change in CDF and LERF assuming target damage occurs. If this can be achieved then the fire modeling results

are immaterial to the analysis since the risk characterization already assumes damage has occurred.

If the initial assessment proves to be successful, then the resulting analysis should be documented and retained. If the initial assessment is not successful, the results can provide useful insights in support of the integrated detailed analysis. If the initial assessment is successful, the supplemental information and requirements of Section 4.4, including defense-in-depth, safety margins, and uncertainty, must be considered. In addition, any needs for monitoring the critical inputs and assumptions must also be addressed.

I.4.2 Initial Fire Modeling

The initial analysis should refer to the fire modeling guidance provided in Appendix D for specific details. The purpose of the fire modeling is to examine the response of the target to a postulated MEFS and to define the LFS. The target for the analysis is typically that plant feature in the fire area of interest that would have otherwise been deemed protected from the effects of fire if the configuration was consistent with the Licensing Basis (CLB pre-transition or NFPA 805 Licensing Basis post-transition). The acceptance criteria for this initial fire modeling analysis are:

1. The MEFS must not result in target damage, AND
2. The LFS must be an incredible event.

The MEFS involves the consideration of the fire types that have a reasonable likelihood of occurrence. This should include treatment of both fixed fire ignition and those that are associated with "transient" activities such as cutting or welding. The philosophy that should be applied here is similar to that traditionally used in performing evaluations related to Single Failure. It is not the intent of MEFS to consider all scenarios that could possibly occur, but rather only those that have a reasonable likelihood of occurring. The MEFS is developed based on the in-situ fire ignition sources, the in-situ fuel loading, and potential transient sources. The resulting fire scenario should consider the following factors, which help define the "reasonable likelihood of occurrence":

a. Fire damage to only the target itself is not likely to cause an undesired result since it is the combination of the target together with a redundant success path in the area that created the need to "protect" that target. Therefore, the MEFS should not result in concurrent damage to the identified target and that redundant success path. If such an MEFS does exist, then the initial fire modeling approach has failed. If the MEFS does not result in these failures, then the analysis should proceed to completion.

b. The consideration of the "closest" credible location for the MEFS may not necessarily be bounding. A more significant ignition source or concentration of fuel further away may produce more adverse results. This is especially important if the closest MEFS results in no target damage.

c. The fire modeling should consider spatial features that would tend to offer shielding from the effects of fire, but shall not credit automatic fire suppression system response. This is because it would inherently introduce risk-informed parameters that would require further examination using PRA techniques. An exception occurs if the change being considered specifically involves the configuration of the suppression system. In this case, the response (performance) of the changed fire suppression system to postulated fire events should be specifically examined.

d. Manual fire fighting activities shall not be credited as the basis for concluding that target damage does not occur, since it also would inherently introduce risk-informed parameters that would require further examination using PRA techniques.

e. Transient combustible based fires could occur almost anywhere. Locations that are difficult to access may be unlikely to have combustibles, but if present are also unlikely to be discovered during the course of routine plant tours and inspections. Areas explicitly under administrative control, such as transient combustible free zones, should be confirmed to be periodically inspected. The results of those inspections should be considered in the analysis.

f. The treatment of transient combustibles should not be based solely on the transient combustible control program limitations. Instead, it should consider the available physical floor space when characterizing the size and burning characteristics of the postulated fire (fuel package). For example, it would be unlikely to have an accumulation that blocks an aisle or stairway landing. The scenario development should also consider the maximum expected transients that are expected beyond the control limitation when compensatory measures are established.

Refer to Appendix D, Section 2.4.4 for additional detail on development of the MEFS.

If the analysis related to MEFS concludes that target damage does not occur, the analysis should progress to defining the LFS. The LFS involves a purely hypothetical condition wherein the fire scenario is increased in severity to the point where unacceptable results occur. For example, using item a) above, the LFS would involve increasing the severity of the fire scenario to a point where both the target and the redundant success path are damaged. In developing the LFS, the treatment of any installed fire suppression system must be consistent with that of the MEFS. In other words, if the guidance for developing the MEFS did not allow credit for suppression, then the LFS must also not credit suppression.

The development of LFS involves the variation of analysis variables to cause failures. The particular variables to be evaluated depend on the specific problem. The following are parameters that one would expect to vary as part of a detailed fire modeling until failure conditions are identified:

- Heat release rate per unit area and total heat release rate
- Fire growth or flame spread rate including consideration of fire propagation
- Flame radiative fraction or radiative power
- Location of fuel package relative to target (if variable)

The development of the LFS should consider the following guidance.

Type of Ignition/Fuel	Discussion
Pump/Motor Lubricating Oil Fires	The development of an LFS for a fire scenario involving an oil spill does not need to increase the volume spilled beyond that physically present in the area. Instead, the resultant heat release rate is increased beyond that considered in the MEFS to develop the LFS. The increase of the rate with a fixed volume results in a reduction of the calculated time to consume the fuel supply. A comparison of the volume against this duration can be used to determine the reasonableness of the LFS for the purposes of determining if the fire is incredible. For example, the EPRI FIVE parameters for an unconfined spill involving DTE 797 would result in a fire duration of about 10 seconds depending on the specific fuel properties being considered. If the LFS requires a duration of less than 10 seconds, it can be considered to be an incredible event. It should not be inferred that the 10 second duration is the recommended criteria for establishing an incredible event. Instead, it is provided only as an example. Similarly, if the volume spilled is large, say 50 gallons, and the LFS requires a duration that is unreasonable given the volume involved can also be considered an incredible event.
Medium Voltage Switchgear Fires	The development of an LFS for a switchgear fire can involve an increase in both the heat release rate as well as duration. However, the available fuel supply (wiring) may be limited but difficult to quantify. The complicating factor for a switchgear fire involves the potential for high-energy arcing or explosive type events that are not amenable to traditional fire modeling techniques. The LFS for non-arcing and explosive events should be developed by increasing the heat release rate, while maintaining the duration equal to that of the MEFS. The LFS for an arcing or explosive event should be developed based only on the spatial distance from the originating switchgear. If the required increase in heat release rate and spatial distance is a factor of 2 or greater, the event can be considered to be incredible.
Load Centers and Low Voltage Switchgears	The development of LFS for Load Centers and Low Voltage (less than 480 V) Switchgears should apply the guidance for medium voltage switchgear except arcing and explosive events need not be considered. These electrical components have breakers similar in design and construction to medium voltage switchgears. However, the lower short circuit energy potential would tend to preclude explosive events from occurring.
MCC and Electrical Cabinet Fires	The development of LFS for an MCC fire should apply the guidance and criteria for medium switchgear except arcing and explosive events need not be considered. This is because of the specific components contained within these types of power distribution equipment combined with the lower short circuit energy potential as compared to medium voltage switchgears.
Transformer Fires	The development of LFS for transformers is dependent on the type of transformer being considered. Medium voltage primary, "open" air cooled transformers should be treated differently than similar sealed oil cooled transformers. Oil filled transformers may require different treatment depending on the type of oil used. Sealed gas filled transformers and low voltage transformers should be excluded. Open air-cooled transformers should apply the guidance provided for switchgears. Oil filled transformers will require specialized treatment on a case-by-case basis.
Transient Combustible Fires	The LFS for a transient combustible fire should be developed by defining the associated physical fuel package size to determine heat release rate and fire duration. If the resultant fuel package cannot fit in the requisite space, then it can be deemed an incredible event.

Refer to Appendix D, Section 2.4.6 for additional discussion on LFS development.

If the fire modeling concludes that the postulated MEFS does not result in target damage and the LFS is deemed to be an incredible event, the change is acceptable and no further analysis is required, as long as the considerations in Section 4.4.2 are adequately addressed. A risk assessment is not required in this case because the analysis effectively demonstrates that target damage does not occur. Both conditions must be satisfied in order for the change to be considered acceptable. If both conditions are satisfied, no further analysis is required to demonstrate the acceptability of the change.

I.4.3 Initial Risk Assessment

The initial risk assessment involves a simplified treatment of the change under consideration. The process involves the comparison of the risk characterization assuming target failure occurs against that assuming no failure occurs. The potential challenge in performing this analysis is the availability of plant fire risk related information to support this comparison. The readily available plant fire risk assessment could vary from a screening type FIVE analysis that has not been updated since the IPEEE efforts to a comprehensive, current fire PRA. The process of performing the initial risk assessment will vary depending on the type of existing study that is available. In some instances, use of the existing internal events plant PRA model may be the most expeditious approach. In other instances, the existing plant fire PRA would effectively result in this initial analysis being equivalent to the detailed integrated analysis discussed in Section I.5. If the existing documentation supports such an approach, the user should refer to Section I.5 for further guidance.

The performance of the initial risk assessment has two prerequisites that must be satisfied in order to proceed.

1. There must be a logic model that realistically represents the physical plant response to initiating events. These initiating events may or may not necessarily be fire events. In all cases, the plant internal events PRA model would satisfy this requirement. In some instances, a fire specific model may be available. If so, it should be used. There may be special circumstances for individual Change Evaluations where an acceptable evaluation can be completed without this prerequisite being met. This must be addressed on a case-by-case basis.
2. The consequences of a postulated fire in the area under consideration must be understood in terms of potentially lost system functions and other fire related effects. This may or may not include specific fire scenarios and detailed spatial information for all targets in the area. If specific fire scenario information is available, it should be used.

An exception to these prerequisites occurs if the change under consideration does NOT involve required indication (process monitoring) instrumentation AND affects only plant system features and/or components that are immaterial to the PRA success criteria. The reason that process monitoring instrumentation is excluded is due to the potential impact on operator recovery actions inherent in the risk model. Depending on plant particulars, examples could include the shutdown cooling mode of RHR for BWR plants, and boron injection for PWR plants for scenarios where RCS integrity is maintained. In these cases, the change in CDF and LERF can be shown to be negligible without the performance of any specific risk analysis. It is noted that treatment of LERF requires consideration of components and functions that are not necessarily modeled in the plant PRA. This may include containment isolation valves. These need to be considered before taking advantage of this exception to ensure that a fire induced containment bypass condition does not occur.

If it is determined that a risk assessment is needed and the two prerequisites are satisfied, the analysis should proceed using the guidance provided below. It is noted that the level of detail associated with each of the prerequisites could vary widely from plant to plant. While the threshold for satisfying the prerequisites is relatively low, the extent of the state of knowledge has a direct influence on the imbedded conservatism in the analysis results. Unfortunately, this conservatism cannot be easily quantified and therefore cannot be extracted from the results.

The guidance for the initial risk assessment has been structured assuming that the existing plant fire risk analysis not an up to date fire PRA. If a plant fire risk assessment is available then it should be used. If this is the case then many of the elements of the analysis will be readily available from that assessment.

a. The fire ignition frequency for the area under consideration needs to be determined. This value should be readily retrievable from the Fire IPEEE. If no significant plant equipment changes have occurred since the completion of the Fire IPEEE the previously calculated value should be used. Otherwise, the plant change(s) should be reviewed to assess their impact on the ignition frequency.

b. The scope of plant systems that have features present in the area under consideration needs to be identified. Alternatively, the set of plant system known to be absent from the area can be identified. In either case, the objective is to develop a listing of plant systems that are available following a postulated fire event. If the status of certain plant systems cannot be determined, then they should be assumed to be unavailable.

   The existing fire risk analysis information should be incorporated into this assessment to the extent possible. This may involve crediting additional plant systems not considered in the fire protection program, previously completed fire modeling analyses, and specific fire scenario definitions.

c. If an existing plant fire risk assessment is available it can be used for this initial assessment. However, if factors such as fire severity and credit for fire suppression are to be incorporated, then the analysis should progress directly to the Combined Analysis discussed in Section I.5.

d. The impact of the change under consideration is then integrated into results of b), above. This effectively creates at least two cases for consideration. If the existing data supports treating only a bounding fire scenario that damages all features within the area, then two cases would result. One is the baseline that would represent a configuration consistent with the CLB and the other would represent the configuration associated with the change.

If data from an existing fire risk analysis is incorporated, then multiple potential cases could arise. If this detail is used, then the analysis should progress directly to the Combined Analysis discussed in Section I.5.

e. The cases to be considered are analyzed using the plant PRA model or the plant fire PRA model if available. The PRA model can be quantified to generate either a conditional core damage probability (CCDP) or a CDF value. If the initiating event frequency is set of 1.0 in the PRA model, then a CCDP will be generated and the fire ignition frequency must be applied (multiplied) separately. If the initiating event frequency is set equal to the fire ignition (scenario) frequency, then a CDF will be generated directly. Either approach is acceptable.

The case(s) that treat the change under consideration should be quantified first. The purpose of this sequencing is that it may eliminate the need to quantify the baseline case(s). If it were assumed that the baseline case resulted in negligible risk contribution, then the CDF obtained by quantifying the "change" would essentially be equal to the change in CDF. If the cumulative value of the CDF for the "change" case(s) is less than 1.0E-07/yr, the screening for LERF described in step (f) shall be performed. Otherwise, the process should continue to step e.

f. The change in CDF is equal to the difference between the CDF for the "change" and the CDF for the baseline configuration.

$$\Delta CDF = \sum_{i=0}^{j} CDF_{Ci} - \sum_{i=0}^{j} CDF_{Bi}$$

$$\begin{aligned} \textit{where}:\ CDF_{Ci} &= \textit{CDF given the change for fire scenario } i \\ CDF_{Bi} &= \textit{CDF for the baseline configuration for scenario } i \end{aligned}$$

If a negative result in obtained, then the change under consideration results in a reduction in CDF. The guidance in Section 4.4.2 is used to determine whether the initial risk assessment demonstrates the acceptability of the change. If the change in CDF is not acceptable, a detailed integrated analysis can be performed using the guidance in Section I.5.

g. If the change in CDF meets the LERF acceptance criteria in Section 4.4.2, then no further assessment for LERF is necessary. Otherwise, an assessment for impact on LERF is required as discussed in step h.

h. The screening for LERF requires that the proposed change does not result in a containment bypass condition. If the containment isolation function remains available, and the ΔCDF criteria has been satisfied, then the guidance in Section 4.4.2 should be used to complete the determination of the acceptability of the change.

I.5 Combined Analysis

The initial assessment described in Section I.4 provides a simplified approach that tends to generate a conservative and bounding result. The guidance provided in this section is intended for those applications where a more detailed assessment of the impact of the change under consideration is desired or necessary. The analysis process discussed in this section will apply many of the accepted industry practices related to fire risk assessments. Detailed guidance for these practices are available in industry literature and through the Electric Power Research Institute (EPRI) and are not discussed in detail here. The user should refer to these industry documents for further information if desired. This section focuses on the process for performing a detailed integrated analysis in support of a Change Evaluation.

The overall objective of the analysis is to develop an estimate of the CDF and LERF increase associated with the change under consideration. The process of performing this analysis can proceed using either a fire source based or target based approach. Either approach can be successful, but certain instances or configurations may arise where one approach may have an advantage over the other in term of required level of effort. Both approaches also have pitfalls that should be avoided.

- The fire source based approach can be viewed as the traditional approach. Using this approach, a fire modeling analyst examines each of the identified fire ignition sources within the area under consideration. The consequences of each of these scenarios is then translated to a target damage set and quantified using the PRA model. This approach would be the preferred method in areas with many potential targets involving redundant systems.

  The key pitfall in the fire source based approach involves areas with numerous fire ignition sources. The rigor applied in the fire modeling analysis for each individual source could be significant. The underlying results for many of the scenarios could be identical with respect to impacted plant system functions. The net effect would be the potential expenditure of significant resources in completing many fire modeling cases that when incorporated into the PRA model all produce identical conditional core damage probability results. These scenarios could have been aggregated into a single fire scenario supported by simplified bounding fire modeling analyses.

- The target-based approach is less commonly used. Using this approach, the entire target set in the area under consideration is reviewed in the context of spatial arrangement. If this arrangement shows spatial separation of redundant features, then the fire modeling task is focused only on determining if an MEFS exists that would damage redundant targets. This approach would be the preferred method in areas that is predominantly of one train with a minimal target exposure for the redundant train. It would also be appropriate in large areas that have redundant targets at "opposite ends" and are also relatively benign with respect to fire ignition sources.

  The key pitfall in the target-based approach involves areas with numerous targets of redundant trains that are intermingled. A significant effort may be required to map the targets in the area of interest followed by a confusing, and sometimes unsuccessful, effort to develop logical groupings by system and system function. The net effect is either an unusable map or a failed attempt that then reverts to the fire source based approach.

The optimal approach to be applied for any given change to be examined needs to be determined on a case-by-case basis. The results of the initial assessment described in Section I.4 should be used if available to assist in determining the appropriate approach. Regardless of the approach taken, the two fundamental tasks are fire modeling and risk assessment. The sections that follow provide guidance for these two tasks that are applicable for either approach.

I.5.1 Fire Modeling Analysis

The discussion of fire modeling presented in this section is intended as a supplement to that provided in Section I.2. The guidance provided in I.2 is not repeated in this section. Appendix D provides information on the technical aspects of fire modeling.

Fire modeling analyses are used to examine the behavior of postulated fire scenarios and the response of targets of interest. For the purposes of this discussion, the heat release rate and total duration of the originating fire are referred to as the fire source term. Depending on the overall approach taken, the objective of the fire modeling may vary. If the ignition source based approach is taken, then the output of the fire modeling analysis is the characterization of the extent of damage for a given fire source term. Multiple fire source terms may be required to adequately address a scenario if fire severity factors are applied.

Fire severity factors are typically used as a partitioning term used to modify the frequency of a particular fire occurring. If fire severity factors are not applied, then all postulated fires for a given fire ignition source must be assumed to result in consequences consistent with the worst credible event. If fire severity factors are applied, it is important to ensure that the selected factor is appropriate given the MEFS and LFS developed in the fire modeling analyses. Various industry documents are available, such as those developed by EPRI, and should be used.

The results of the fire modeling analysis should be presented in a format that simplifies the development of individual fire scenarios in the fire risk assessment. To achieve this objective, the analysis should provide the following information in instances where the fire source based approach is used.

1. A brief summary of the analysis results should be provided. This is intended to be used primarily as a scenario identifier. This could be as simple as MCC Fire, Severe MFW Pump Oil Fire, etc. Suppression system response should be specifically noted if credited in the analysis. In each instance where suppression system response is credited, a complementary scenario where suppression fails must be provided.

2. The fire source term should be defined – heat release rate and originating fire duration.

3. Depending on the organization of the available plant information, the fire scenario should provide a detailed listing of impacted plant features. The plant features that should be listed need to have been previously coordinated with the risk analyst. Some plant fire risk analyses have comprehensive linked databases that track credited equipment, associated, cables, cable routing points, associated fire areas, and related PRA model basic event.

In cases where a target-based approach is used, the risk analyst should have already provided a problem statement to be addressed. In this case, the fire modeling objective is to determine the group of credible fire scenarios that would cause the undesired condition to occur. If a credible fire event does not exist, then the fire modeling analysis should present that conclusion and whatever documentation is needed to justify that conclusion. The following information should be provided where the target based approach is used.

1. A statement of the problem or condition being examined should be provided.
2. The fire source term that was used needs to be defined.
3. A narrative of the sequence of events that cause the undesired condition to occur should be presented. The risk analyst will model the sequence of events. For example:

   A particular area in a plant is found to contain redundant safe shutdown circuits. These circuits are routed to instrument racks on opposite walls of a room. The fixed fire ignition source in the area is limited to an oil lubricated pump located along a third wall that is not required to perform a post fire safe shutdown function. The problem statement describes a risk significant condition if redundant instrument racks (circuits) are damaged in a single fire scenario. The fire modeling effort concludes that transient combustible based fires can disable an individual rack, but cannot disable both racks. The fire modeling for the pump concludes that fires could impact redundant circuits. However, such an event would require involvement of the majority of the oil inventory in the pump. A fire involving less than 25% of the oil inventory was determined to cause damage to circuits associated with only one rack.

In order to satisfy the requirements of NFPA 805, LFS must also be determined. If the target based approach is used, the determination of LFS can be determined by incrementing the fire source term until unacceptable results as defined in the problem statement occurs. The resulting margin between MEFS and LFS is then determined and compared to the criteria provided in Section I.4.2. If the margin meets the criteria, then no further assessment is required. If it does not, then further reviews should be performed to ascertain if an alternative basis for concluding that the LFS is incredible can be developed.

If the source-based approach is used, the determination of LFS can be very difficult. This is because the set of fire-induced failures that would cause an unacceptable result may require a lengthy iterative process with the risk analysis. Rather than pursue an iterative approach, it is recommended that the LFS be set equal to a value consistent with acceptance criteria provided in Section I.4.2. The corresponding target failure set is then defined and evaluated for CDF. If the difference between the CDF for the MEFS and LFS cases is negligible, then no further assessments related to this topic is required. If it is not, then consideration should be made to base the risk assessment on the LFS rather than the MEFS.

I.5.2 Fire Risk Analysis

The development of a fire risk analysis is described in numerous industry guidance documents. These documents include the EPRI FIVE and Fire PRA Implementation Guides. A discussion is also provided in NEI 00-01. This document does not attempt to repeat nor provide a comprehensive procedure for performing a fire risk assessment. Instead, it focuses on providing guidance is several key technical areas that may be encountered in the Change Evaluation process.

The overall process for performing the fire risk analysis involves three basic steps. These steps are:

1. Fire PRA Input Parameters – this involves the development of the fire scenarios and the associated numerical inputs such as fire ignition frequency.
2. Fire Scenario Quantification – this involves the definition of the individual fire scenarios and the quantification of those scenarios.
3. Fire PRA Results – the results of the analysis in terms of change in CDF and LERF need to be determined.

I.5.2.1 Fire PRA Input Parameters

In order to perform a fire risk assessment, 3 basic inputs should be available.

1. A logic model that can be quantified is needed. This model needs to realistically represent the response of the plant to a postulated fire event. In some instances, the plant internal events PRA model is sufficient.
2. The set of objects in the logic model that are not available given the fire scenario under consideration must be determined. These unavailable objects are treated as failed in the logic model by setting them to "TRUE".
3. The annual frequency of occurrence of the scenario under consideration must be known.

The effort to obtain each of these inputs is likely to vary from plant to plant depending on the status of their Fire IPEEE or Fire PRA. In most cases, the logic model can be created with relative ease from the plant internal events PRA model. However, the plant PRA model addresses a scope of initiators that is much more expansive than needed for the fire analysis. In addition, the plant PRA model includes objects for various operator recovery actions. These actions may include actions outside of the main control room. The failure probability assigned for these recoveries may not necessarily be application given a postulated fire event. This is especially true if the available response time is short, or the postulated fire is located either at the location of the action or along the pathway. In most instances in is appropriate to alter the failure probabilities for these operator actions and set them to 1.0. This is useful since this will allow them to appear in the individual cutset results.

In the case of initiators, if the PRA model is being used to generate CCDP values, then the focus should be on selecting a representative initiator that has an underlying fault tree structure that will produce an accurate CCDP value. In most instances, this would be the general plant transient initiating event. Exceptions are expected to occur if certain fire induced failures result in a loss of coolant type event. An example of this is a postulated spurious actuation of Automatic Depressurization System (ADS) valves for a Boiling Water Reactor (BWR) plant, or the inability to isolate the spurious opening of a pressurizer Power Operated Relief Valve (PORV) for a Pressurizer Water Reactor (PWR) plant.

The development of information to determine the set of unavailable equipment given a postulated fire event is usually taken primarily from the existing fire protection program data sources. However, several cautions should be observed.

1. A fire protection program focuses on demonstrating a single success path remains free of fire damage. As such, there are usually other available systems that are not credited and have not been analyzed as part of a traditional, deterministic safe shutdown analysis. Typically, the most important of these is offsite power. For most analyses, loss of decay heat removal will be the dominant core damage sequence. Therefore, it is important to supplement the data set with additional means of performing this function using the plant PRA for guidance.
2. The crediting of a system function not addressed in the fire protection program can be accomplished by either inclusion or exclusion. Inclusion involves an approach where all of the equipment and circuits required to support that function are included in the data set and explicitly treated in the analysis. Exclusion involves an approach where the system components and circuits required to support the function are not known, but based on general plant knowledge there is reasonable confidence it they are not present in the specific area under consideration. For example, at most BWR plants, the Residual Heat Removal Pumps, valves, and heat exchangers are located in the Reactor Building on the opposite the turbine building. PCS could be credited in most instances based on the exclusion approach.

3. There will likely be instances where components are credited in the fire protection program and modeled in the plant PRA. However, they may not necessarily be considering the same function. For example, the containment sump valves at a PWR plant are likely treated only in the closed position in the fire protection program while the PRA may treat them in the open position in support of recirculation following primary bleed and feed. Care should be taken to ensure that the functions are consistent. This consistency in credited function forms the basis for integrating the associated cable relationships. Otherwise, supplemental cable tracing may be required to identify required circuits.

4. Most plants have some type of system for tracking cables and raceways in the plant. This tracking system may be manual (drawings) or electronic. In addition, a subset of this data may also be maintained in a separate tracking system satisfy the requirements of the fire protection program. The ideal data relationship would provide the following:

    a. Credited equipment and their location in terms of fire area
    b. Credited equipment and the associated set of cables required to support its functioning
    c. Cables and their associated raceway routing points
    d. Raceway routing points and their location in terms of fire area

    At some plants, item d will not be available and the cables will be associated directly with the fire areas rather than individual raceways. While this is sufficient to support the fire protection program, it creates a barrier to detailed fire scenario development. This is because the data no longer allows the complete target set for a fire area to be translated into specific raceways for the fire modeling task. The lack of this data effectively introduces an imbedded conservatism into the analysis. Instances where an adverse risk characterization occurs because of this conservatism should be evaluated further by developing the detailed spatial information for the affected area.

I.5.2.2 Fire Scenario Quantification

In most of the reference documents for performing a fire risk assessment, the calculation of CDF is presented in the form of an equation with a variety of terms. While the various sources present different representations of the equation, they all share a common underlying concept. The equations are basically composed of three types of parameters.

1. A baseline factor that represent the annual frequency of any fire occurring in the area of interest. This value should be taken from the existing plant Fire IPEEE (Fire PRA) and updated as necessary to reflect plant-specific experience and industry experience data.
2. A frequency modification factor that reduces the baseline frequency so that it represents only the single specific event, or group of events specifically under consideration. This includes fire severity factors, fire suppression system performance, and other conditional probability values such as spurious actuation.
3. A CCDP value which is the probability of core damage given that the specific event or group of events under consideration occurs. This value is obtained by propagating the fire-induced failures through a PRA model.

While the presentation of these equations suggests that the consideration of additional terms would always tend to reduce the resultant CDF, the addition of each term requires the consideration of a complementary case. For example, if a frequency modification terms is applied to treat the random failure of an automatic fire suppression system, a complementary case must be considered to examine the case where suppression succeeds. Failure to treat these complementary cases could result in the exclusion of a dominant risk sequence. The same concept applies for severity factor and fire induced spurious actuation events. A pictorial representation of this treatment is referred to as an event tree. A sample event tree is shown in Figure I-2.

I.5.2.3 Fire PRA Results

The Fire PRA results that are needed to support the Change Evaluation are ΔCDF and ΔLERF.

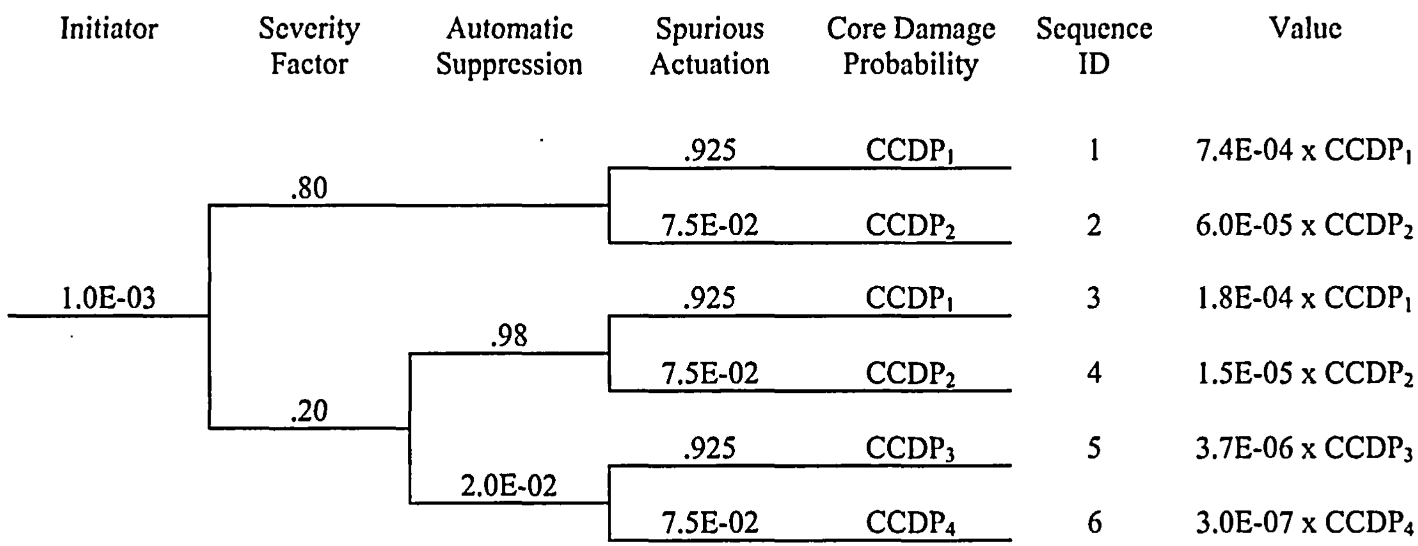
$$\Delta CDF = \sum_{i=0}^{j} CDF_{Ci} - \sum_{i=0}^{j} CDF_{Bi}$$

$$\begin{aligned} where:\ CDF_{Ci} &= CDF\ given\ the\ change\ for\ fire\ scenario\ i \\ CDF_{Bi} &= CDF\ for\ the\ baseline\ configuration\ for\ scenario\ i \end{aligned}$$

As described earlier, the second term in the equal can be set to zero to obtain conservative results. This would eliminate the need to quantify results for the baseline case.

A similar equation is applicable for ΔLERF. However, LERF models may not be as readily available. In addition, even if a model is available, it may not be necessary to quantify that model to conclude that the ΔLERF acceptance criterion is satisfied. This is discussed further in Section 4.4.2.

Figure I-2 – Sample Event Tree



In the sample event tree it is assumed that the consequences of a non-severe fire are the same as a severe fire if successful suppression system actuation occurs. Therefore, sequence 1 and 3 have the same CCDP value. Similarly, sequences 2 and 4 have the same value. Sequences 5 and 6 are expected to have higher values because of the greater extent of damage that would be expected to occur given suppression failure. In addition, the CCDP value assuming a spurious actuation occurs is also expected to be higher as compared to the case where it does not.