Guidance for Development of Response to Generic Request for Additional Information on Fire Individual Plant Examination for External Events (IPEEE)

A Supplement to EPRI Fire PRA Implementation Guide (TR-105928)

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REPORT SUMMARY

This report documents the responses to NRC generic questions on utility fire IPEEE submittals. The report also contains supplemental guidance to the Fire PRA Implementation Guide and recommendations for preparation of the site-specific response to these generic questions.

Background

In December 1995 EPRI published “Fire PRA Implementation Guide,” to present a detailed method and supporting technical bases to help nuclear utilities respond to the Nuclear Regulatory Commission’s Generic Letter 88-20, Supplement 4, “Individual Plant Examination of External Events for Severe Accident Vulnerabilities.” This report was utilized by a significant number of licensees to prepare their response to the generic letter.

In August of 1997, the Nuclear Regulatory Commission published a review of EPRI’s Fire PRA Implementation Guide. The review provided comments on the guide as well as fifteen (15) questions documented as a generic Request for Additional Information (RAI). In the interest of time, the NRC offered the industry, through the Nuclear Energy Institute (NEI), the opportunity to provide generic responses to these 15 questions. The communication states that an adequate response to these questions would remove the need for asking the same questions of individual licensees unless under special circumstances. NEI asked EPRI to provide responses to these questions. Subsequently, the NRC referred one additional question for a generic response by the industry.

Objectives

To provide guidance to the nuclear utilities for preparation of response to the NRC’s generic Request for Additional Information on the Fire IPEEE submittals.

Approach

This report documents discussions with the NRC on a number of issues related to the Fire Risk Analysis methodology as documented in the EPRI’s Fire PRA Implementation Guide and utilized in preparation of the fire IPEEE submittals. The technical basis for each of these issues was invetigated through further research of fire event records, fire tests and various fire models. Supplemental Guidance was provided where correction and/or clarification to the Guidance in the Fire PRA Guide was needed. This report also offers guidance for preparation of site-specific response to generic fire IPEEE RAI questions.

Results

Responses to the generic questions were first drafted on August 26, 1998. After several reviews and discussions with the NRC staff, the staff concluded that these responses are acceptable for use in the implementation of the fire IPEEE.

Either because of issues raised in the Review or because of EPRI's critical reevaluation motivated by the Review, we have determined that supplemental guidance in a number of areas will help further improve the EPRI fire risk analysis methods and strengthen the results towards plant support applications. Several of these areas could be important to the conclusions of the fire IPEEE.

EPRI Perspective

Over the past decade EPRI has been developing improved fire risk methods that resulted in Fire Induced Vulnerability Evaluation (1992) and Fire PRA Implementation Guide (1995). These methods were used by nuclear licensee in preparation of response to NRC's Generic Letter 88-20 supplement 4, "…." Use of these methods in fire IPEEEs identified a number of areas that these methods can be improved to help with closure of the IPEEE program. In addition, in recent years use of risk in regulatory decision making has attracted a great deal of interest from the NRC and the nuclear industry. This project is one more step in development of robust methods to support risk-informed fire protection decision making.

Keywords

Fire IPEEE
Fire Risk Analysis
Risk and Reliability
Risk Management
Fire Protection
Fire Safety
Probabilistic Risk Assessment (PRA)

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1 INTRODUCTION

In August of 1997, the Nuclear Regulatory Commission published a review of EPRI's Fire PRA Implementation Guide (Ref 1). The review provided comments on the guide as well as fifteen (15) questions documented as a generic Request for Additional Information (RAI) (Ref. 2). In the interest of time, the NRC offered the industry, through the Nuclear Energy Institute (NEI), the opportunity to provide generic responses to the 15 questions (Ref. 3). The letter states that an adequate response to the questions in Appendix A of the report would remove the need for asking the same questions of individual licensees unless under special circumstances. In a meeting with the NRC (and some of their contractors who prepared the NRC review) on January 8, 1998, the 15 questions were reviewed to understand the nature of the questions and clarify any misunderstandings. Subsequently, the NRC referred one additional question for a generic response by the industry (Letter from Alan Rubin, NRC-RES to Dave Modeen, NEI).

The responses to these questions were first drafted on August 26, 1998. After several reviews and discussions with the NRC staff, these responses have been finalized in this report.

Section 2.0 provides a brief summary of the NRC questions and the resulting responses. Either because of issues raised in the Review or because of our own critical reevaluation motivated by the Review, we have determined that supplemental guidance in a number of areas will help further improve the EPRI fire risk analysis methods and strengthen the results towards plant support applications. Several of these areas could be important to the conclusions of the fire IPEEE. Details of the supplemental guidance and recommendations for preparation of the site-specific response to these generic questions are provided in Sections 3.0 and 4.0 respectively. Appendix A of this report contains the generic fire IPEEE questions as reported in Reference 2.

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SUMMARY OF THE RESPONSES TO THE GENERIC RAI QUESTIONS

The following is a summary of the response for each question.

Question 1 – Screening Human Reliability Analysis

The use of screening values is as appropriate in fire PRA as it is in PRA for internal events. Therefore, if used with a proper HRA procedure, the Guide will yield an acceptable "fire HRA". However, the Review indicates the Guide is prone to misinterpretation particularly for calculating dependencies of multiple human actions during screening.

Supplemental guidance is provided for cases where use of the screening HEPs may have resulted in inappropriate truncation of cutsets and screening of potentially important fire scenarios. Then, if such potential is identified, the HEP(s) should be demonstrated to be appropriate given the fire unique considerations. No additional HRA guidance to calculate screening HEPs is developed.

Question 2 – Heat Loss Factor

FIVE recommended use of 0.7 heat loss factor (HLF) for all fire scenarios. The Fire PRA Guide recommends values of 0.85 and 0.94 in special circumstances. The Generic RAI (Ref. 2) requests justification for use of values other than 0.7.

After thorough review of the evidence and discussion with the staff, we agree that use of 0.94 generally provides non-conservative results and should not be used unless its use is demonstrated to be applicable for the scenario under consideration. The 0.85 HLF, used with the FIVE model, provides realistic hot gas layer HGL temperatures for fire scenarios where the virtual surface of the fire is assumed to be above the floor level (thus reducing the HGL volume), such as in an electrical cabinet/cable tray fire. However, use of 0.85 HLF may result in non-conservative HGL temperatures during the initial stages of a floor-based fire (e.g., oil pool fire). The HLF of 0.7 generally results in conservative HGL temperatures throughout the fire events and may yield overly conservative temperatures for extended duration events as the FIVE model continues to add heat to the enclosure at a faster rate than supported by any of the available tests. Supplemental guidance is provided to clarify this position including consideration of the HGL temperature in determining exposure at the target.

During our discussions with the staff they offered the compromise position of using 0.7 for all fire scenarios with the virtual surface of the fire for electrical cabinet/cable tray fires located at the floor instead of top of the cabinet.

Question 3 – Fire Propagation in Horizontal Cable Tray Stacks

This question refers to use of specific tests to predict fire propagation and its timing in horizontal cable tray stacks described in the Guide. Supplemental guidance is provided to allow for use of this model only for fire scenarios in which the configuration either matches or is bounded by the tested configuration.

Question 4 – Control Room Evacuation Scenarios

The generic RAI raises questions about partitioning of the main control room (MCR) ignition frequency, use of the severity factors and non-suppression probability and probability of the MCR abandonment.

The Supplemental Guidance requires that any partitioning of MCR ignition frequency inconsistent with the generic ignition frequency model employed by both EPRI FIVE and Fire PRA methods be adequately justified. The supplemental guidance also advises against use of both severity factors and non-suppression in the same MCR fire scenarios. In recognition of the uncertainties inherent in these factors, the supplemental guidance recommends against screening of the control room evacuation scenarios without evaluation of the post-evacuation safe shutdown capability.

Question 5 – Automatic/Manual Suppression Dependency

We agree with the importance of the dependency between automatic and manual suppression. The Guide provides a great deal of discussion in Section 4 and Appendix K to address the topic.

Supplemental guidance has been developed to remove the source of the confusion and provide further guidance when crediting manual recovery of automatic suppression system and subsequent manual suppression.

Question 6 – Fire Risk Scoping Study (FRSS) Issue, Seismic/Fire Interactions

The concern here is:

- Seismically induced spurious actuation of suppression systems leading to diversion of fire suppressants to non-fire areas rendering them unavailable for a fire, and

- Spurious actuation of detectors potentially complicating operator response to the seismic event and/or causing actuation of automatic fire suppression systems.

Supplemental guidance is provided to:

- assess the possible impact on the safe shutdown capability if a seismically-induced fire were to burn for a longer time than the other scenarios in the room, and

- describe plant personnel response to fire alarms and availability of personnel to perform safe shutdown actions as well as deal with actual or spurious alarms.

when a potential for seismically initiated fire is identified following the seismic walkdown.

Question 7 – Fire Risk Scoping Study (FRSS) Issue, Control Systems Interactions

Supplemental guidance is provided to direct the analyst to specifically address the following questions when evaluating post-evacuation safe shutdown capability as part of the evaluation of main control room fires.

a) Electrical independence of the remote shutdown control systems,

b) Ability to transfer control to remote shutdown locations,

c) Spurious actuation of components leading to component damage, LOCA or interfacing systems LOCA, and

d) Total loss of system function

Question 8 – Fire Risk Scoping Study (FRSS) Issue, Manual Fire Fighting Effectiveness

Generic Question 8 deals with the adequacy of the response to the FRSS issues, i.e., hampering effect of the smoke on the efforts of the fire brigade to promptly and effectively suppress fires. In particular:

- The impact of smoke on manual fire suppression efforts, and

- Misdirected manual suppression efforts that can cause failure of additional components.

The Supplemental guidance requires discussion of the plant provisions for smoke control and fire fighting under smoke conditions that apply to the scenarios where manual suppression is credited. The analyst is also instructed to discuss the plant's fire protection program elements that would minimize the potential for misdirected manual suppression efforts.

Question 9 – Fire Risk Scoping Study (FRSS) Issue, Total Environment Equipment Survival

Generic Question 9 deals with the adequacy of the response to one FRSS issue in particular:

> "Fire suppression system actuation events can have an adverse effect on safety related components through direct contact with suppression agents or through indirect interaction

with non-safety components. Components outside the immediate area of the fire can be impacted as a result of actuation resulting from transport of smoke, propagation of hot gas layers, or misdirected manual suppression efforts."

Guidance has been provided using the response to IN 83-41 and/or IN94-12. This remains consistent with the requirements of the FIVE method.

Question 10 – Special Accident Initiators

Supplemental guidance removes the reference to special initiators whose (non-recoverable) frequency is greater than 1E-4/yr and requires that use of any quantitative threshold be adequately justified.

Question 11 – Screening of Enclosed Ignition Sources

The guidance on screening fixed ignition sources has been modified to caution against screening of enclosed high-energy (480V and higher) cabinets and transformers.

After thorough review of over 180 electrical cabinets fire events (including the events at Oconee, Yankee Rowe and Waterford) we have concluded that only the potential for damage to immediately adjacent cabinets, in the case of high energy switchgear fires, needs to be modeled beyond the existing thermal damage models.

Question 12 – Electrical Cabinet Heat Release Rate

The guidance for selection of heat release rates for electrical cabinets with IEEE-383 qualified cables has been revised as follows: when it is reasonable to expect that the fire remains limited to a single bundle of cables, use of 65 Btu/s is appropriate. Otherwise, a HRR value of 190 Btu/s is recommended.

Question 13 – Fixed Ignition Source Screening, Non-combustible Shield

The current wording in the Guide (Ref. 1, Page 4-18, 1st sentence of the last paragraph) is incorrect. Supplemental guidance provided in the document should be used for evaluation of fire scenarios involving non-combustible shields.

Question 14 – Fixed Ignition Source Screening, Consideration of Transient Fires

The intent of the Guide is as follows: if enough fixed ignition sources within a compartment can be screened such that the compartment core damage frequency (CDF) falls below the screening cutoff, the compartment may be screened from further single-compartment evaluation eliminating the need for modeling transient fire scenarios. The statement of concern in the Guide has been revised (see Supplemental Guidance in section 3.0 of this report) to eliminate any confusion.

Question 15 – Automatic Suppression Dependency

There is an inconsistency in the Guide with respect to detection and suppression, which could lead to misinterpretation. The supplemental guidance provided should eliminate this inconsistency and clarify the guidance.

Question 16 – Piloted Cable Ignition Temperature

This deals with the cable ignition temperature, in particular, the basis for 932°F as the piloted ignition temperature for both qualified and non-qualified cable.

The supplemental guidance provided here recommends use of 700°F for ignition of both qualified and unqualified cables in the plume and ceiling jet region based on the SNL tests conducted for cable aging (NUREG/CR-5546). These tests involved energized cables in a rapidly heating convective oven with ventilation.

3

SUPPLEMENTAL GUIDANCE

3.1 RAI Question 1 - Screening Human Reliability Analysis

In a fire PRA, the human reliability analysis (HRA) must consider those fire unique factors that could particularly influence the probability of the outcome of a human action or even preclude the action. Because a fire PRA often begins with an HRA for internal events already complete, practical guidance for performing a fire PRA should consider how to best deploy these "IPE values". Use of these IPE values is only appropriate if they have been verified to be applicable to fire conditions.

The following describes how to perform a fire HRA with these considerations in mind. The guidance is not intended though to be a full HRA method, rather it is to be used as a supplement to an appropriate HRA method.

The overriding concern in HRA guidance for a fire PRA is that a complete assessment is done of fire unique factors. The importance of the assessment varies in degree to the importance of the potential effects of the fire. Actions occurring after the fire has been suppressed, may in many cases be performed "independently" from the effects of the fire. The fire less often influences actions occurring in the control room than local actions that must be performed in the plant. It is local actions where the effects of the fire on humans may be more pronounced. Alternatively, some local human actions, that are clear in normal procedures and trained for regularly under internal events conditions, may be impossible because the fire prevents access to the area or because the person performing the action has been assigned to the fire brigade.

HRA methods typically provide a structure for ensuring completeness in the evaluation of factors that influence human errors. The following discussion offers a structure and then lists a set of examples of fire unique factors that correspond to that structure. While every attempt was made to have the set of examples be complete (and therefore valid for use in a checklist approach), the user should ensure that other fire unique effects are not applicable to the particular fire area, accident sequence or fire damage scenario.

The "environmental" factors that influence human events can be organized as follows:

a) quality (type and frequency) of training

b) environment for the operator (lighting, heat, radiation, smoke, etc.)

c) accessibility of equipment

d) necessity, adequacy and availability of special tools, parts and clothing

e) quality of man machine interface

f) availability of instrumentation

g) availability of operations staff

h) communications

a) Quality (type and frequency) of training

The quality of training may well be lower for fire procedures than for EOPs. Training on operator actions that only appear in fire procedures often is less frequent. Also the type of training may be less effective because the actions occur locally and cannot be simulated as effectively in training as they can for events occurring in the control room and trained on the simulator.

Additionally, changes in roles and responsibilities of the operating crew may impact operator response in case of a fire, particularly when the control room team is depleted to staff the fire brigade. The quality and frequency of training in this regard, even for in-control room actions, may be relevant.

b) Environment for the operator (lighting, heat, radiation, smoke, etc.)

Of particular concern in this case is smoke and inadequate emergency lighting and their impacts on local operator actions. The basis for this concern is that these two effects can be widespread and fire procedures rarely credit operator actions in the area of the fire where heat would be a factor. Also emergency lighting is only required for operator actions credited in the fire procedures. Because additional human actions may be modeled by the PRA, the availability of emergency lighting should be validated when local actions are credited.

For smoke effects, the Review references a method for evaluating them. Simple rules may also be sufficient to demonstrate the effects of smoke have been adequately considered. Such rules as lack of proximity of the fire to the location of the human action or differences in ventilation zones for the fire and the action may be useful screening tools.

The analyst needs to remember that the human action is like a circuit. Because the operator may start in the control room and travel to the location where the human action must occur, environmental effects can occur anywhere along the path taken by the operator.

c) Accessibility of equipment

Actions in fire procedures generally involve only equipment that can be accessed while the fire is in progress. Much like environmental effects, some actions credited in the PRA model may not be in fire procedures and it will be necessary to verify that the fire scenario does not affect equipment access. Again, this typically applies only to local actions.

d) Necessity, adequacy and availability of special tools, parts and clothing

Because some safe shutdown actions are unique in nature, human response in a fire procedure may involve special tools, parts and clothing.

e) Quality of man machine interface

Clearly the man machine interface for operations from the Remote Shutdown panel is different from the man machine interface in the control room. Other fire unique examples may exist.

f) Availability of instrumentation

Safe shutdown analyses typically protect a limited amount of instrumentation from fire effects. Because determining instrumentation cabling may be difficult, the fire HRA may need to consider human events with the instrumentation available limited to that identified in the safe shutdown analysis.

g) Availability of operations staff

The operator required to perform the action may have been assigned to the fire brigade.

h) Communications

Unique requirements for coordination and communication could accompany the requirement by fire procedures for operator actions to be performed in a particular sequence in multiple areas of the plant. Such actions might be particularly difficult to perform reliably.

In addition to environmental factors, other factors can also influence the quantification of human events:

- timing
- characteristics of the task
- dependencies (for multiple events in the cutsets)

Timing

The timeline for operator actions may well be different in fire scenarios. For in-control room actions, more time may even be available as the plant may trip initially, but some systems may operate for a period of time before fire growth and propagation causes them to fail. However, in the case of local actions specific to the fire procedure, timelines from the IPE may no longer apply. Regardless, the user should ensure that the correct available time is used in the HRA quantification method. Timing such as the following should be considered:

– time needed to perform the action

– time available

– time operators receive indications

Characteristics of the task

The characteristics of human tasks required by fire procedures to be performed outside the control room are often different from the human actions modeled in the IPE. In particular, the number of subtasks and the complexity and difficulty of the tasks may be much different, most notably when operators are required to perform many local actions to prevent spurious operations.

Dependencies (for multiple events in the cutsets)

If multiple screening actions can occur in the same cutsets, it is important to ensure that unique dependencies related to fire are also considered. In particular, more environmental factors may be applicable. Review of the cutsets when calculating compartment screening conditional core damage probability (CCDP) or scenario CCDP (detailed modeling) is one way to identify multiple HEPs in the same cutset. If such conditions are identified, dependencies between the actions should be determined using plant-specific information (e.g., plant procedures). Quantification of the HEPs may use any one of the HRA methodologies (preferably consistent with the IPE) with appropriate shaping factors to reflect fire conditions.

The above supplemental guidance is intended to address the concerns raised in the Review of the Fire PRA Guide. This guidance should be applied in conjunction with the user’s understanding of both the Review and the response provided above.

3.2 RAI Question 2 - Heat Loss Factor

The NRC's questions use of HLF values other than 0.7 in the FIVE fire models. However, they have indicated that when 0.7 is used, it would be acceptable to assume that the HGL descends all the way to the floor even if the virtual surface of the fire is not at the floor (e.g., cabinet fires or cable tray fires).

The following table provides supplemental guidance for selection of heat loss factors.

HLF	CONDITIONS OF USE /EXPECTED RESULTS
0.70	Generally results in conservative HGL temperatures throughout the fire event and under any conditions. May yield overly conservative temperatures especially for extended duration events (i.e., longer than brigade response time). • Appropriate for approximating HGL temperatures during the early portion of fast growing floor-based fires (i.e., oil spills prior to brigade response).
0.85	Generally results in conservative HGL temperatures when the HGL volume is calculated assuming that the virtual surface of the fire is at least 0.40H (where H is the ceiling height). May be unconservative for events involving rapidly developing floor-based fires. • Appropriate for fires initiated by electrical cabinets including those involving cable trays (virtual surface at cabinet top). • Appropriate for overhead cable tray fires where the HGL is based on the volume above the burning tray (HGL volume = 0.60 * room volume, or less).
0.94	Generally non-conservative except possibly for slow growing, long duration fire scenarios. • This value should only be used when demonstrated to be appropriate for the scenario being considered.

3.3 RAI Question 3 - Fire Propagation in Horizontal Cable Tray Stacks

The following guidance supplements the existing contents of the Implementation Guide.

- The purpose of the propagation model is to define the time-dependent HRR resulting from a fire in horizontal cable tray stacks filled with IEEE 383 qualified cable. The model is not intended to directly define cable damage. As stated on page 4-28 of the Guide, "The EPRI modeling solution bases ignition timing and heat release on experiments, assumes damage based on worst case plume, and bases initial ignition on ignition source HRR." Damage is also discussed on page 4-29 of the Guide, *Step 5.3.5 - Time-to-Damage Calculations.*

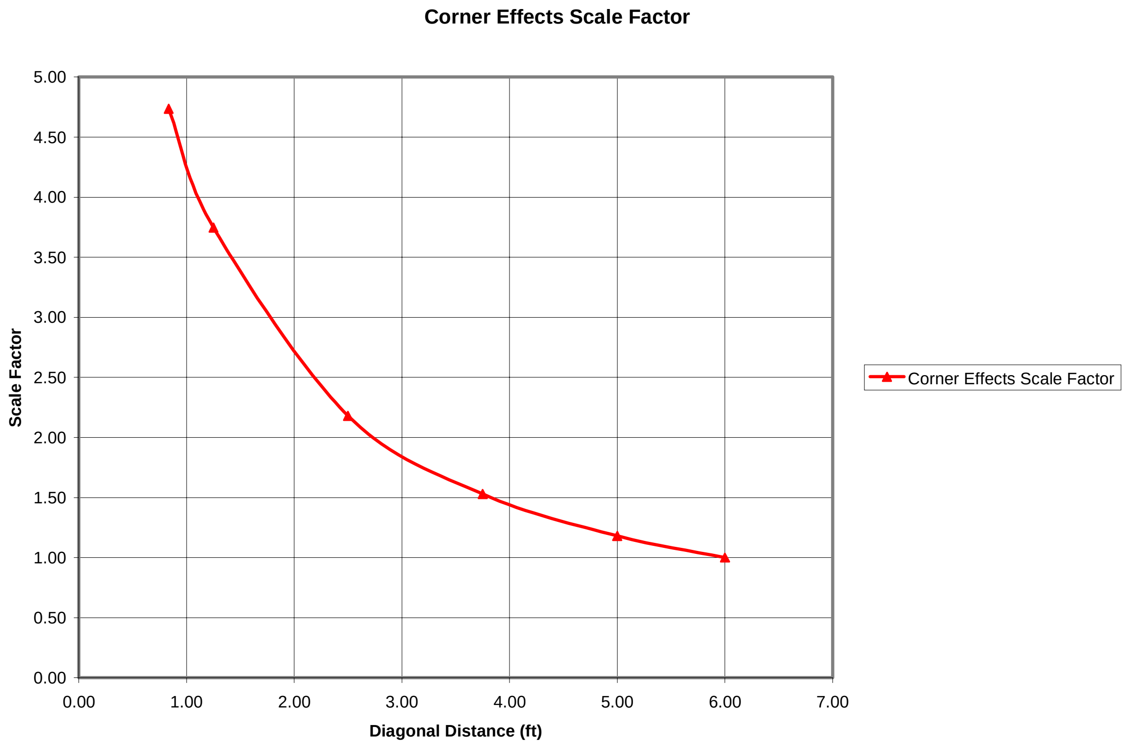
- It should be assumed that fires propagate instantly along the length of vertical (or diagonal) cable trays. Therefore, it may not be appropriate to use the propagation model when there are vertical trays in the configuration being modeled (i.e., if vertical trays could become involved as the fire propagates upward from tray to tray at approximately a 35 degree angle).

- The existing model is applicable for determining the time-dependent HRR for fire propagation in horizontal cable tray stacks with the following attributes. If the scenario conditions are significantly different, use of the model is not appropriate.

    - Trays are located more than 6' from a (wall/ceiling) corner
    - Cable is IEEE 383 qualified
    - Trays may be ladderback or solid bottom steel (without or without covers)
    - Tray spacing is at least 10.5" vertical separation between trays in the same stack and at least 8" horizontally between tray stacks; this is the minimum separation allowed by RG 1.75
    - Fire size is limited to 190 Btu/s

- The HRR for trays located within 6' of a ceiling or wall corner should be scaled as defined by Figure 1.

Figure 1 HRR Scaling Factor for Cable Trays within 6' of a Ceiling or Wall Corner



In summary, the model currently presented in the Guide adequately predicts the time-dependent HRR resulting from fire propagation in a stack of horizontal cable trays with IEEE 383 qualified cable, except when the trays are located in close proximity to the ceiling/wall corner. When the trays are located in close proximity to the ceiling/wall, Supplemental Guidance is provided for scaling HRR in a manner consistent with experimental data.

3.4 RAI Question 4 - Control Room Evacuation Scenarios

The control room fire analysis is essentially made up of three elements:

- Fire ignition frequency,
- Non-suppression probability, and
- Safe shutdown probability

It is important that the analysis of each element be done in a manner consistent with the assumptions of the other elements. NRC reviewers have identified three topics for which we agree that caution is appropriate, namely:

a) The use of severity factors in conjunction with suppression probabilities in control room scenarios;

b) Calculation of control room ignition frequency; and

c) MCR non-suppression probability and post-evacuation safe-shutdown capability.

The following provides supplemental guidance for these topics.

a) Severity factors

Severity factors such as the control room electrical cabinet factors discussed in Section D.3.1 of the Guide should not be multiplied by non-suppression probabilities for control room fires displayed in Figure M-1 of Appendix M of the Guide. The two events use some of the same data for their bases and are therefore dependent. It is the intent of the Guide that severity factors are used for scenarios where damage must occur, but no damage time can be estimated. The non-suppression probabilities are for cases where damage times can be estimated and when the fire is expected to grow beyond the initial region of the ignition source.

b) MCR ignition frequency

Control room ignition frequencies have been adjusted by some users to account for the fact that some plants have cabinets in relay rooms or auxiliary electrical equipment rooms that are normally located in the control room at most plants. The intent of the ignition frequency method is to ensure that location fire frequencies are developed based on the type and function of the sources present in the location. The first step in the FIVE ignition frequency method requires that the user selects an appropriate "Plant Location" which corresponds best to the fire compartment in question (FIVE, page 6-7, step 1.1). Plant-to-plant variability makes it nearly impossible to know ahead of time the nature of ignition sources in the compartment. In one plant the relay room may contain all the ESF control circuits for the plant, while in another a relay room may be outside the power block and contain no safety equipment and possibly few control cabinets. Therefore, caution should be exercised when placing a fire compartment in one of the "Plant Locations" defined by the FIVE ignition frequency method (FIVE, Table 1.1). The following may be necessary to confirm the appropriateness of the selection.

1. The ignition sources in the fire zone should be similar to the ignition sources of the "Plant Location" that it is being assigned to. Similarity should be established based on ignition source type, configuration, ignition causes or sub-components indicated in the fire events assigned to the "Plant Location". For example when an Auxiliary Building fire zone called "Inverter Room" also contains station batteries, it should be placed in the "Battery room" plant location instead of "Auxiliary Building".

2. The selection of the location should remain consistent with the "Plant Location" selected in the generic ignition frequency method. For example, if the fire (e.g., in the Relay Room) is binned in the control room "Plant Location" in the generic database, then assigning that fire zone (i.e., Relay Room) to the control room "Plant Location" is appropriate. Otherwise, these fires should be counted and included in the frequency along with the applicable control room fires.

c) MCR Non-Suppression Probability and Safe shutdown Capability

Regarding safe shutdown probability for control room fires, the Guide values for detection and suppression are of sufficient uncertainty that it is inappropriate to use them as the sole basis for screening control room evacuation scenarios. An evaluation of the remote shutdown panel often generates valuable insights and should not be omitted. Appendix M of the Guide provides insights on how this analysis should be performed. The analyst should also consider the related supplemental guidance provided in Sections 4.1 and 4.7.

3.5 RAI Question 5 - Automatic/Manual Suppression Dependency

The following supplemental guidance to the Fire PRA Guide, Appendix K, page K-11 is appropriate:

> *"When recovery of the automatic suppression and manual suppression by the fire brigade is credited in the same fire scenario, the dependency between the two should be considered. Given failure of the automatic suppression system and an attempt to recover it, the following considerations can impact the effectiveness of manual suppression by the brigade:*
>
> - *The time spent in recovering the automatic suppression system and progression of the fire. This means less time for the brigade and the potential for secondary fires making fire fighting more difficult.*
> - *Hazard or accessibility of the room. For example, partial CO2 discharge.*

3.6 RAI Question 6 - Fire Risk Scoping Study (FRSS) Issue: Seismic/Fire Interactions

The FIVE approach provides instructions about verification of the seismic ruggedness of the suppression system piping and components during seismic walkdown. This will identify any potential for diversion resulting from a break in the system. Potential inadvertent discharge causing diversion of the suppression was investigated in response to IN 83-41 or 94-12. If any potential for post-earthquake inadvertent discharge of the suppression system is identified, the impact of the discharge on post-fire operator actions should be considered. The impact of inadvertent discharge with no fire is considered under seismic IPEEE as the impact of SSEL is investigated. The impact of actual discharge should be determined similar to non-seismic fire scenarios.

The spurious operation of the detectors, however, is not explicitly addressed. For this concern, the FRSS recommends that one may consider installing either a flame or heat detector in areas with smoke detectors to minimize the number of spurious alarms by dust actuating smoke detectors. Both FIVE and the Guide require that any potential for seismically initiated fires be determined during the seismic walkdown. If the potential for a seismically initiated fire is identified during the walkdown:

a) assess the possible impact of a seismically-initiated fire on the safe shutdown capability if the fire were to burn unchecked (because of the postulated seismic damage to detection/suppression systems) for longer than the other scenarios modeled in the room, and

b) describe plant personnel response to fire alarms after a seismic event and availability of personnel to perform safe shutdown actions as well as deal with actual or spurious alarms.

3.7 RAI Question 7 - Fire Risk Scoping Study (FRSS) Issue: Control Systems Interactions

The Fire PRA Guide Appendix M describes the method for analysis of control room fires. Step 2.3 of the Main Control Room (MCR) evaluation requires that the reliability of the Remote Shutdown Panel (RSP) be evaluated based on the availability equipment and operator actions. These require determination of the availability of the needed equipment and/or control outside of the MCR. The evaluation should account for actual post-fire response based on the plant's safe shutdown strategy including Self-Induced Station Blackout (SISBO) or Loss of Offsite power (SILOOP) if part of plant's safe shutdown methodology.

The following need to be verified to ensure availability of the remote functions, in post evacuation.

a) Electrical independence of the remote shutdown control systems,

b) Ability to transfer control of safe shutdown equipment to remote shutdown locations, including consideration of potential fire-induced failures that may impair or prevent transfer,

c) Spurious actuation of components leading to component damage, LOCA or interfacing systems LOCA, and

d) Total loss of system function.

3.8 RAI Question 8 - Fire Risk Scoping Study (FRSS) Issue: Manual Fire Fighting Effectiveness

When manual suppression is credited, a discussion of the impact of smoke on the brigade should be provided. Plant provisions for smoke control and the ability to fight the fire under smoke conditions should be examined and tied to the scenarios where manual suppression is credited. The source of the data for the manual non-suppression probability (e.g., the cable fire curve in Appendix B of the Guide) can provide additional basis as the data reflects actual fire and smoke conditions. Misdirected manual suppression resulting in damage to additional equipment also needs consideration even if manual suppression was not credited in a fire scenario or fire compartment.

3.9 RAI Question 9 - Fire Risk Scoping Study (FRSS) Issue: Total Environment Equipment Survival

The issue here is," the impact on component and system availability arising from the actuation of fire suppression systems in areas not directly involved in a fire." FIVE's instructions, if adequately implemented, do provide response to this question.

3.10 RAI Question 10 – Special Accident Initiators

The 4th bullet under step 2.4e on page 4-5 is to be removed from the Fire PRA Implementation Guide (Ref. 1).

3.11 RAI Question 11 - Screening of Enclosed Ignition Sources

The following supplemental guidance is provided regarding screening of enclosed ignition sources.

Transformers:

Transformers of voltage 480V or higher should not be screened during Step 5.2 Screening Walkdown (Ref. 1), on the basis that they are fully enclosed. A detailed fire modeling assessment as described in Step 5.3, should be completed.

Electrical Cabinets:

Electrical cabinets rated for voltages at and above 480V should not be screened during Step 5.2 Screening Walkdown, on the basis that they are fully enclosed. These cabinets should be treated as vented cabinets and a detailed fire modeling assessment as described in Step 5.3, should be completed. Cabinets that should be treated as vented would normally include the following, but may include others:

- Switchgear cabinets of 480V or greater,
- Diesel generator cabinets supplied with AC power by the running diesel generator (e.g., DG excitation cabinets, DG switchgear, and some DG control cabinets).

Because of their position in the electrical lineup, most motor control centers will have adequate breaker protection and therefore may be screened if they are unvented. However, analysts should consult plant drawings or knowledgeable plant personnel to ascertain whether exceptions exist.

After thorough review of over 180 electrical cabinets fire events (including the events at Oconee, Yankee Rowe and Waterford) we have concluded that only the potential for damage to immediately adjacent cabinets, in the case of high energy switchgear fires, needs to be modeled beyond the existing thermal damage models. Therefore, the PRA model should account for the potential for loss of function of the switchgear cubicles immediately adjacent to the cubicle where the fire originates.

Reflash of a nominally suppressed fire could occur and is reflected in the historical data or manual suppression of electrical cabinet fires (EPRI Fire PRA Guide, Figure K-1).

3.12 RAI Question 12 - Electrical Cabinet Heat Release Rate

The analysis of cabinet fires in the plant typically confronts a broad spectrum of electrical cabinets, most of which can be adequately represented by the recommended heat release rate, provided they contain qualified cable. These include:

- Wall-mounted panels, on the basis that they are small, contain limited combustibles, and (if vented) are poorly ventilated;

- Switchgear, load centers and motor control centers, on the basis that combustible loads are low, internal cables are typically routed through internal wireways or cable troughs;

- Battery chargers and inverters on the basis that combustible loads are low.

The recommended heat release rate (65 Btu/s) should be applied with caution to electronics cabinets. Electronics cabinets are considered to be vertical cabinets with significant numbers of relays and/or circuit cards. They are typically found in control rooms, relay rooms, auxiliary electric equipment rooms, but may be found in cable spreading rooms as well as other plant locations.

For electrical cabinets that contain qualified cable, providing the fuel configuration is such that there is a reasonable expectation that the fire will remain confined to a single bundle of cables, a heat release rate of 65 Btu/s is appropriate. Otherwise, a different value should be used that is based on the configuration of the combustibles in the cabinet as they contribute to the exposed surface area. We recommend a value of 200KW (190 Btu/s) for these cases. The basis is provided below.

NUREG/CR-4527 reports 11 cabinet fire test with qualified cables. In two of the tests the transient ignition source did not cause ignition of the cabinet combustible load. The peak heat release rate for 7 of the remaining 9 is reported between 23 and 65 Btu/s. These test were all in vertical cabinets with both open and closed doors and combustible loads of varying configuration ranging from 110,000 to 1,000,000 Btu. Two tests involving benchboard-type cabinets with 1,470,000 Btu loading and configurations similar to the vertical cabinet tests produced peak heat release rates of 175 Btu/s (Test PCT6: cabinet with open door) and 1148 Btu/s (Test 23: cabinet with front ventilation grill & open backdoor). The NUREG offers no explanation for the significant increase particularly in the case of Test 23. A series of cabinet fire tests were conducted in Finland with unqualified cables that produced heat release rates between 48 and 360 Btu/s. These tests are used to derive the recommended 190 Btu/s value. Test 23 is taken into account as one-in-nine evidence.

Exposed cable surface can be an important contributor to the intensity of an electrical cabinet fire. Selection of the heat release rate for an electrical cabinet (or any electrical fire source) should take into account the configuration of the combustible, i.e., high density of loose cables and wires. Unfavorable configurations can promote fire propagation and intensity. High combustible loading is a less important factor (particularly in the case of cabinets with qualified cables) if the exposed surface area is reduced with tight bundling of the cables and wires.

3.13 RAI Question 13 - Fixed Ignition Source Screening, Non-Combustible Shield

The guidance in the Fire PRA Implementation Guide (page 4-18, Step 5.2 – Screening Walkdown, first sentence of the 3rd paragraph) is revised to:

> "Ignition sources that meet all the following criteria can be screened from further consideration in defining fire scenarios;

a) no targets above the source within the plume damage height
b) targets located farther than the radiant damage to the adjacent targets or separated from radial targets by a non-combustible radiant shield (review the basis for adequacy of the shield for protection of the targets against radiant heat damage in the zone of influence) and
c) the hot gas layer temperature from the source does not reach the lowest damage threshold of the important targets in the room or the ignition temperature of potential intervening combustibles."

3.14 RAI Question 14 - Fixed Ignition Source Screening, Consideration of Transients

The guidance in the Fire PRA Implementation Guide, the 3rd and 4th sentence under Step 5.1 in page 4-15 is revised to read as follows:

> "The compartment may be screened following the fixed ignition source screening if the compartment CDF, considering the remaining fixed sources and transient fires, drops below the cutoff core damage frequency (i.e., 1E-06/yr)."

3.15 RAI Question 15 - Automatic Suppression Dependency

On page 4-39 of the Guide, next to the last paragraph, the last two sentences are revised to read:

> "Using the original time-to-damage as the fire duration, the analyst determines the probability of manual suppression. If no external targets are ignited the suppression curve for the ignition source is used. The cable fire suppression curve should be used after ignition of external targets."

3.16 RAI Question 16 - Piloted Cable Ignition Temperature

The piloted cable ignition temperature recommended for cables in the plume or ceiling jet region of a fire scenario is 700°F.

4

PREPARATION OF SITE SPECIFIC RESPONSES

4.1 RAI Question 1 - Screening Human Reliability Analysis

We believe that appropriate HRA methods have a corresponding structure to that proposed in section 3.1. However, the licensee is expected to respond to the NRC according to how they employed their preferred HRA method in lieu of considering the above supplemental guidance as a complete fire HRA method.

In particular, it is worth noting that the majority of fire unique factors identified in section 3.1 relate to actions performed outside the control room or actions performed while the effects of the fire are present. The Fire PRA Guide is structured along the same process for implementation. Hence, it is logical to demonstrate the completeness of a fire HRA in an IPEEE submittal by listing the human actions credited in the screening analysis organized by these two criteria. The response to this question can then focus on those actions that are most influenced by a fire.

For those actions that are least influenced by the fire (and the ones most likely to be credited in the screening analysis), inappropriate screening is most likely to occur when multiple events of low probability appear in the same cutset. This possibility can be eliminated if it can be shown that the truncation value used for CCDP cutset quantification is set too low (e.g., 1E-9) to allow significant screening (of cutsets) to occur based on the screening HRA values used (e.g., greater than or equal to 0.01).

The generic RAI requests, "*Please identify: a) the scenarios screened out from further analysis whose quantification involved one or more HEPs, b) the HEPs (description and numerical values) for each of these scenarios and c) how the effects of the postulated fires are treated*." The approach described here is based on identifying instances where use of the screening HEPs may have resulted in inappropriate truncation of cutsets and screening of potentially important fire scenarios. Then, if such potential is identified, the HEP(s) should be demonstrated to be appropriate given the fire unique considerations described in section 3.1.

In summary:

a) Create a list of all human actions credited during screening, the HEPs used, and categorize those actions as most influenced by a fire if performed outside the control room or while the effects of the fire are present.

b) Compare the cutset truncation value used in quantification of the conditional core damage probability (P2 value in FIVE) with the screening HEPs (no less than 0.01) to determine the potential for inappropriate screening of cutsets with HEPs. If screening HEPs are low enough and the truncation limit is set high enough, it is possible to screen cutsets with one or more HEPs that could lead to inappropriate screening of fire scenarios. If such cases are possible, identify the HEPs and potential compartments affected (if different truncation value is used for different fire compartments).

c) If the actions credited in these cases are influenced by a fire, then it should be demonstrated that the HEPs used in these cases are appropriate considering the fire unique factors discussed in section 3.1.

4.2 RAI Question 2 - Heat Loss Factor

The instructions provided here are in accordance with the supplemental guidance provided in Section 3.2 and are applicable only to those submittals that have used HLFs greater than 0.70 in the FIVE fire models.

a) Any screening of fire compartments that assumes failure of all circuits/components in the compartment (in accordance with FIVE steps 1 and 2 or EPRI Fire PRA Method steps 1 through 4) is not affected by the HLF and the compartments do not require consideration in response to this question.

b) If HLF = 0.85 was used for single compartment scenarios involving electrical cabinet fires or elevated cable tray fires, and the hot gas layer was conservatively assumed to descend only to the top of the cabinet or to the elevation of the lowest tray (virtual surface 0.40H above the floor, where H = ceiling height), the scenario need not be revised.

c) If HLF = 0.94 or 0.85 was used for other single compartment scenarios, revise the HLF to 0.7 unless it can be demonstrated that the resulting damage was bounding with the higher heat loss factor and the analysis did not credit timing.

d) The user should develop a quantified justification for the use of 0.94 in multi-Compartment fire scenarios. Factors to consider in the justification may include:

- The percentage of combustible materials in the exposing compartment that become involved in the fire,
- The extent of failure of the barrier between the exposing and exposed compartments and its impact on migration of hot gases.

4.3 RAI Question 3 - Fire Propagation in Horizontal Cable Tray Stacks

All fire scenarios using the Guide's horizontal cable tray stack model (Hot Gas Layer Timing Study) should be identified and reviewed against the criteria discussed in the supplemental guidance. Scenarios inconsistent with these criteria should employ an alternative method to predict fire propagation timing.

The following describes the process for identifying the specific fire scenarios that may be affected by the supplemental guidance.

- None of the screened fire compartments need to be considered as long as FIVE Steps 1 and 2 or Fire PRA Implementation Guide Steps 1 through 5.2 have been followed. This is because these steps screen using the initial ignition source and damage to all circuits/equipment in the compartment ignoring the timing of the damage. Only ignition sources that produce no damage to any target are screened.

- Existing detailed fire modeling (Implementation Guide Step 5.3) should be reviewed to identify potentially affected scenarios. Only scenarios that meet the following specific criteria may require further evaluation:
    - Timing and heat (BTUs) were specifically calculated using the model in Appendix I, or
    - The model was considered to define the "region of damage" within a cable tray stack.

- Scenarios where the model was used only to define the amount of cable involved in a fire and the timing of equipment/cable damage was assumed to occur instantaneously need NOT be addressed if the scenario being modeled is sufficiently similar to the criteria set in section 3.3, 3rd bullet.

- Walkdowns or drawing review may be required to determine, from the candidate scenarios, any involving tray stacks located within 6' of the wall/ceiling corners. For such fires, the scenarios should be reevaluated and the heat contribution to the compartment increased by the appropriate scale factor shown in Figure 1.

- In the evaluation of scenarios involving cable tray configurations that are NOT similar to those tested (described in Section 3.3), it should be recognized that use of the model may not be appropriate.

- Scenarios where the model was inappropriately used to define damage should be reevaluated recognizing that the model approximates ONLY the region of burning cable.

- The impact on the effectiveness and/or timing of detection and suppression should be reevaluated for any fire scenarios that are revised.

4.4 RAI Question 4 - Control Room Evacuation Scenarios

The site-specific response needs to address the following issues.

If severity factors were multiplied by non-suppression probabilities for the main control room scenarios, one or the other needs to be removed (i.e., set to 1.0) and MCR scenarios re-evaluated.

If the control room fire frequency was not apportioned to other areas, this only needs to be stated. If control room frequency is apportioned to other areas, a justification should be provided using the supplemental guidance provided in section 3.4(b) of this report.

Finally, an analysis of the remote shutdown capability is required if one was not performed. In this case, an analysis of safe shutdown should be performed using the guidance provided in Appendix M of the Guide and supplemental guidance in sections 4.1 and 4.7 of this document.

4.5 RAI Question 5 - Automatic/Manual Suppression Dependency

This question does not require examination of the fire compartments screened during qualitative screening step (FIVE methodology step 1) or the quantitative screening step where ignition frequency and damage to all equipment in the compartment is assumed. No credit for manual suppression by the brigade is appropriate in these steps before the fire modeling defines the available time.

For those fire scenarios where recovery of the automatic suppression and manual suppression by the fire brigade is credited, check for the following dependencies in addition to those listed in pages K-5 and K-12 of the Guide:

- The time to fire brigade response should include the time that was spent in the attempt to recover the automatic suppression. For example, if in the case of 60 minutes available time (when a barrier provides 1-hour protection), 30 minutes has already been spent in trying to recover the automatic suppression the available time for brigade may only be 30 minutes. Fire brigade training documents are a good source for estimating the timing.

- The effectiveness of the brigade should account for the potential fire progression. For example, if a transient fire has ignited cable trays, the fire brigade non-suppression probabilities for cable fire should be used.

- In case of recovery of CO2 or Halon systems, the fire brigade probability using the hose stream may be affected due to their hesitation to enter the room. This dependency should be reflected in the estimating the fire brigade non-suppression probability.

Revise the compartment and plant CDF as necessary.

4.6 RAI Question 6 - Fire Risk Scoping Study (FRSS) Issue: Seismic/Fire Interactions

Confirm, by walkdown if necessary, that the fire protection piping and components are installed in accordance with the nationally-recognized codes and standards, including the II/I criteria. Explain how (possibly from response to IN 83-41 and/or IN 94-12) the suppression systems are protected against inadvertent discharge. Describe the walkdown approach and results. Describe whether the areas with smoke detectors have heat or flame detectors as well. If a potential for seismically initiated fire is identified in a room:

a) assess the possible impact of a seismically induced fire on the safe shutdown capability in that room if the seismic-fire were to burn for a longer time than the other scenarios in the room because of the potential seismic failure of detection/suppression;

b) describe plant personnel response to fire alarms after a seismic event and availability of personnel to perform safe shutdown actions as well as deal with actual or spurious alarms; and

c) in addition, if any potential for post-earthquake inadvertent discharge of the suppression system is identified, the impact of the discharge on post-fire operator actions should be considered.

An example is provided in Table 1. A response specific to your site needs to be prepared.

The analyst should be cognizant of the impact of these instructions on the site fire risk evaluation and provide additional explanation of relevant site-specific plant features and/or analyses.

4.7 RAI Question 7 - Fire Risk Scoping Study (FRSS) Issue: Control Systems Interactions

The response is based on two parts. The first is an explanation of the way the plant's safe shutdown methodology ensures availability of the necessary functions at the remote shutdown locations. This information should be available as part of the plant's safe shutdown analysis and related fire procedures. The second part is an explanation of how the fire IPEEE modeled these conditions.

Review the Safe Shutdown Analysis and fire procedures to obtain and discuss the following attributes of the plant's safe shutdown methodology:

a) Provide a discussion of the actions described in the MCR evacuation procedure, pre- and post-evacuation,

b) Explain features and/or actions taken to ensure electrical isolation of the remote shutdown capability,

c) Explain features and/or actions taken for preventing spurious actuations that could potentially impact component availability at the remote shutdown locations, and

d) Explain features and/or actions taken for preventing spurious actuations that could cause LOCA or interfacing systems LOCA..

Discuss where and how the fire IPEEE models:

a) The extent (e.g., all circuits in the panel fail in the undesired mode) and timing (e.g., before or after the transfer) of the fire induced failures in the MCR including hot shorts,

b) The ability to recover from fire-induced LOCA and interfacing systems LOCA.

A response specific to your site needs to be prepared. The analyst should be cognizant of the impact of these instructions on the site fire risk evaluation and provide additional explanation of relevant site-specific plant features and/or analyses.

Table 1 - An Example Response for Seismic/Fire Interactions

Seismic Actuation of Fire Suppression Systems

As part of the seismic assessment, verify that the design of the water suppression system considers the effects, if appropriate, of inadvertent suppression system actuation and discharge on that equipment credited as part of the seismic safe shutdown path in a margins assessment that was not previously reviewed relative to the internal flooding analysis or concerns such as those discussed in NRC I&E Notice 83-41.

Response *This issue was also addressed by Information Notice 94-12, Effects of Fire Suppression System Actuation on Safety Related Systems. The Browns Ferry response to these issues was as follows:*

Mercury Relays. No mercury relays are present in the fire protection control systems.

Seismic Dust/Smoke Detectors. Smoke and/or heat detectors are used at Browns Ferry to actuate fire suppression systems in various areas of the plant. The CO_2 systems are actuated by heat detectors or by a combination of smoke and heat detectors. Therefore, dust particles created during a seismic event alone will not activate the CO_2 systems.

Most safety related areas in the plant are protected with fusible link (closed head) preaction sprinkler systems. If the preaction sprinkler system is inadvertently actuated (due to a seismic event), there will still be no water discharge due to the closed head sprinklers. The only safety related areas where open head spray systems area used are in the Unit 1 Reactor Building cable trays and the Unit 3 Diesel Generator Building cable and pipe tunnel area cable trays. The Unit 1 spray system is planned to be decommissioned prior to restart and the pertinent areas of the Unit 3 DG building do not contain any components that are susceptible to water damage. As part of the Appendix R analysis, fire suppression damage evaluations have been made. It has been concluded that spurious discharge of water from fire suppression systems will have no adverse impact on the safe shutdown capability of the plant.

Water Deluge Systems. As noted above, open head deluge systems are only used for cable tray protection in two areas of the plant that contains safety-related equipment. These systems do not provide protection for electrical cabinets or non-spray proof components.

Fire Suppressant Availability during a Seismic Event. Halon systems are not used to protect areas that contain safety-related equipment. The CO_2 systems are seismically qualified, with the exception of the refrigeration system, which is not required except for prolonged periods. The water suppression system used three electric motor driven pumps and one diesel driven fire pump. The pumps and associated 4kV shutdown boards are located in seismic class 1 structures.

Switchgear Fires. There are few cases where electrical cables and raceways are located close to the top of electrical cabinets and could become directly involved in a fire. These cases are evaluated in Section 6.1 of this report.

Electro-Mechanical Components in Cable Spreading Rooms. No electric cabinets are present in these areas at Browns Ferry. HVAC equipment and control panels in these areas are installed such that tipping or sliding is prevented.

Seismic Degradation of Fire Suppression Systems

As part of the seismic assessment walkdown, verify that plant fire suppression systems have been structurally installed in accordance with good industrial practice and reviewed for seismic considerations, such that suppression system piping and components will not fail and damage safe shutdown path components, nor is it likely that leaking or cascading of the suppressant will result.

Response *The fire protection system piping is designed to maintain pressure boundary integrity where spray damage to safety related components would affect the safe shutdown capability of the plant. The fire protection system piping is designed at a minimum for position retention (seismic II/I design criteria). Additionally, the seismic portion of the IPEEE analysis will identify any potential outliers, where seismic class II components could damage seismic class I components.*

4.8 RAI Question 8 - Fire Risk Scoping Study (FRSS) Issue: Manual Fire Fighting Effectiveness

A discussion should be provided to demonstrate that the impact of smoke on fire fighting activity is accounted for in the fire scenarios that are credited. The discussion should directly relate the impact of the program attribute(s) to the smoke control issue, e.g., provision for smoke removal in plant areas, training with SBCA, how availability of the equipment is verified through surveillance, etc. Regarding the misdirected manual suppression effort, the discussion should explain how the plant's fire protection program elements, (e.g., training) would minimize that potential.

4.9 RAI Question 9 - Fire Risk Scoping Study (FRSS) Issue: Total Environment Equipment Survival

Use the response to IN 83-41 and/or IN94-12 to explain how safety related equipment is protected against inadvertent actuation of multiple suppression systems. This includes verification that design of fire protection systems considers the effects of inadvertent actuation and discharge on equipment credited for safe shutdown.

4.10 RAI Question 10 – Special Accident Initiators

Ensure that the accident initiators used for fire scenarios follow the guidance provided in step 2.4e on page 4-5 of the Fire PRA Implementation Guide (Ref. 1) excluding the 4th bullet. Use of any quantitative threshold in selection of the fire-induced accident initiators should be adequately justified.

Revise the compartment and plant CDF as necessary.

4.11 RAI Question 11 - Screening of Enclosed Ignition Sources

The following describes the process for identifying the electrical cabinets that were previously screened, but may require reevaluation as ignition sources.

Within the compartments previously addressed under 5.1, 5.2 and 5.3 of the Implementation Guide, perform the following:

- Identify any transformers that were previously considered enclosed; reevaluate as exposed ignition sources. Low voltage transformers (<480V) do not need to be re-examined.
- Identify any switchgear that was previously considered enclosed; reevaluate as exposed ignition sources.
- Identify any other electrical cabinets fed by high-energy sources such as a diesel generator or high voltage (480V or greater) transformer. Determine whether there are at least two breakers in the electrical lineup that could be demonstrated to interrupt a potential fault and isolate the cabinet. If not, reevaluate as exposed ignition sources.

- Determine whether there is any motor control centers (480V or greater) that do not have the required level of breaker protection. If any, reevaluate as exposed ignition sources.

The exposed high-energy cabinets should be modeled to investigate the potential for thermal damage following these steps from the Fire PRA Implementation Guide:

1. Evaluate the zone of influence (see the guidance on Question 12 for selection of a heat release rate), including the potential for damage from a high-energy switchgear event to the immediately adjacent cabinets. If a potential target (or targets) are identified within the zone of influence, follow the guidance in Step 5.3 of the Guide.

2. If no target is identified in the zone of influence, and rules for non-propagating fixed ignition sources are met (Fire PRA Guide, pages 4-19), then the cabinet may be screened from further modeling.

3. Account for damage to the immediately adjacent cubicles in the case of a high energy event in a switchgear.

4.12 RAI Question 12 - Electrical Cabinet Heat Release Rate

Plants should examine electrical cabinets, primarily located in (but not limited to) control rooms, relay rooms, auxiliary electric equipment rooms and cable spreading rooms, if they were analyzed using a heat release rate of 65 Btu/s. If the cabinets contain qualified cable and the fuel configuration is such that there is a reasonable expectation that the fire will remain confined to a single bundle of cables, the cabinets need not be reevaluated. Otherwise the cabinets should be reevaluated using a heat release rate of 200 kW (190 Btu/s).

Note that the fire may not remain confined to a single bundle if:

- cable bundles in the same cabinet are separated by less than 1.5 ft (based on calculation of the critical radiant flux distance using a HRR of 65 Btu/s);

- There is a propagation path such as a diagonal cable between two cable bundles separated by >1.5 feet;

- There is the potential for a mini hot gas layer to develop within the cabinet;

- There are significant amounts of other fuels in the cabinet (e.g. circuit cards) and the fuels are distributed within the cabinet.

4.13 RAI Question 13 - Fixed Ignition Source Screening, Non-Combustible Shield

Any fixed ignition source screened during the fixed ignition source walkdown (step 5.2 of the Guide) based on the non-combustible shield in the plume or ceiling jet region should be analyzed. Only fixed sources with no target in the zone of influence that are not capable of causing a damaging hot gas layer can be screened. If there is a target in the radiant zone of influence but separated by a radiant energy shield, it may be considered out of the radiant zone of influence if the shield is designed and maintained to protect against the source-target combination being considered.

Revise the compartment and plant CDF as necessary.

4.14 RAI Question 14 - Fixed Ignition Source Screening, Consideration of Transients

Possibility of transient fires should not be excluded if all fixed fire sources are screened. This is consistent with both FIVE and Fire PRA Methodologies.

Provide a justification for any compartment in which transient fires are not considered. If necessary include transient fire scenarios and revise the compartment and plant CDF.

4.15 RAI Question 15 - Automatic Suppression Dependency

In the fire scenarios where manual suppression by the fire brigade is credited, ensure that:

- To protect against damage to the first target, use the suppression curve for the ignition source,

- To protect after ignition of cables, use the cable suppression curve.

Any fire scenario where suppression unreliability is computed as the product of suppression unreliability for the ignition source and for the target combustibles should be revised to follow the guidance in Appendix K of the Guide (Ref. 1) supplemented by guidance in section 3.15 of this document.

4.16 RAI Question 16 - Piloted Cable Ignition Temperature

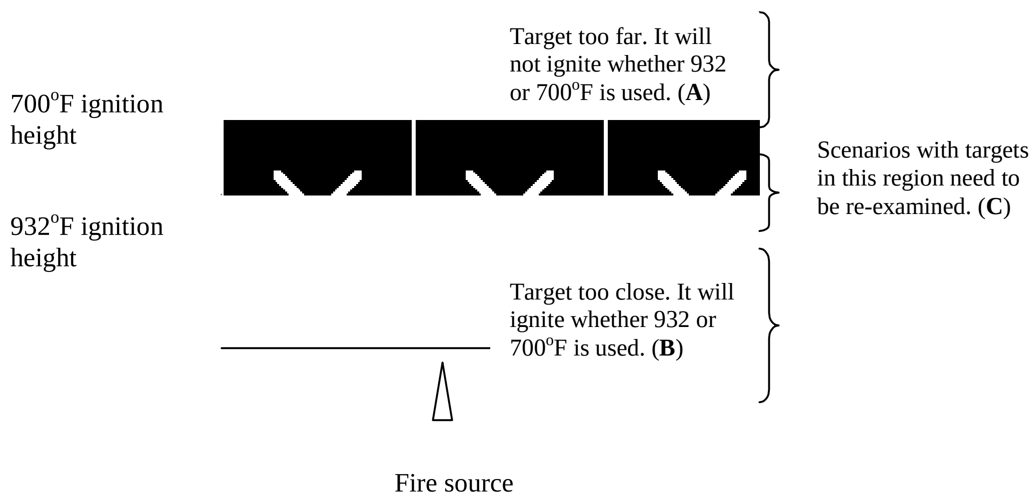
All plume and ceiling jet scenarios that are impacted by the use of the cable ignition temperature of 932^{o}F are to be identified and revised to an ignition temperature of the 700^{o}F. The following describes a process for identifying the specific fire scenarios that may be impacted by the lower cable ignition temperature.

None of the screened fire compartments need to be reexamined as long as FIVE (Steps 1 and 2) or Implementation Guide (Steps 1 through 5.2) have been followed. Both methods rely upon damage temperature (700°F and 450°F for IEEE-383 qualified or unqualified cable, respectively) and not on ignition temperature (932°F) for screening. If higher temperatures were used for these steps (against the guidance in FIVE or the Guide) the screened scenarios need to be reexamined.

Existing detailed fire modeling (FIVE step 3 or Implementation Guide Step 5.3) should be reviewed to identify potentially affected compartments and/or scenarios. These are the scenarios that consider ignition of cables and subsequent damage to additional targets of interest. Fire compartments that were subject to detailed fire modeling (i.e., limiting damage in the compartment) and used cable ignition temperature of 932°F may require further evaluation.

These compartments should be reviewed to identify exposed cable in proximity to the ignition source(s) that would experience a plume or ceiling jet exposure greater than 700°F, yet less than 932°F. Scenarios where the exposed cable is either too close to the fire source and will be ignited with either 700 or 932°F (figure 2 below, region A) or is too far and will not be ignited by 700 or 932°F (figure below, region B) can be excluded. Only scenarios with exposed cables in region C need to be re-evaluated. A scoping evaluation process, potentially followed by walkdown of the specific scenario(s), is recommended. The purpose of the scoping evaluation is to facilitate identification of any affected scenario in the field.

Figure 2 - A Pictorial Guide for Identification of Fire Scenarios Affected by Cable Ignition Temperature



A example of such scoping evaluation is demonstrated in Table 2 that calculates the range of (FIVE) plume ignition heights WITHIN which the exposed cable must be located to be ignited at temperatures between 700°F and 932°F. Plant-specific information should be prepared prior to the walkdown. Caution should be exercised when dealing with ignition distances to account for uncertainty in numbers (i.e., do not preclude a scenario if the target is inches out of the ignition height).

The table is based on a very large compartment (provides largest spread of ignition heights) and calculated plume ignition heights for three representative ignition sources. The plant-specific table should bound the range of compartments where detailed modeling was done.

Table 2 - A Sample Representative of Critical Ignition Distances in a Fire Plume (ft)

Ignition Source HRR (Btu/s)	65	138	2000
Ignition Temps			
932°F	3 ft	4 ft	12 ft
700°F	4 ft	5 ft	15 ft

Where:

- 65 Btu/s is representative of a vertical cabinet with qualified cable,
- 138 Btu/s is representative of a transient ignition source, and
- 2000 Btu/s roughly corresponds to a 4 foot diameter oil fire. Addressing larger spills may be required, but is not expected. Suggestions to use large oil spills serve no purpose for screening since the critical distances corresponding to 932°F and 700°F would be larger than NPP room heights.

A walkdown of the scenario(s) may be performed to search for in-plant conditions where exposed cable is located within the range of calculated ignition heights (e.g., between 3' and 4' above an electrical cabinet) above ignition sources. For those scenarios that fall within this narrow range, reevaluation of the scenario should be performed with a 700°F ignition temperature.

5

REFERENCES

1. W. J. Parkinson, et al., *Fire PRA Implementation Guide,* TR-105928, Electric Power Research Institute, Palo Alto, CA, Final Report, December 1995.
2. ERI/NRC 97-501, "Review of the EPRI Fire PRA Implementation Guide," August 1997.
3. Letter from M.W. Hodges (NRC-RES) to D. Modeen (NEI), Dated December 1997.

A

GENERIC FIRE IPEEE REQUEST FOR ADDITIONAL INFORMATION (RAI)

A.1 Generic RAIs

The following generic requests for additional information (RAIs), when appropriate, will be sent to those licensees if the applicable issues were used in the fire portion of their individual plant examination of external events (IPEEE) submittal:

1. It is important that the human error probabilities (HEPs) used in the screening phase of the analysis properly reflect the potential effects of fire (e.g., smoke, heat, loss of lighting), even if these effects do not directly cause equipment damage in the scenarios being analyzed. If these effects are not treated, the HEPs may be optimistic and result in the improper screening of scenarios. Note that HEPs which are conservative with respect to an internal events analysis could be non-conservative with respect to a fire risk analysis.

   Please identify: a) the scenarios screened out from further analysis whose quantification involved one or more HEPs, b) the HEPs (descriptions and numerical values) for each of these scenarios, and c) how the effects of the postulated fires were treated.

   A reanalysis may be requested if performance shaping factors (PSFs) besides stress associated with fires (e.g., smoke, loss of lighting, poor communication) are relevant and have not been considered.

2. The heat loss factor is defined as the fraction of energy released by a fire that is transferred to the enclosure boundaries. This is a key parameter in the prediction of component damage, as it determines the amount of heat available to the hot gas layer. In Fire-Induced Vulnerability Evaluation (FIVE), the heat loss factor is modeled as being inversely related to the amount of heat required to cause a given temperature rise. Thus, for example, a larger heat loss factor means that a larger amount of heat (due to a more severe fire, a longer burning time, or both) is needed to cause a given temperature rise. It can be seen that if the value assumed for the heat loss factor is unrealistically high, fire scenarios can be improperly screened out. Figure A.1 provides a representative example of how hot gas layer temperature predictions can change assuming different heat loss factors. Note that: 1) the curves are computed for a 1000 kW fire in a 10m x 5m x 4m compartment with a forced ventilation rate of 1130 cfm; 2) the FIVE-recommended damage temperature for qualified cable is 700 F for qualified cable and 450 F for

unqualified cable; and, 3) the SFPE curve in the figure is generated from a correlation provided in the Society for Fire Protection Engineers Handbook [1].

Based on evidence provided by a 1982 paper by Cooper et al. [2], the *EPRI Fire PRA Implementation Guide* recommends a heat loss factor of 0.94 for fires with duration's greater than five minutes and 0.85 for "exposure fires away from a wall and quickly developing hot gas layers." However, as a general statement, this appears to be a misinterpretation of the results. Reference [2], which documents the results of multi-compartment fire experiments, states that the higher heat loss factors are associated with the movement of the hot gas layer from the burning compartment to adjacent, cooler compartments. Earlier in the experiments, where the hot gas layer is limited to the burning compartment, Reference [2] reports much lower heat loss factors (on the order of 0.51 to 0.74). These lower heat loss factors are more appropriate when analyzing a single compartment fire. In summary, (a) hot gas layer predictions are very sensitive to the assumed value of the heat loss factor; and (b) large heat loss factors cannot be justified for single-room scenarios based on the information referenced in the *EPRI Fire PRA Implementation Guide*.

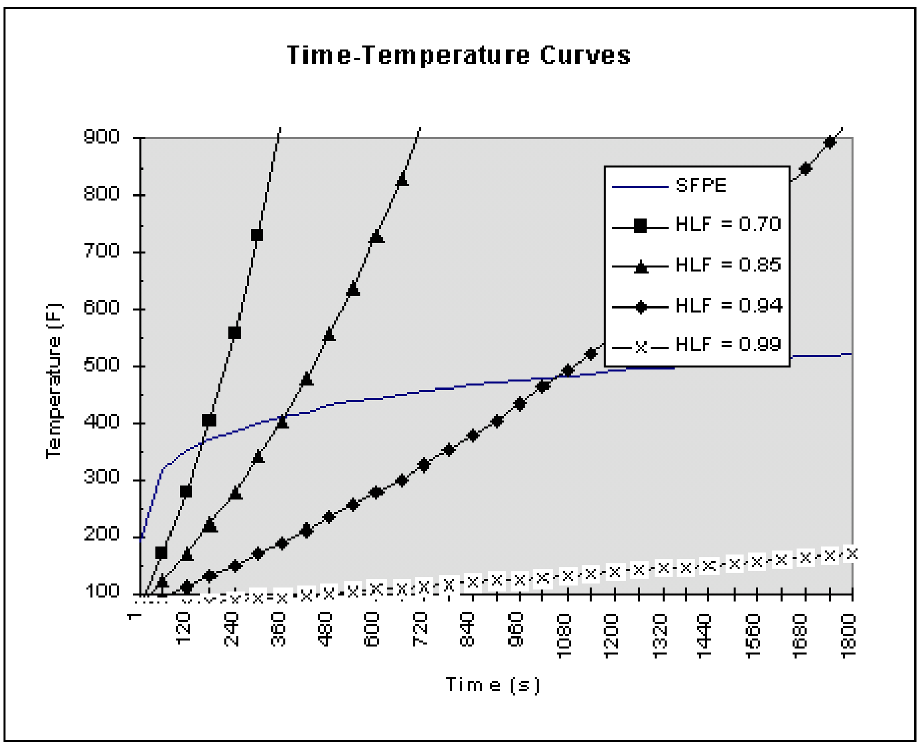


Figure A.1 Sensitivity of the hot gas layer temperature predictions to the assumed heat loss factor

For each scenario where the hot gas layer temperature was calculated, please specify the heat loss factor value used in the analysis. In light of the preceding discussion, please either: a) justify the value used and discuss its effect on the identification of fire *vulnerabilities, or b) repeat the analysis using a more justifiable value and provide the resulting change in scenario contribution to core damage frequency.*

3. In computing the extent of fire propagation and equipment damage for a given scenario, it is important that experimental results not be used out of context. Inappropriate use of experimental results (e.g., employing propagation times specific to a particular cable tray separation to fires involving cable trays with lesser separation) can lead to improper assessments of scenario importance. In one case [3], rather than performing fire model calculation and using the results, experimental data from a test performed to model cable tray fire propagation in the absence of an exposure fire was used to model cable response to an exposure fire, which led to over an order of magnitude reduction in predicted fire-induced core damage frequency.

   For each fire scenario in which experimental data were used to estimate the rate and extent of fire propagation, please: (a) indicate if FIVE (or similar) calculations were performed for the scenario and provide the results (equipment damaged) of these calculations; (b) indicate which experimental results were used and how they were utilized in the analysis; and, (c) justify the applicability of these experimental results to the scenario being analyzed. The discussion on results applicability should compare the geometries, ignition sources, fuel type and loadings, ventilation characteristics, and compartment characteristics of the experimental setup(s) with those of the scenario of interest.

4. Fires in the main control room (MCR) are potentially risk-significant because they can cause I&C failures (e.g., loss of signals or spurious signals) for multiple redundant divisions, and because they can force control room abandonment. Although data from two experiments concerning the timing of smoke-induced, forced control room abandonment is available [4], the data must be carefully interpreted, and the analysis must properly consider the differences in configuration between the experiments and the actual control room being evaluated for fire risk. In particular, the experimental configuration included placement of smoke detectors inside the cabinet in which the fire originated, as well as an open cabinet door for that cabinet. In one case, failure to account for these configuration differences led to more than an order of magnitude underestimate in the conditional probability of forced control room fire abandonment [3]. In addition, another study raises questions about control room habitability due to room air temperature concerns [5].

   Please provide the detailed assumptions (including the assumed fire frequency, any frequency reduction factors, and the probability of abandonment) used in analyzing the MCR and justifications for these assumptions. In particular, if the probability of abandonment is based on a probability distribution for the time required to suppress the fire, please justify the parametric form of the distribution and specify the data used to quantify the distribution parameters.

5. The *EPRI Fire PRA Implementation Guide* methodology for evaluating the effectiveness of suppression efforts treats manual recovery of automatic suppression systems as being

independent of subsequent manual efforts to suppress the fire. This assumption is optimistic, as the fire conditions (e.g., heat, smoke) that lead to the failure of recovery efforts can also influence the effectiveness of later suppression efforts. Such an approach, therefore, can overlook plant-specific vulnerabilities.

It is important that all relevant factors be considered in an evaluation of the effectiveness of fire suppression. These factors include: (a) the delay between ignition and detector/suppression system actuation (which is specific to the configuration being analyzed); (b) the time-to-damage for the critical component(s) (which is specific to the fuel type and loading as well as to the configuration being modeled); (c) the response time of the fire brigade (which is plant-specific and fire-location-specific); (d) the time required by the fire brigade to diagnose that automatic suppression has failed and to take manual action to recover the automatic suppression system; and, (e) PSFs affecting fire brigade actions. These PSFs could include factors such as perseverance (persistent efforts made to recover a failed automatic suppression system), smoke obscuration, and impaired communications [3].

Finally, it should be noted that the Nuclear Regulatory Commission (NRC) staff's evaluation of the FIVE methodology [6] specifically stated that licensees need to assess the effectiveness of manual fire-fighting teams by using plant-specific data from fire brigade training to determine the response time of the fire fighters.

Please identify those scenarios for which credit is taken for both manual recovery of automatic suppression systems and manual suppression of the fires (if manual recovery efforts are unsuccessful), and please indicate the plant equipment that may be affected by the fires. In the analysis of these scenarios, how are dependencies between manual actions treated? Please justify the treatment, considering the expected fire environment, the recovery actions required, and the manual fire suppression actions required.

6. The *Fire Risk Scoping Study* (FRSS) [7] identified a number of seismic-fire interaction issues. Resolution of these issues via the Individual Plant Examination of External Events (IPEEE) analysis was identified in NUREG-1407 [8] and Generic Letter (GL) 88-20, Supplement 4 [9]. Among the seismic-fire interaction issues identified in the FRSS was the seismically induced spurious actuation of suppression systems leading to diversion of fire suppressants to non-fire areas rendering them unavailable in the event of a fire elsewhere in the plant. Spurious operation of detectors might both complicate operator response to the seismic event and/or cause the actuation of automatic fire suppression systems. Such actuations could result in flooding problems, habitability concerns (in the case of carbon dioxide systems), diversion of suppressant to non fire-areas, pressurization of compartments (due to over-dumping of gaseous suppressants), and spraying of important plant components not affected by a fire.

   Please describe how the issue of fire suppressant diversion in seismic events due to spuriously induced fire suppression system actuation was addressed in the IPEEE analysis. If this issue was addressed by means of a walkdown, please describe the methodology used to evaluate this issue and provide the results of the walkdowns and *your conclusions with respect to resolution of this issue. If this issue was addressed through other means, please identify how the issue was addressed, providing a description of the methodology used, the results of the assessment, and your conclusions with respect to resolution of this issue.*

7. NUREG-1407 [8], Section 4.2 and Appendix C, and GL 88-20, Supplement 4 [9], request that documentation be submitted with the IPEEE submittal with regard to the FRSS [7] issues, including the basis and assumptions used to address these issues, and a discussion of the findings and conclusions. NUREG-1407 also requests that evaluation results and potential improvements be specifically highlighted. Control system interactions involving a combination of fire-induced failures and high probability random equipment failures were identified in the FRSS as potential contributors to fire risk. This issue was later classified as Generic Safety Issue 147 (GSI-147), "Fire-Induced Alternate Shutdown/Control Room Panel Interactions." Subsequent to the issuance of GL 88-20, Supplement 4, the NRC staff determined that they would assess the extent to which GSI-147 is addressed in the IPEEE submittals.

   The issue of control systems interactions is associated primarily with the potential that a fire in the plant (e.g., the MCR) might lead to potential control systems vulnerabilities. Given a fire in the plant, the likely sources of control systems interactions could happen between the control room, the remote shutdown panel, and shutdown systems. Specific areas that have been identified as requiring attention in the resolution of this issue include:

   (a) Electrical independence of the remote shutdown control systems: The primary concern of control systems interactions occurs at plants that do not provide independent remote shutdown control systems. The electrical independence of the remote shutdown panel and the evaluation of the level of indication and control of remote shutdown control and monitoring circuits need to be assessed.

   (b) Loss of control equipment or power before transfer: The potential for loss of control power for certain control circuits as a result of hot shorts and/or blown fuses before transferring control from the MCR to remote shutdown locations needs to be assessed.

   (c) Spurious actuation of components leading to component damage, loss-of-coolant accident (LOCA), or interfacing systems LOCA: The spurious actuation of one or more safety-related to safe-shutdown-related components as a result of fire-induced cable faults, hot shorts, or component failures leading to component damage, LOCA, or interfacing systems LOCA, prior to taking control from the remote shutdown panel, needs to be assessed. This assessment also needs to include the spurious starting and running of pumps as well as the spurious repositioning of valves.

(d) Total loss of system function: The potential for total loss of system function as a result of fire-induced redundant component failures or electrical distribution system (power source) failure needs to be addressed.

Please describe your remote shutdown capability, including the nature and location of the shutdown station(s), as well as the types of control actions, which can be taken from the remote panel(s). Describe how your procedures provide for transfer of control to the remote station(s). Provide an evaluation of whether loss of control power due to hot shorts and/or blown fuses could occur prior to transferring control to the remote shutdown location and identify the risk contribution of these types of failures (if these failures are screened, please provide the basis for the screening). Finally, provide an evaluation of whether spurious actuation of components as a result of fire-induced cable faults, hot shorts, or component failures could lead to component damage, a LOCA, or an interfacing systems LOCA prior to taking control from the remote shutdown panel (considering both spurious starting and running of pumps as well as the spurious repositioning of valves).

8. NUREG-1407 [8], Section 4.2 and Appendix C, and GL 88-20, Supplement 4 [9], request that documentation be submitted with the IPEEE submittal with regard to the FRSS [7] issues, including the basis and assumptions used to address these issues, and a discussion of the findings and conclusions. NUREG-1407 also requests that evaluation results and potential improvements be specifically highlighted. Sensitivity studies in the FRSS showed that prolonged fire-fighting times can lead to a noticeable increase in fire risk. Smoke, identified as one of the major contributors to prolonged response times, can also cause misdirected suppression efforts and hamper the operator’s ability to safely shut down the plant. This issue was later classified as GSI-148. Subsequent to the issuance of GL 88-20, Supplement 4, the NRC staff determined that they would assess the extent to which GSI-148 is addressed in the IPEEE submittals.

   This issue concerns itself with the hampering effects of the potential buildup of smoke on the efforts of the manual fire brigade to promptly and effectively suppress fires. Simply not crediting manual fire suppression in the IPEEE fire analysis does not fully address the issue since the issue involves whether or not manual fire-fighting actions could result in additional failures. Not crediting manual fire suppression does not address whether such activities could result in additional failures under some circumstances.

   Please describe your provisions for smoke control in the event of fires at your facility. For any fire scenario in which manual fire suppression efforts are credited in calculating core damage frequency (CDF), please describe how your analysis accounted for smoke control issues. For scenarios in which manual fire suppression is not credited in the analysis, please describe how your analysis evaluated the potential that additional component failures could be caused by misdirected manual fire suppression efforts.

9. NUREG-1407 [8], Appendix D, identifies the effect of fire suppressants on safety equipment as one of the safety issues identified in the FRSS [7]. Subsequent to the issuance of NUREG-1407 and GL 88-20, Supplement 4 [9], this issue was designated as

part of GSI-172, "Multiple System Response Program (MSRP) Issues." Fire suppression system actuation events can have an adverse effect on safety-related components either through direct contact with suppression agents or through indirect interaction with non-safety related components. It is important to recognize that fire suppression can impact components outside the immediate area of the fire as a result of actuation of fire suppression systems due to transport of smoke, propagation of hot gas layers, or misdirected manual suppression efforts.

Please describe how the IPEEE fire analysis accounted for the impact on component and system availability arising from the actuation of fire suppression systems in areas not directly involved in a fire.

10. As defined in the *EPRI Fire PRA Implementation Guide* (page 4-2 of [1]), a special initiator trips the plant and causes loss of a mitigating safety system. Examples of such special initiators include loss of service water and loss of component cooling water. It can be seen that a special initiator, even if it occurs at a relatively low frequency, can be risk-significant because of the consequences of the initiator. (In some plants, an unrecovered special initiator can lead directly to core damage.)

    Fire is a potential cause of special initiators. If the frequency of a fire-induced special initiator is comparable to or greater than the random frequency for that initiator (and note that there may be a number of areas in the plant where a fire can cause the initiator), then an analysis which does not evaluate the CDF contribution due to the fire-induced special initiator may overlook an important vulnerability. Note that potential collateral damage caused by the fire may increase the importance of this issue.

    Please discuss the process used to identify and analyze fire-induced special initiators. In particular, if special initiators with non-recoverable frequencies less than 10^{-4} per year were screened, please provide the basis for this screening criterion. If recovery actions are assumed, please include in the discussion the approach used to address the impact of fire on recovery.

11. The *EPRI Fire PRA Implementation Guide* assumes that all enclosed ignition sources cannot lead to fire propagation or other damage (page 4-18 of [1]). This can be an optimistic assumption for oil-filled transformers and high-voltage cabinets. The *Guide* also assumes that fire spread to adjacent cabinets cannot occur if the cabinets are separated by a double wall with an air gap or if the cabinet in which the fire originates has an open top (page H-3 of [1]). This can also be an optimistic assumption for high-voltage cabinets since an explosive breakdown of the electrical conductors may breach the integrity of the cabinet and allow fire to spread to combustibles located above the cabinet. For example, switchgear fires at Yankee-Rowe in 1984 and Oconee Unit 1 in 1989 both resulted in fire damage outside the cubicles.

    Please provide the basis for the assumption and a discussion on how the specific enclosures were analyzed to ascertain that the assumption is applicable to them.

12. In the EPRI Fire PRA Implementation Guide, test results for the control cabinet heat release rate have been misinterpreted and have been inappropriately extrapolated. Cabinet heat release rates as low as 65 Btu/sec are used in the Guide. In contrast, experimental work has developed heat release rates ranging from 23 to 1171 Btu/sec.

    Considering the range of heat release rates that could be applicable to different control cabinet fires, and to ensure that cabinet fire areas are not prematurely screened out of the analysis, a heat release rate in the mid-range of the currently available experimental data (e.g., 550 Btu/sec) should be used for the analysis.

    Discuss the heat release rates used in your assessment of control cabinet fires. Please provide a discussion of changes in the IPEEE fire assessment results if it is assumed that the heat release from a cabinet fire is increased to 550 Btu/s.

13. The *EPRI Fire PRA Implementation Guide* allows the screening of ignition sources if a non-combustible shield lies between the source and key targets. This screening may not be valid in cases where: (a) there is a high hazard source (e.g., an oil fire); (b) flames are impinging on the shield; or (c) hot gases in the plume above the fire can move around the shield. Improper screening of ignition sources may lead to improper screening of fire scenarios.

    a. Have any ignition sources with targets directly above been screened out because a non-combustible shield lies between the source and the targets? If so, please identify and describe the sources and their targets.

    b. Have any high hazard fire ignition sources (e.g., rotating machinery with large amounts of oil) been screened out because a non-combustible shield lies between the source and its targets? If so, please identify and describe the sources and their targets.

A reanalysis may be requested for any improperly screened ignition sources.

14. In general, the fire risk associated with a given compartment is composed of contributions from fixed and transient ignition sources. Neglect of either contribution can lead to an underestimate of the compartment's risk and, in some cases, to improper screening of fire scenarios. The *EPRI Fire PRA Implementation Guide* allows the screening of transient ignition sources in compartments where all fixed ignition sources have been screened out. Based on this approach, a cable spreading room or a cable shaft that does not contain any items other than IEEE 383 qualified control and instrumentation cables, and access to the compartment is strictly controlled, can be screened out. If such compartments contain the cables for all redundant trains of important plant safety systems, a major vulnerability may be overlooked, without sufficient analysis of potential accident sequences and needed recovery actions.

    In compartments where all fixed ignitions sources have been screened out, has the possibility of transient combustible fires been considered? For each compartment where *transient fires have not been considered, please provide the justification for this conclusion and provide a discussion on compartment inventory in terms of system trains and associated components (i.e, cables and other equipment). Please explain whether or not the conditional core damage probabilities, given damage to all cables and equipment in these compartments, are significant (i.e., cables from redundant trains are present). If the conditional core damage probability for a compartment is considered significant, please provide justification for assigning a very low likelihood of occurrence to transient fuel fires for the compartment.*

15. In order for suppression efforts to be successful, all fires within a compartment must be suppressed. The *EPRI Fire PRA Implementation Guide* appears to consider suppression efforts successful if fires involving the ignition source or any subsequently ignited targets are suppressed (see p. 4-39 of the *Guide*). Analyses employing such an erroneous success criterion will result in optimistic assessment of fire scenario risk and may lead to improper screening of fire scenarios.

    Are there any scenarios where the overall suppression unreliability is computed as the product of suppression unreliabilities for the ignition source and target combustibles? If so, please identify the scenarios and discuss the risk impact of a more appropriate suppression success criterion.

In a subsequent letter (Letter from Alan Rubin, NRC-RES to Dave Modeen, NEI), the NRC referred the following question for a generic response by the industry.

16 The [insert name of plant] fire analysis has assumed a cable ignition temperature of 932oF (see page xxx of the submittal) and cites the Fire PRA Implementation Guide as the basis for this value. The PRA Guide recommends that this value be used for both spontaneous and piloted ignition. This value is significantly optimistic in comparison to piloted ignition temperatures observed in tests by Sandia National Laboratories (see NUREG/CR-5546) and in comparison to the practice recommended by EPRI FIVE. The SNL tests show that the piloted ignition temperature for cables will be as low or lower than the thermal damage threshold; hence, use of a piloted ignition temperature of no greater than 700oF, the damage threshold assumed in the analysis, would be appropriate. The EPRI FIVE method recommendation is also consistent with these SNL test results; namely, use 700°F as the threshold for both damage and ignition for IEEE-383 qualified cables (see page 6-14 of the FIVE documentation). The assumption of a 932°F piloted ignition temperature may have resulted in the optimistic treatment of cable fire growth behavior.

    Please provide an assessment of the change in fire CDF if it is assumed that the piloted ignition temperature of the cables is 700oF. Include in the response an assessment of how a reduced-piloted ignition temperature would impact the screening results of the analysis as well.

A.2 References

1. P.J. DiNenno, et al, eds., “SFPE Handbook of Fire Protection Engineering,” 2nd Edition, National Fire Protection Association, p. 3-140, 1995.

2. L. Y. Cooper, M. Harkleroad, J. Quintiere, W. Rinkinen, “An Experimental Study of Upper Hot Layer Stratification in Full-Scale Multiroom Fire Scenarios,” ASME Journal of Heat Transfer, 104, 741-749, November 1982.

3. J. Lambright, et al., "A Review of Fire PRA Requantification Studies Reported in NSAC/181," prepared for the United States Nuclear Regulatory Commission, April 1994.

4. J. Chavez, et al., "An Experimental Investigation of Internally Ignited Fires in Nuclear Power Plant Cabinets, Part II-Room Effects Tests," NUREG/CR-4527/V2, October 1988.

5. J. Usher and J. Boccio, “Fire Environment Determination in the LaSalle Nuclear Power Plant Control Room,” NUREG/CR-5037, prepared for the United States Nuclear Regulatory Commission, October 1987.

6. A. Thadani, “NRC Staff Evaluation Report on Revised NUMARC/EPRI Fire Vulnerability Evaluation (FIVE) Methodology,”, U.S. Nuclear Regulatory Commission, August 21, 1991 (letter to W. Rasin, NUMARC, with enclosure, “Staff Evaluation of the Fire Vulnerability Evaluation (FIVE) Methodology for Use in the IPEEE”).

7. J. Lambright, et al., "Fire Risk Scoping Study: Investigation of Nuclear Power Plant Fire Risk, Including Previously Unaddressed Issues," NUREG/CR-5508, prepared for the United States Nuclear Regulatory Commission, January 1989.

8. J. Chen, et al., “Procedural and Submittal Guidance for the Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities,” NUREG-1407, United States Nuclear Regulatory Commission, June 1991.

9. “Independent Plant Examination for External Events (IPEEE) for Severe Accident Vulnerabilities - 10CFR 50.54(f),” Generic Letter 88-20, Supplement No. 4, United States Nuclear Regulatory Commission, June 1991.

B

DETAILED TECHNICAL BASES

B.1 RAI Question 1 - Screening Human Reliability Analysis

B.1.1 Review of Generic Question

The Review primarily takes issue with the Guide's allowance of use of IPE screening values for human errors. The Review asserts that 1.0 probabilities should be used for all human errors during the screening analysis. Further, the Review indicates that smoke propagation analysis should be considered when detailed HRA evaluations are done and references studies performed by one of the authors.

Question 1 specifically asks for the licensee to identify all scenarios screened out if their quantification involved one or more HEPs as well as a description of the HEPs and how the effects of fire are treated.

B.1.2 Guidance

The Guide provides guidance for use of HRA values during screening. The Guide attempts to strike an appropriate balance between using 1.0 for all human errors during screening and using IPE human error probabilities, neither of which is reasonable or representative of plant practice. The Guide acknowledges the concerns that fire can impact human reliability analysis. In particular those concerns are outlined in Appendix B, Section 3 and in Appendix M, Steps 1.1, 2.3 through 2.5.

The Guide did not attempt to develop an HRA methodology for fires and instead builds upon the HRA quantification done for internal events. The problem of quantification with 1.0 values exists for internal events as well as external events. Consequently, in the internal events process, HRA analysts developed screening values that were intended to apply to all plant or scenario specific conditions that might result. The Guide uses those values to represent equally undefined conditions for fire, with two provisions. First the Guide attempts to establish whether the actions are possible in the environment of a fire. Second, the Guide limits screening values to those above 0.01 and sometimes requires that they be increased to 0.1.

All control room actions (not prevented by circuit damage) are deemed to be possible. Local actions are only deemed possible if the fire has been suppressed. Using these two basic principals, a set of simple logic is constructed to employ the use of screening values and in some cases IPE values (meaning values obtained after screening analysis conservatisms have been removed).

As a result of our recent review, we will add some clarification to the appropriate sections of the Guide. The Guide uses the terms long term actions and short term actions, but does not define them. In some other cases, the basis is not given for a specific recommendation in the Guide, which could allow values to be applied inappropriately or not applied when they should be. For example, the Guide includes a discussion of pre-fire plans that could allow IPE values to be applied where not intended. Finally, the Guide in some cases is written for a post-screening HRA analysis, but this needs to be made clearer.

B.1.3 Response

Screening values are used in all HRA methods. The conditions of an arbitrarily complex internal events scenario, while different from fire, can be more complex. Consequently, if screening values can be applied to internal events, they can be applied to fire. The question then becomes how the screening values for internal events were developed, whether they are indeed bounded when implemented as restricted by the Guide, and if not bounded, how significant a potential non-conservatism might be.

The Guide presumes that screening values will be applied appropriately. That is, the user is expected to apply an accepted HRA method to ensure that inappropriate scenario screening does not occur. For example, this is especially problematic for cutsets/scenarios involving two or more human actions when relatively low IPE screening HRA values are used resulting in screening the scenario or the compartment inappropriately.

For actions outside the control room, the Guide is more restrictive with the use of IPE screening values. The restrictions are necessary because the action may normally be performed by a person now assigned to the fire brigade and because the location in which the action is to be performed or the access path to it may be inaccessible due to the fire. The time periods selected by the Guide represent essentially probabilities that the fire will be suppressed. At four hours, the Guide assumes the fire to be extinguished. This assumption is based on a review of fire event experience. At one hour, the suppression model for cable fires predicts approximately a 0.1 probability of non-suppression. In essence, this HEP screening value is selected to ensure the HEP is limited to no lower than the worst case probability of suppression. Again the Guide assumes if the fire is suppressed, then the staff is available and the fire environment is not too restrictive for the action. However, despite our belief this guidance is correct, we feel that the Guide would be improved by providing these bases so that the reader can confirm its applicability as necessary.

The Review also addresses the issue of smoke propagation and its impact on operators. Because of the possibility of smoke influencing the stress level of operators in the control room, the Guide requires that screening values be used for control building fires (by implication, the locations with potential smoke communication paths to the control room). This basis should be made clear in the Guide to ensure that due consideration is given to smoke entering the control room from fires in areas other than the Control Building, at least when plant specific ventilation conditions require it.

Finally, the Guide will be modified to separate screening from post-screening guidance and avoid the possibility that its guidance could be misinterpreted or used to screen compartments erroneously. The Guide then goes on to say that it is permissible to use IPE values under certain conditions. This statement should be modified since it is inappropriate to use anything but screening values in the screening analysis.

B.2 RAI Question 2 - Heat Loss Factor

B.2.1 Review of Generic Question

Generic Question 2 deals with selection of heat loss factors for use in determining hot gas layer temperatures. The heat loss factor is defined as the fraction of energy released by a fire that is transferred to the enclosure boundaries. The concern is whether the values recommended in the Implementation Guide are appropriately conservative.

- The reviewer's interpretation is that the higher heat loss factors in the experimental data (Ref i), which provide the basis for the heat loss factors used in the analysis, result from gases spreading from the burn compartment to adjacent cooler compartments. The reviewer contends that therefore lower heat loss factors are more appropriate for single compartment fires. The reviewer recommends heat loss factors in the range of 0.51 to 0.74 as being more appropriate.
- For illustration, the reviewer presents a time-temperature curve based on the work of McCaffrey, Quintiere and Harkleroad (Ref. ii), compared to time-temperature predictions based on the FIVE method using HLFs of 0.7, 0.85, 0.94 and 0.99.

B.2.2 Guidance

The Guide recommends using at least 0.94 for times greater than or equal to 5 minutes (i.e., slowly developing hot gas layers) where the whole compartment is filled by the hot gas layer. The Guide recommends smaller values (0.85) for exposure fire scenarios away from a wall and quickly developing hot gas layers (e.g., large flammable liquid pool fires) [Ref. iii, p. 4.29].

Based on the conclusions drawn from the comparisons below, supplemental guidance has been developed for the Guide that addresses selection and use of HLFs.

B.2.3 Response

The purpose of this section is to provide the utility fire protection engineers an understanding of the basis for the HLF values specified. It also provides an overview of the issues that have been discussed with the NRC and their consultant Sandia.

The goal of the modeling method defined in the Guide is to provide a realistic approximation of the exposure temperature at a PRA target.

The basis for the recommended HLF is comparison with four fire tests performed by Sandia (Refs. iv, v) as described below. Each test simulated a fire located in a plant Main Control Room (60 ft x 40 ft x 20 ft). Detailed temperature-time histories were recorded throughout the room. HGL temperatures were calculated using FIVE/Implementation Guide methods and compared to temperature histories in the upper portion of the room adjacent to a corner (location 17 from the report). These temperatures were used because they were judged to most closely represent the HGL. In the plots below they are labeled as "Test @ .98H" (or .90H or .70H, where H is the room height).

Calculated HGL temperatures were developed using HLFs of 0.70, 0.85 and 0.94. The temperatures are presented as time-histories. This is consistent with actual HGL behavior and the time-dependent approach in Appendix I, Hot Gas Layer Timing Study, and in the Example Problem on page 4-30 of the Guide.

The selected tests all used a ventilation flow rate of one room change per hour. This was selected because it most closely represents in-plant conditions.

Observations from the comparisons, shown in Figures 4-1 through 4-4, are summarized below:

- The peak HGL temperatures in the tests were all less than 200°F and fire durations were less than 20 minutes. Since these temperatures are significantly below cable damage temperatures, engineering judgement/extrapolation is necessary to determine the effect of larger fires and fires that result in damaging temperatures.
- Tests 4 and 7 (10 minute - 490 Btu/s floor-based fires in the open compartment) indicate measured temperatures approximately equal to those calculated using HLF = 0.70. The FIVE model produced a better comparison with Test 4, which was a growing fire, than with Test 7, which was an instantaneous peak HRR fire.
- Tests 21 and 22 (a 490 Btu/s and a 950 Btu/s fire inside open cabinets) indicate measured temperatures approximately equal to those calculated using HLF = 0.85 (and virtual surface of the fire assumed to be at the top of the cabinet), especially at later times in the test.

Based on the comparisons, the following conclusions are drawn regarding selection of appropriate HLFs for fire scenarios:

- A HLF of 0.70 generally results in conservative HGL temperatures throughout the fire event and under any conditions. This value may yield overly conservative temperatures especially for extended duration events (i.e., longer than brigade response time). A HLF of 0.70 is appropriate for approximating HGL temperatures during the early portion of fast growing floor-based fires (i.e., oil spills prior to brigade response).
- A HLF of 0.85 generally results in conservative HGL temperatures when the HGL volume is calculated assuming that the virtual surface of the fire is at least 0.40H (where H is the ceiling height). This value may be unconservative for events involving rapidly developing

floor-based fires. A HLF of 0.85 is appropriate for fires initiated by electrical cabinets including those involving cable trays (virtual surface at cabinet top), and for overhead cable tray fires where the HGL is based on the volume above the burning tray (HGL volume = 0.60 * room volume, or less).

- A HLF of 0.95 is generally non-conservative except possibly for slow growing, long duration fire scenarios. This value should only be used when demonstrated to be appropriate for the scenario being considered.

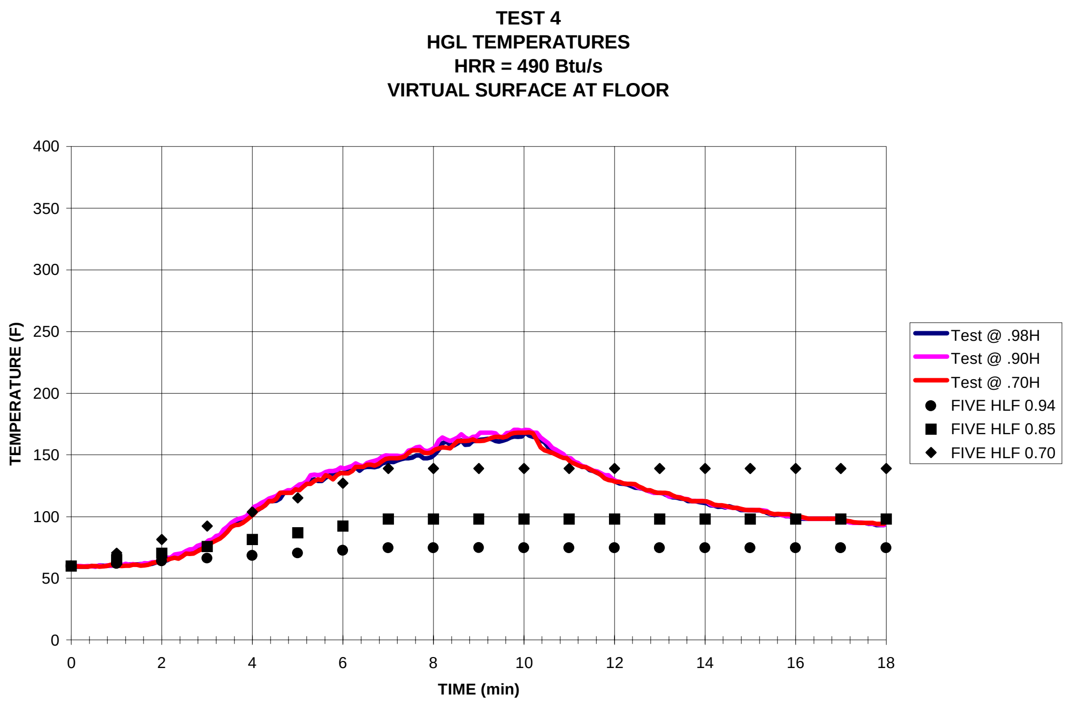


Figure 4-1 Comparison of Hot Gas Layer Temperatures Predicted by the FIVE Models (Virtual Surface at the Floor) with Results of Test #4 (Fast Growing Floor-Based Fire).

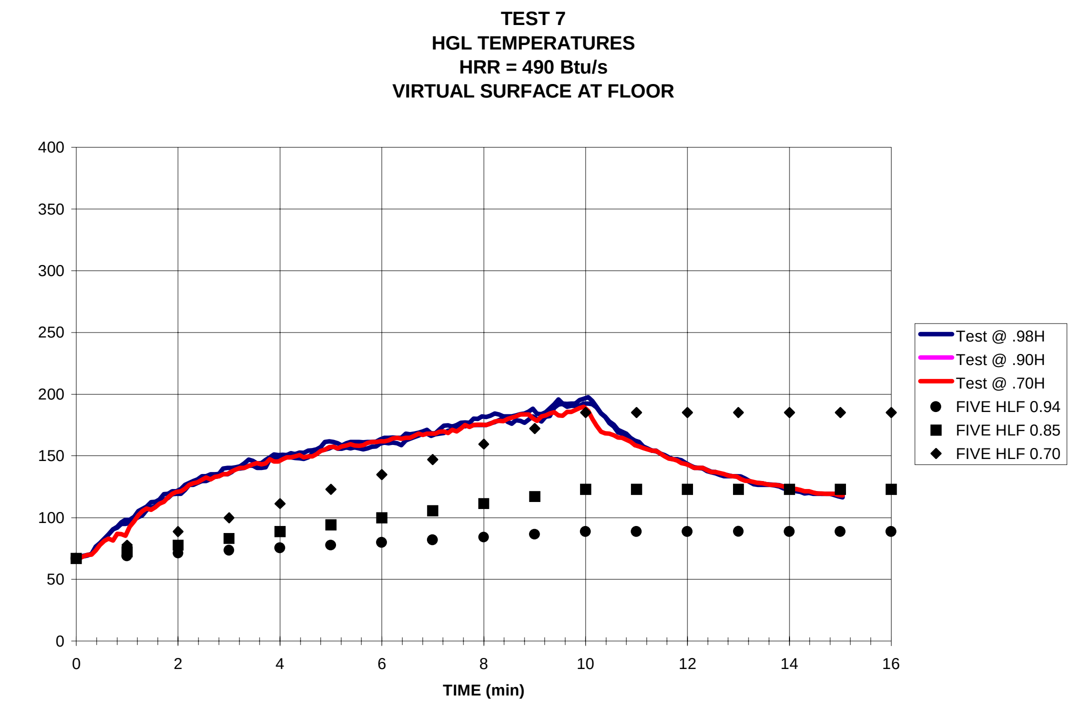


Figure 4-2 Comparison of Hot Gas Layer Temperatures Predicted by the FIVE Models (Virtual Surface at the Floor) with Results of Test #7 (Instantaneous Peak HRR Floor-Based Fire).

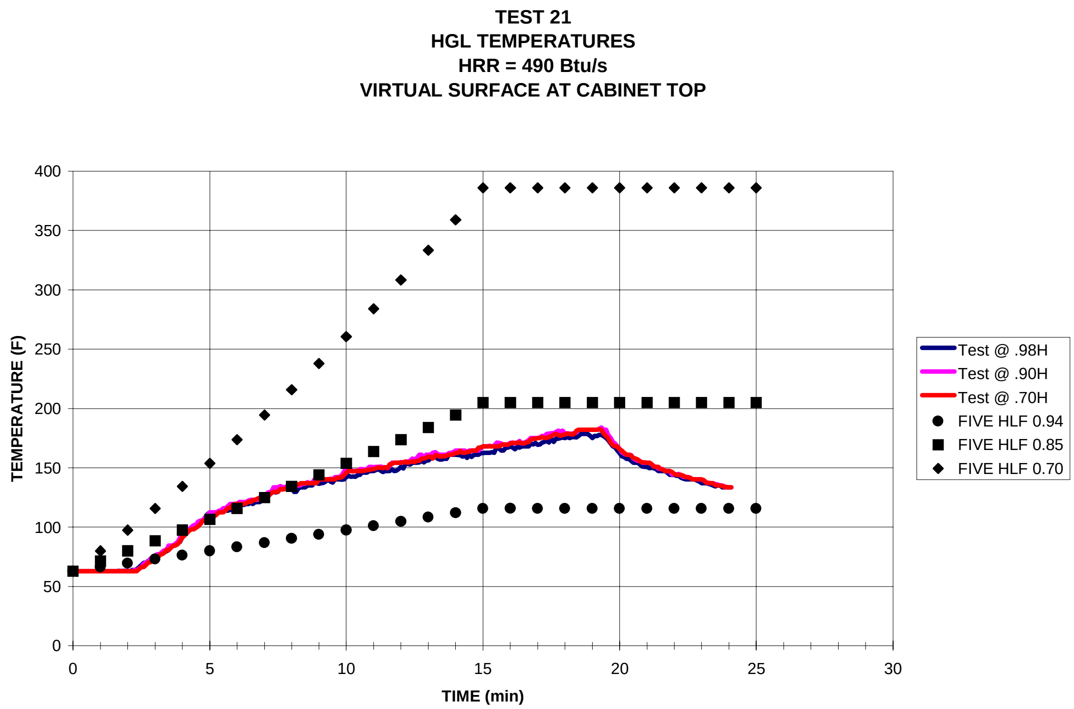


Figure 4-3 Comparison of Hot Gas Layer Temperatures Predicted by the FIVE Models (Virtual Surface on Top of cabinet) with Results of Test #21 (Electrical Cabinet Fire).

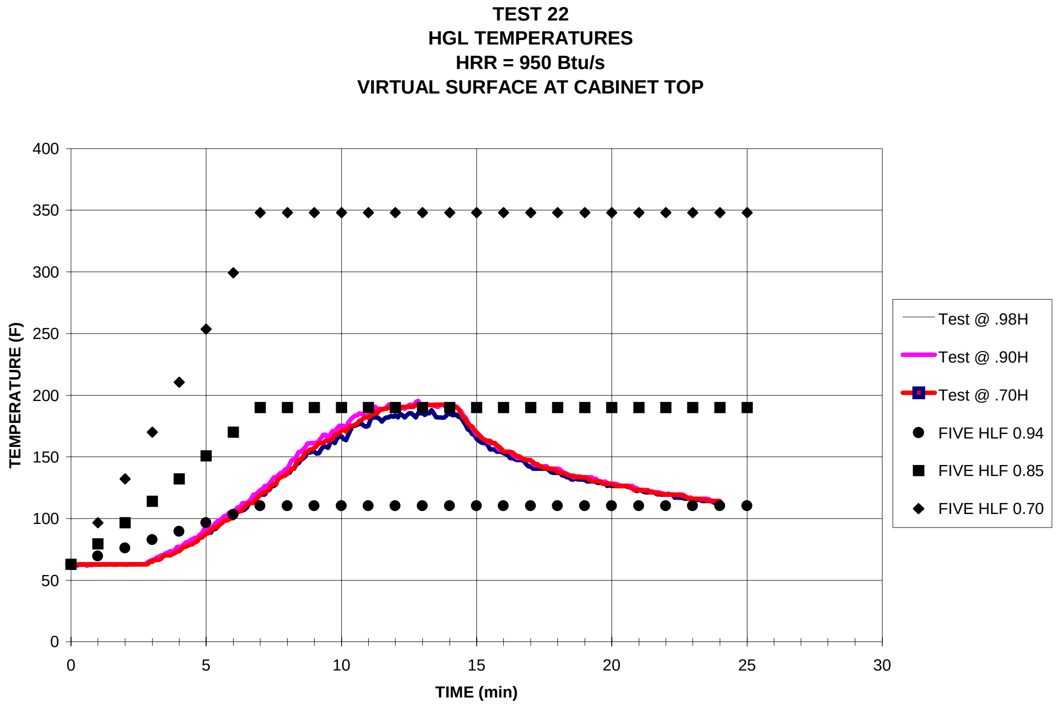


Figure 4-4 Comparison of Hot Gas Layer Temperatures Predicted by the FIVE Models (Virtual Surface on Top of Cabinet) with Results of Test #22 (Electrical Cabinet Fire).

B.3 RAI Question 3 - Fire Propagation in Horizontal Cable Tray Stacks

B.3.1 Review of Generic Question

Generic Question 3 deals with determining the time-dependent heat release rate (HRR) resulting from vertical fire propagation in a horizontal cable tray stack. The apparent concern is what the reviewer calls inappropriate use of experimental results (i.e., employing propagation times specific to a particular tested configuration to fire involving cable trays with lesser separation) potentially resulting in improper assessments of fire scenario importance.

Embedded in the Generic Question are two fundamental issues:

1. The applicability of experimental results used to evaluate plant-specific fire scenarios. Specifically, that limitations for use of the results are defined in order to prevent miss-application; and
2. The potential misuse of the propagation times as estimates of cable damage times.

B.3.2 Guidance

The Implementation Guide (Ref. iii, page 4-28, Fires in Horizontal Cable Trays and Appendix I, HOT GAS LAYER EFFECTS STUDY) present data to enable the user to calculate time dependent heat release in horizontal cable tray stacks with IEEE 383-74 qualified cable. The data is derived from experimental evidence developed by Sandia and documented in reference vi.

The Guide clearly states that the data is for IEEE 383-74 qualified cable and tray that meet RG 1.75 minimum separation. Appendix I elaborates on the basis for selection of the specific test used for the model and provides a detailed example for calculating a time-dependent HRR.

B.3.3 Response

The purpose of the model presented in the Guide is to provide the user a simplified approach for determining the time-dependent heat release to the hot gas layer that approximates actual behavior.

The Guide describes the logic for developing the model including the weaknesses of analytical models such as COMPBRN and FIVE to approximate appropriate fire growth/heat release behavior.

A large number of cable tray fire tests were reviewed during the model development process. For the reasons cited below, the testing described in "A Summary of Nuclear Power Plant Fire Safety Research at Sandia National Laboratories, 1975-1987" (Ref. vi) was used to develop the model in the Guide.

The Sandia test provided what was considered the best descriptive data to enable development of a model that could be adapted to a variety of plant-specific configurations. The data included both the timing of the fire growth as well as descriptions of the extent of the growth. The ignition source was approximately 40 Btu/s which is similar to typical ignition sources (primarily electrical cabinets) in close proximity to cable trays. The model in the Guide was therefore developed based the SANDIA test and was designed for trays with IEEE 383 cable and configurations similar to those tested (horizontal trays, RG 1.75 spacing, etc.).

The timing specified in the model was conservatively derived as follows.

The timing of the fire propagation model in the Guide ignores the initial 5 minutes of the test, assumes that the bottom tray is fully involved at time = 0, and that the timing of the subsequent vertical propagation of the fire is consistent with the test. Table 3-1 demonstrates this.

Table 3-1. Comparison of EPRI Tray Fire Propagation Model Times with the Sandia Test

SANDIA TEST	EPRI MODEL TIMING
T=0 In the Sandia test, a bottom tray was ignited by ribbon burners while the remaining trays were separated from the fire by a non-combustible barrier.	
T=5 Minutes A five-minute exposure to the burners produced a "fully developed fire" in the tray. The burners were extinguished and the barrier removed.	T=0 The bottom tray is assumed to be "fully involved". The "fully involved" bottom tray is considered to represent an external source (such as an electrical cabinet with IEEE 383 qualified cable).
T=10 Minutes Second and third trays involved.	T=5 Minutes Second and third trays involved.
T=15 Minutes Forth tray involved.	T=10 Minutes Forth tray involved.
After 15 Minutes Vertical propagation continues	After 10 Minutes Vertical propagation continues as defined by the test.

A number of tests conducted by EPRI/FMRC (EPRI NP-2660, Ref. vii and EPRI NP-1881, Ref. viii) were also reviewed for comparison with the Guide's horizontal cable tray stack propagation model. Those that were eliminated from further consideration included:

- test assemblies with non-IEEE 383 cable.
- tests where sprinklers were applied and impacted the fire propagation characteristics,
- test assemblies were horizontal cable trays included vertical risers.

Four of the EPRI/FMRC tests (tests 2, 10, 11 and 12 from NP-1881) were Free Burns involving assemblies similar to that addressed by the model (horizontal trays with IEEE 383 qualified cable), but were ignited with a 4.5 ft2 pan containing 2 gallons of heptane. Although this ignition source is substantially larger than an ignition source representative of a NPP electrical cabinet with qualified cable or transient combustible, the test data was compared with data calculated by the model.

Comparison of the time-dependent heat released from the model with that determined from these tests is shown in Figure 3-1. Data from tests 10 and 11 appeared to be essentially identical, so only test 10 was plotted.

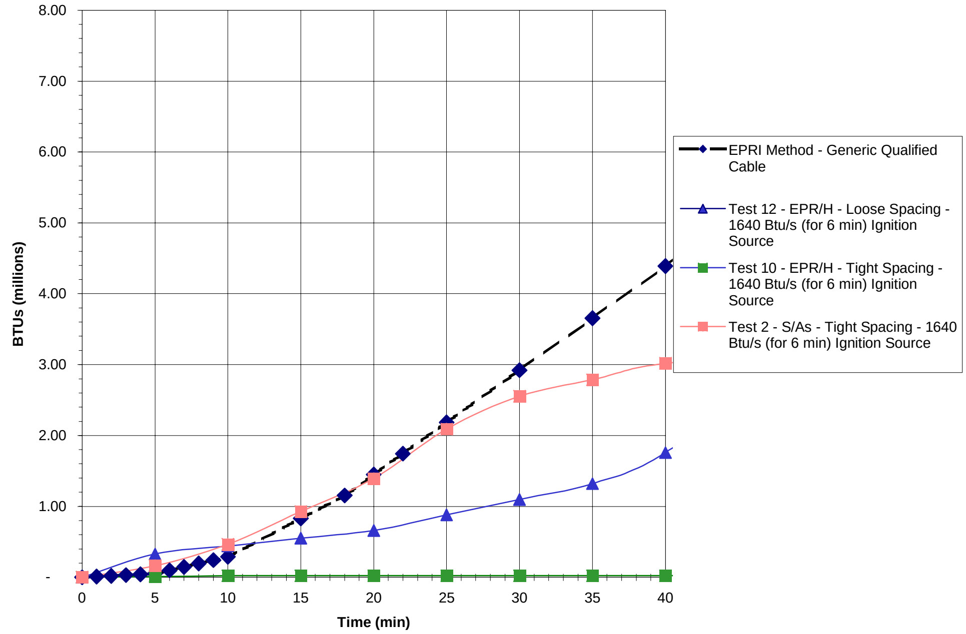


Figure 3-1 *Comparison of the Time-Dependent Heat Released from the Model with that Determined from Tests with IEEE 383 Cable and the Heptane Ignition Source.*

As can be seen from the plot, the model generally provides results that bound test data even though the testing used the 2 gallon heptane ignition source. The following observations and conclusions were drawn from the comparison:

- Because the 2 gallon heptane (4.5 ft^2) ignition source is so much larger that a representative NPP ignition source (i.e., vented electrical cabinet or transient fire) the higher than calculated heat release data in the early stages of tests 2 and 12 is consistent with expectations. The higher initial heat release rate in these tests undoubtedly results from the very large ignition source involving much more cable in the very early stages of the fire than would a representative NPP ignition source.

- Data for test 10 (Extra Tightly packed IEEE 383 cable of moderate fire hazard) is bounded by the model results throughout the duration.

- The calculated total heat released at the conclusion of the event is substantially higher than that from any of the tests, independent of cable type or cable arrangement.

- In conclusion, the model reasonably well represents vertical fire propagation in horizontal cable tray configurations (horizontal only, IEEE 383 cable, RG 1.75 separation) for a representative IEEE 383 cable types and arrangements ignited by typical NPP ignition sources up to 190 Btu/s.

To summarize, the model in the Guide provides good correlation with actual test data and is therefore appropriate for approximating the total heat released in scenarios involving a vertically propagating fire in a cable tray stack with the following characteristics:

- IEEE 383 qualified cable
- RG 1.75 spacing (minimum)
- Horizontal trays (only)
- Solid bottom or ladderback trays; covered or uncovered
- Ignition source smaller than 190 Btu/s.
- Trays located farther than 6' from a wall or ceiling

The impact on HRR when trays are located in close proximity to walls and the ceiling (closer than 6') is based on the Sandia Corner Effects Testing (Ref. ix). A relationship (for IEEE 383 cable trays) between distance from the corner and increased HRR is presented in the Supplemental Guidance to account for this impact.

B.4 RAI Question 4 - Control Room Evacuation Scenarios

B.4.1 Review of Generic Question

The generic question asks for the detailed assumptions used in analyzing the MCR and justifications for those assumptions, including:

- Fire frequency
- Fire reduction factors
- Probability of abandonment, including specifically
- Justification for the parametric form of the distribution
- Data used for quantification

The preamble to the question implies that the Guide fails to account for differences in configuration between the experiments and the plant control room being evaluated. It references the “NSAC-181 Critique”, apparently the principal bases for the generic questions, and NUREG/CR-5037, a BNL evaluation of the LaSalle control room.

We believe that the Review’s implication is not correct. Said more precisely, the Review represents a conservative viewpoint that, taken by itself, is misleading for an analysis that is intended to be realistic. The discussion below in Section 3.4.3 will indicate why we believe the Implementation Guide to be a more realistic representation than the Review and, therefore, appropriate for IPEEE analyses.

However, NRC staff has indicated that their concern is that the Implementation Guide does not fully represent the uncertainties associated with control room evacuation scenarios. They have indicated that a number of IPEEEs have screened control room evacuation scenarios based in large part on the FPRA Guide estimates. The NRC staff has also pointed out to us a number of misapplications of the Guide that have similarly lead to screening.

Screening reduces the insights that might be gained from a more detailed assessment of safe shutdown under the conditions that represent control room evacuation scenarios. We agree with the NRC staff that such insights can be valuable. The discussion in Section 3.4.4 provides supplemental guidance to reflect concerns about misapplication and ensure that adequate insights are gained from the analysis of safe shutdown.

It should also be noted that Section 3.7.4 provides additional guidance as it relates to control systems interactions that might result in a control room fire scenario.

B.4.2 Guidance

At the time of development of the EPRI Fire PRA Implementation Guide, little or no guidance was publicly available to fire risk analysts for the purposes of evaluating control room fires. Of the “approved methods” for GL 88-20 Supplement 4, FIVE, NUREG-2300 (Ref. x) and NUREG/CR-2815 (Ref. xi) provided essentially no specific guidance, only a general framework. NUREG/CR-4840 (Ref. xii), solely through its applications in NUREG-1150 (Ref. xiii), provided suggested assumptions, data and example analyses. (Note that NUREG/CR-4840 essentially does not mention the control room.) However, the associated NUREG-1150 reports provided very little information to justify them, determine whether they were realistic, or apply them to different plants. For this reason, EPRI set out to develop plant specific guidance for control room fire risk evaluation that provided realistic estimates for fire risk. NSAC-181 (Ref. xiv) was the first step in that process and the Guide was a refinement based on more than one dozen plant specific implementations.

The FPRA Guide describes how to perform a plant specific control room fire risk evaluation in Appendix M. The Guide reflects insights from applying the method to about a dozen plants and remains consistent with the similar number of studies performed by the authors since the publication of the Guide.

The Guide lays out analysis methods for determining the effects of direct fire damage to critical circuits and the probability and consequence of control room evacuation. Because the Generic question deals only with the topic of control room evacuation, only those portions of the Guide are discussed below.

The Guide provides a method for apportioning control room fire frequency to individual cabinets. This method is based on the control room fire events documented in NSAC-178L (Ref. xv). Those fire events indicate that the most likely fires are in relays or circuit cards. The guidance indicates how to apportion fire frequency given the relative number relays and circuit cards in individual cabinets as compared to the control room as a whole. It should be noted that in plant specific applications it was often noted that the Main Control Board (MCB) had only a small fraction of the relays and circuit cards in the control room.

The Guide also provided a method for determining control room fire non-suppression probabilities. The Guide refers to NSAC-181 and its interpretations of the SNL tests and operating experience. It then provides a set of plant specific considerations that should be applied when determining whether the generic data is applicable. These considerations include:

a) Control room HVAC smoke removal capability and control room volume

b) Suppression training for control room personnel

c) Presence of automatic in-cabinet suppression capability

After this plant specific assessment is complete, the Guide provides general direction as to how plant specific factors should be considered. Admittedly however the Guide is not always specific. For example it does not indicate how specifically an analyst should change the control room non-suppression probability if the control room volume is less than the SNL test enclosure volume. In application to more than twenty control rooms, this case was never found. Instead, many control rooms were significantly larger than the SNL test enclosure volume. This conservatism was typically noted in the plant specific evaluations, but its quantitative impact on an individual plant's control room fire risk was not evaluated.

B.4.3 Response

Background. The Review of the EPRI Fire PRA Implementation Guide does not question the control room fire frequency method nor does it question the methodology for evaluating circuit damage except in one particular instance. This instance is described in question 7 where the Review raises the issue of control systems interactions or the so-called "spurious actuation" issue that applies generally to circuit analyses.

The Review also does not question the completeness or content of the plant specific factors identified in the Guide for applying experimental data to a plant specific evaluation of control room non-suppression probability, except in the important instance of the time of fire detection. Even in this instance, the Review implicitly acknowledges consensus on one important consideration. Namely, discussion in the Review and in the Critique of NSAC-181 start with the basic premise of NSAC-181 that the two electrically initiated fires are the most representative of the SNL control room cabinet fire tests for determining time of detection and time available for suppression.

Similarly, while the Review questions the form and result of extrapolating existing operating experience data, it does not question whether successful human response to fires experienced to date can be used as a basis for determining the possibility of unsuccessful response. Even these questions do not lead to a significant difference in results according to the NSAC-181 Critique (Ref. xvi) (4.0E-2 versus 6.0E-2 (pp. 2-7, 2-8)). More important to the question is the assumption and plant specific consideration of when fires are detected. It is this issue which leads to potential order of magnitude differences in fire risk estimates (at least when all other factors are held constant).

The following discusses the selection of the detection time used by the Guide and its basis, conservatisms in the timeline used by the Guide, sensitivity of the results to the operating experienced used, the functional form of the suppression curve and its basis, and finally discusses the BNL report. A conclusion is then presented.

Detection Time. To best evaluate the probability of non-suppression, the analysis should consider a timeline of opportunities for detection. For each opportunity in the timeline, the analysis should consider the associated plant specific factors that might impact the effectiveness of detection at that point. Given an agreed upon probability of non-suppression that is a function of time available to suppress the fire, the control room non-suppression time can then be calculated on a plant specific basis.

The EPRI Fire PRA Implementation Guide (and by implication NSAC-181) is a simple representation of that timeline. It was developed as a realistic alternative to a conservative method available at the time GL 88-20 Supplement 4 was issued, namely NUREG/CR-4840. The Guide's evaluation represents a mid-point in the selection of detection opportunities that apply primarily to human detection. That is, the detection time assumed is neither the earliest opportunity for detection, namely when the initiating electrical malfunction occurs, nor the latest opportunity, namely the time when rapid smoke generation occurs.

The Guide represents quite well the most likely conditions for those control rooms in which in-cabinet detectors are present. In those cases where effective in-cabinet smoke detectors are installed, human detection provides increased margin. In those cases where in-cabinet detection is either not present or less effective, human detection is the principal means for early detection of control room fires.

Eleven of twelve control room fires in the FEDB are electrical cabinet fires. (There is one kitchen fire listed in the control room area.) Numerous control room ignition source walkdowns were performed to test the Guide and these did not identify significant transient combustible inventories or other unique sources. Consequently, the Guide assumes that electrical cabinet fires are the only significant fires that have the potential to cause control room evacuation.

Control room electrical fires do not involve high-energy electrical circuitry because the control room contains only instrumentation and control circuitry. Fire events experience with low voltage electrical fires indicates that these fires are slowly developing and are most often diagnosed by local personnel, even when such fires occur in areas outside of the constantly manned control room. For this reason, the Guide assumes that the electrically ignited cabinet fire tests (Test 24 and Test 25) are representative of the expected timeline of fire development in a control room electrical cabinet.

Similarly, the Guide assumes that human detection is the most likely means of fire detection in the control room. In the case of the control room fires reported in NSAC-179L**,** only two of ten applicable fires were detected by smoke detectors. Even in these cases, the event description lists local personnel in conjunction with automatic detection. This experience provides strong qualitative evidence that detection of control room fires is a "competition" between human and automatic means that is often "won" by the human.

This fact holds true even when the plant location is typically unmanned. As documented in NSAC-179L, plant personnel detect the overwhelming majority of nuclear power plant fires. Switchgear room fires provide a good example and the following typifies the response to many switchgear room fires. Often the electrical malfunction is indicated by problems with component operation and a person is dispatched to investigate the problem. Upon arrival at the scene, they quickly locate the offending cabinet and open it and then determine that a small fire or smoking component is involved. The event is quickly terminated by either normal circuit protection, operations de-energizing the component, or by use of a portable extinguisher. Automatic detection does not even actuate.

Similar experience is indicated for other lower voltage electrical fires outside the control room. In these cases, where component condition is less likely to be indicated in the control room, human detection can also occur by smell either of smoke or ozone. Indeed, fire protection professionals recognize that the most effective fire detector is a human. US nuclear plant experience anecdotally supports this professional experience. Regardless, these fires have not led to widespread damage within the cabinet.

Table 3-2 lays out the time line for a control room fire based on SNL tests 24 and 25. The table indicates that substantial time is available for detection prior to the time selected in NSAC-181 and the Guide. It also indicates that the number of means by which detection can occur increases substantially over time. The detection time selected by the Guide is roughly two-thirds of the period between the time of initiation of the electrical malfunction and the time of cable ignition (the detection time suggested by the Review).

Table 3-2. Timeline of Control Room Fire Events

Representative Event from SNL Tests	Time(s) from SNL Tests (24, 25)	Scenario Event	Available Means of Detection
Time ignition source was energized	0:00, 0:00	Electrical malfunction occurs	Control board indication Ozone smell in CR
Time smoke became visible	10:30, 9:30	Electrical item (relay, resistor on circuit board or cable) overheats and starts smoking	Control board indication Ozone smell in CR Smoke observed inside the cabinet with direct viewing In-cabinet detector actuates
Time cable ignition was observed	15:20, 15:40	Electrical item (relay, resistor on circuit board or cable) ignites	Control board indication Ozone smell in CR Smoke observed inside the cabinet with direct viewing In-cabinet detector actuated Flaming visible with direct viewing Smoke visible outside the cabinet Ceiling detector actuates?
Not addressed by test scenario	NA	Fire propagates from electrical item to cables or other combustibles (e.g., adjacent plastic - relay cover or circuit board)	Same as above
Rapid growth in measured heat release rate and smoke generation rate	22:20, 20:00	Cables fully involved in burning, dense smoke accumulates at the ceiling	Same as above Flame visible outside the cabinet Smoke level begins to descend from ceiling
Time control panels are no longer visible	27:00, 23:00 30:00, 30:00 (1)	Smoke begins to obscure full length of control board panels	Same as above

The first set of times is the point of measured obscuration and the second set of times is the point when obscuration was observed.

Starting with the electrical malfunction, the opportunity for detection begins. As time grows, the amount of ozone will increase and this means of detection will correspondingly grow rapidly. Once visible smoke is produced, a similar condition will occur. That is, the continuous puffs of smoke mentioned in the review will accumulate and be more likely to be noticed. From a practical perspective, it is difficult with the information available to date to predict detection rates for each of these time periods. In lieu of that, the Guide selects a time that is consistent with operating experience described above. The following describes conservatisms in this selection that gave us confidence that selecting a less conservative detection time than NUREG-1150 would yield a more realistic, but not non-conservative result.

Conservatisms in the Timeline Used by the Guide. The following conservatisms in the Guide deserve mention.

- Selection of the evacuation criterion as measured optical density versus actual observation
- Likelihood that the fire will start in relay or circuit card and then have to propagate to cable
- Probability of ignition of cable and delays in qualified cable ignition

The SNL tests document how actual observations seemed to indicate that the control board was visible even when measured values indicated that it should not be. Using the detection time suggested in the Review of the Guide and the "observed" time for forced evacuation, about 15 minutes would be available for suppression. That is, either using a conservative detection time and a possibly more realistic evacuation time or using a more realistic detection time and a more conservative evacuation time yields the same available time as that used in the Guide. It is only when conservatism is applied on both ends of the timeline that a much shorter time is obtained (such as that suggested by the Review and by the Critique of NSAC-181).

Operating experience clearly indicates that fires in control room cabinets are much more likely to begin in relays and circuit cards than in cable. (In fact the only fire starting in cable was caused by human error and immediately detected.) Fires that begin in relays or circuit cards will begin with a malfunction and eventually develop into a small fire. We believe the electrically initiated fire test would be a reasonable approximation for this. However, at this point the two scenarios would diverge. The small fire in the relay or circuit card would still have to heat and ignite cable. This process would result in a further time delay for growth and propagation of the fire. Because such fires have not resulted in widespread damage within the cabinet in either control room or other low voltage electrical cabinets, we believe that time delay could be a number of minutes. In the SNL tests, cabinet fires initiated by one quart of acetone took a few minutes before cable began to significantly contribute to the fire. For much smaller fires characteristic of relays and circuit cards, this time would be extended. Hence, a time delay comparable to the difference between the Review timeline and the Guide timeline may well be possible.

The probability of actual ignition of cable given the presence of an electrical malfunction has long been argued between industry and NRC risk analysts. The difficulty in obtaining electrical self-ignition, especially in qualified cable, leaves us without equivalent cabinet fire tests for qualified cable. That is, test 24 and 25 each involve non-qualified cable. For those plants with qualified cable, the initial portion of the timeline may well be extended. Even more importantly, cable ignition may not occur at all. The test reports describe how difficult it was to obtain cable ignition. Wiring configurations had to be altered to create a non-standard configuration in order for the experiments to be performed even for non-qualified cable. Consequently, the probability of ignition for both non-qualified and qualified cable and an extended timeline for qualified cable are both ignored in the Guide.

Sensitivity to Operating Experience Data. The operating experience used in the Guide to determine a suppression time distribution is described there and reasonably well described in the Review of the Guide. However, while the Review of the Guide does indicate some potential shortcomings in the quantitative data, it does not acknowledge that the other control room fire events also imply quick response times. That is, the lack of a reported time does not mean that the fire was not suppressed quickly. Had we used judgement to estimate suppression times, the non-suppression probability curve would have been improved. In summary, we conclude that the Guide is not sensitive to changes in the applicability of a few fire events, based on our interpretation of those events.

As indicated in the Guide, a sensitivity study was performed and presented so those users would have available information on the sensitivity of the method to the data set selected. This sensitivity study yielded similar results as those reported in the Critique of the Guide, namely that the results changed very little with changes to one or two events. The Critique points out that the non-suppression probability at seven minutes changes only from 0.04 to 0.06 (p. 2-10). Again, this information reinforces our conclusion that there is not much sensitivity to the interpretation of a small number of database events.

<u>Functional Form of the Distribution</u>. The functional form of the distribution selected is lognormal. This distribution form was selected because it was found by EPRI to be the best fit for extrapolating human response data collected from simulators. EPRI considered at one time the Weibull distribution but finally concluded that the lognormal was the best selection for post accident human events.

In reviewing the simulator data it collected at a number of different power plants, EPRI found that goodness of fit tests generally were comparable or better for the lognormal distribution. In addition, the lognormal distribution had been selected by a number of other interpreters of simulator data and found acceptable. Finally, the lognormal distribution tends to give a higher probability at longer times, i.e., on a relative basis it is conservative.

In concurring that this functional form was best suited to the control room fire suppression, the authors of the Guide considered the following. The HCR method used to interpret simulator data often had been used to consider data involving short response times and to extrapolate that data to obtain probabilities for longer response times. The method had been used to consider events requiring diagnosis and the operators may be required to diagnose the location of the fire from alarms or smell. The control room fire suppression event involves no hesitancy of operators to act; they will attempt to put out fires of this type immediately.

Finally, the functional form of the distribution and the results when interpreted meet a sanity check against operating experience. That is, the control room evacuation probability (12 fires times 3.4E-3 = 0.04) seemed reasonable given experience. Similarly, the fact that intermediate or precursor events have not occurred, namely widespread damage within any cabinet nor dense smoke at the ceiling also tends to support the resulting distribution.

This finding contrasts with other estimates which do not sanity check well. For example, in the Critique of NSAC-181 the authors suggest that using Swain and Guttmann may be more appropriate and that such an estimate would predict a probability of 0.3 for control room evacuation. Given 12 control room fires, we would have expected roughly 3 to 4 control room evacuations in the period up until 1988. Similarly a probability of 0.06 (the modified NSAC-181 value suggested in the Critique) times 12 events implies that precursor events should have been observed before 1988. Given the roughly 20 control room fire events in EPRI's FEDB92, (includes fire events up to December 92) the consistency of the Guide with operating experience seems to be acceptable.

The BNL Report. The Review mentions a BNL report (NUREG/CR-5037) and indicates that control room temperature effects may even be more limiting than smoke in causing evacuation. The excerpts of the BNL report contained in the Critique do not seem to be consistent with the SNL cabinet fire tests. In SNL test 24, the time of assumed evacuation occurs while room temperature is still at its nominal value at the 6-foot elevation (Figure 31, p. 37). In SNL test 25, the temperature at 6 foot elevation was only slightly above nominal at the assumed time of evacuation and never even reached 40 degrees C (Figure 38, p. 43). Test 25 involved operation of the facility with 8 room changes per hour (versus 1 room change per hour in test 24). The SNL report speculates that cooling from the ventilation system probably kept the temperature low. Hence, we would conclude that as long as operators initiated the smoke removal system in the control room, it is unlikely that room temperature would become a significant concern.

Conclusion. In developing the Guide, the authors and the implementers of the pilot plant applications were all aware that it was possible to develop a more detailed model of fire detection and suppression for control room fires. The question became whether the additional accuracy from a more detailed model would significantly enhance the insights to be gained from the analysis, in light of various other limitations. Examining each control board panel for the location of smoke detectors if present, performing circuit analysis to determine which initiating relays and circuit cards would provide direct indication of malfunction at the MCB and considering how local ventilation would influence ozone and smoke smells are all possible activities. These activities would have allowed us to develop cabinet-specific non-suppression probabilities; but such probabilities would not change control room risk insights. Consequently, it was decided not to go to the option of a more detailed model.

Similarly, the Guide could have adopted the NUREG/CR-4840 fire method as it was published and described at the time. However, in this case it would not have been possible to perform any plant specific assessments because the method was not described in a correspondingly amenable form. More importantly, evidence from operating experience implied this method was very conservative. By that we mean that the distinct lack of evidence of precursor events was inconsistent with 12 control room fires and a mean value probability of 0.12 for control room evacuation given a fire. That is, if the methods of NUREG/CR-4840 were realistic, there was about a 78% probability (using a binomial distribution) that we should have experienced one or more control room evacuations before 1988. Yet to date there still has not been evidence of even a significant fire in the control room (see AEOD's report for recent history).

We acknowledge that additional research could improve our capability to model control room detection and suppression and would definitely reduce our level of uncertainty. We also have noted a number of conservatisms in the Guide's analysis of detection and suppression that would tend to compensate for associated non-conservatisms. As such we believe that further plant specific analysis of detection and suppression for IPEEEs is not warranted. Instead, we suggest that continued diligence be given to the collection and interpretation of relevant fire event experience to ensure that the assumptions in the Guide remain reasonable. The industry, under a cooperative effort of NML and EPRI are doing just that.

However, as mentioned in Section 3.4.1, the following provides supplemental guidance to ensure the Guide is used as intended, including the development of plant specific insights regarding safe shutdown from control room fires.

B.5 RAI Question 5 - Automatic/Manual Suppression Dependency

B.5.1 Review of Generic Question

Generic Question 5 deals with the adequacy of the response to the issue of manual recovery of automatic suppression systems; in particular:

- The Review concluded that the Guide treats manual recovery as being independent of subsequent manual efforts to suppress the fire,
- The Review states all relevant factors should be considered including: a) delay between ignition and detection/suppression actuation, b) component time-to-damage, c) brigade response time, d) time for brigade to diagnose automatic system failure, and e) PSFs affecting brigade actions.
- A reminder that brigade effectiveness must be based on plant specific response times.

B.5.2 Guidance

The Implementation Guide (page 4-33, Step 6 – Evaluate Fire Detection and Suppression, and referenced Appendices) provides detailed guidance for determining the following:

- Time delay between fire ignition and detection
- Time delay between detection and automatic suppression system actuation
- Calculation of component time-to-damage
- Development of fire compartment-specific brigade response times using plant-specific fire drill data with consideration of normal variations in response times
- Effectiveness of detection and suppression including manual suppression, automatic suppression, recovery of automatic system failures and system dependencies (i.e., both automatic sprinklers and hose stations rely on the fire pump/fire water distribution system.

On page 4-39, Step 6.3 – Evaluate Manual Detection and Suppression Reliability, the Guide states the following:

- Brigade response time is compared to calculated component damage time to determine if manual suppression can be credited, and
- Manual suppression probability is determined (as described in Appendix K) from data derived from actual fire events and using component damage times (not brigade response times).

B.5.3 Response

Additional guidance may be added to the Guide which, in its current version, does not specifically address manual recovery of automatic suppression system and subsequent manual suppression.

Because the Implementation Guide uses real power plant manual suppression data in the development of the manual suppression reliability models actual delays experienced in real fire events (and corresponding fire growth) are accounted for. Additionally, component damage time (which is independent of detection time, actuation time and brigade response time) is used to establish the suppression reliability.

The key point of the Review, is that if there is a time delay resulting from failure of an automatic suppression system, the resulting fire scenario may be further developed which could impact manual suppression activities.

Examination of fire scenarios where automatic system failure would cause a delay results in the following:

- Failure of wet-pipe or pre-action sprinkler systems would not have a negative impact on the brigade's response (manual action) to promptly initiate manual suppression activities upon arrival. However, availability of the delivery system needs to be accounted for after failure of the automatic system consistent with the guidance provided in Appendix K of the Guide, pages K-12 and K-13.
- Failure of an automatic CO_2 or Halon system could potentially result in a delay of manual suppression activities. Brigades are well trained in the use of SCBA, and would only enter a CO_2 or Halon zone with SCBA. In the event of failure of a gaseous system, a delay in initiating manual fire fighting could result for the brigade to confirm failure of the automatic suppression and enter the zone.

Therefore, a delay of the type questioned by the Review would only be plausible if the brigade is trained to wait outside a CO_2 or Halon protected compartment assuming a discharge.

Finally, since the time for the brigade to initiate manual fire fighting activities is only used to compare with equipment damage times to determine if manual suppression can be credited, the final manual suppression probability is not sensitive to minor variations in brigade response times. The following exemplifies the role brigade response times would play in fire scenarios:

- If a component were located in the plume or hot gas layer in close proximity to a fire, the damage time for the component would be much shorter than the brigade response time; manual suppression would not be credited.
- If a component were located in the hot gas layer removed from the fire, the time to damage could be sufficiently long that manual suppression would be credited. The actual suppression probability would be determined based what was burning and the damage time for the component.

In summary, allocating additional brigade response time to diagnose suppression system failure can be addressed in the Implementation Guide, but the basic method for determining the probability of manual suppression will not be impacted. Such guidance will be added.

B.6 RAI Question 6 - Fire Risk Scoping Study (FRSS) Issue; Seismic/Fire Interactions

B.6.1 Review of Generic Question

Generic Question 6 deals with the adequacy of the response to one FRSS issue; in particular:

- Seismically induced spurious actuation of suppression systems leading to diversion of fire suppressants to non-fire areas rendering them unavailable for a fire, and
- Spurious actuation of detectors potentially complicating operator response to the seismic event and/or causing actuation of automatic fire suppression systems.

B.6.2 Guidance

The Implementation Guide (page 4-49, Issue 1, Part 2 – Seismic Actuation of Fire Suppression Systems) refers to FIVE for resolution of this FRSS issue.

Regarding the seismically induced degradation of suppression, FIVE and the Fire PRA Guide rely on verification of the suppression systems during seismic walkdown. These walkdowns are to ensure that these systems are structurally installed in accordance with good industrial practice such that the piping and components will not fall and damage safe shutdown equipment nor are likely that leaking or cascading of the suppressant will occur thus preventing delivery where needed (FIVE, Attachment 10.5).

By letter dated 8/21/91 (Ref. xvii), the NRC found the FIVE methodology adequate for use in the IPEEE. The NRC provided their final acceptance of FIVE, in a letter dated 7/26/93 (Ref. xviii), with one requested clarification that was unrelated to FRSS issues.

B.6.3 Response

The response to this question is prepared based on review of the submittals that reviewers considered adequately addressed the issue, simply those that did not receive this question. The submittal by Browns Ferry was selected for this purpose.

B.7 RAI Question 7 - Fire Risk Scoping Study (FRSS) Issue; Control Systems Interactions

B.7.1 Review of Generic Question

Generic Question 7 deals with the adequacy of the response to one FRSS issue; in particular:

- Electrical independence of remote shutdown control systems,

- Loss of control equipment or power before transfer
- Spurious actuation leading to component damage, LOCA or interfacing LOCA systems, and
- Loss of total system function

The question also requests that detailed descriptions of the following be provided:

- Remote shutdown capability including nature and location of shutdown stations,
- How procedures provide for transfer of control,
- Provide an evaluation of whether loss of control power due to hot shorts and/or blown fuses could occur prior to transferring control… and identify risk contribution,
- Provide an evaluation of whether spurious actuation of components as a result of fire-induced cable faults, hot shorts, or component failures could lead to component damage, LOCA or an interfacing LOCA system prior to taking control at the remote shutdown station.

B.7.2 Guidance

The Implementation Guide (page 4-52, Issue 5 – Control Systems Interaction) refers to FIVE for resolution of this FRSS issue. FIVE requires review of the safe shutdown analysis to verify that the circuits needed in post-evacuation are physically independent of, or can be isolated from, the control room for a fire in the control room fire area.

By letter dated 8/21/91 (Ref.xvii), the NRC found the FIVE Methodology adequate for use in the IPEEE. The NRC provided their final acceptance of FIVE, in a letter dated 7/26/93 (Ref.xviii), with one requested clarification that was unrelated to FRSS issues.

B.7.3 Response

The response to this question is prepared based on the response to the RAI provided by the Davis-Besse Station (Ref., Docket No. 50-346).

B.8 RAI Question 8 - Fire Risk Scoping Study (FRSS) Issue; Manual Fire Fighting Effectiveness

B.8.1 Review of Generic Question

Generic Question 8 deals with the adequacy of the response to the FRSS issues, i.e., hampering effect of the smoke on the efforts of the fire brigade to promptly and effectively suppress fires. In particular:

- The impact of smoke on manual fire suppression efforts, and
- Misdirected manual suppression efforts that can cause failure of additional components.

B.8.2 Guidance

The Implementation Guide (page 4-50, Issue 3 – Manual Fire Fighting Effectiveness) refers to FIVE for resolution of this FRSS issues.

FIVE's approach in addressing the manual fire fighting effectiveness is based on demonstrating that the fire protection program has the attributes, such as training, equipment availability and drills, necessary to ensure that the fire fighting capability represents the fire scenarios that it is credited for. This is intended to show that operators are trained and equipped for prolonged fire fighting times, working in smoke environment when needed and to minimize the occasions of misdirected fire fighting efforts (FIVE, Attachment 10.5, Manual Fire Fighting Effectiveness). For safe shutdown actions, FIVE instructions are to verify that there are safe shutdown procedures that identify the steps in the event of a fire and that the operators receive training on these procedures (FIVE, Attachment 10.5, Operator Action Effectiveness).

By letter dated 8/21/91 (Ref.xvii), the NRC found the FIVE Methodology adequate for use in the IPEEE. The NRC provided their final acceptance of FIVE, in a letter dated 7/26/93 (Ref.xviii), with one requested clarification that was unrelated to FRSS issues.

B.8.3 Response

The Fire PRA Guide model for the manual suppression relies on a combination of industry and plant-specific experience including the plant's fire protection program. The program review will check attributes of the program, such as training, equipment availability and drills, necessary to ensure that the fire fighting capability represents the fire scenarios that it is credited for and the likelihood of misdirected manual suppression is minimized based on training. The industry experience (Fire PRA Guide, Appendix K, sections K.1 and K.2) accounts for the brigade effectiveness including under smoke conditions. This is reflected in the rather high non-suppression probability numbers for cable fires (page K-1) that are more likely to introduce smoke filled environment. This approach was employed instead of detailed determination of smoke migration due to the current state of such models.

B.9 RAI Question 9 - Fire Risk Scoping Study (FRSS) Issue; Total Environment Equipment Survival

B.9.1 Review of Generic Question

Generic Question 9 deals with the adequacy of the response to one FRSS issue; in particular:

> Fire suppression system actuation events can have an adverse effect on safety related components through direct contact with suppression agents or through indirect interaction with non-safety components. Components outside the immediate area of the fire can be impacted as a result of actuation resulting from transport of smoke, propagation of hot gas layers, or misdirected manual suppression efforts.

B.9.2 Guidance

The Implementation Guide (page 4-51, Issue 4 – Total Environment Equipment Survival) refers to FIVE for resolution of this FRSS issue. Regarding the impact of suppression system actuation on equipment, FIVE's instructions are based on an evaluation similar to the response to NRC Information Notice 83-41 (FIVE, Attachment 10.5, Total Environment Equipment Survival). FIVE requires plant-specific evaluation of the susceptibility of both trains of safe shutdown simultaneously being damaged from inadvertent actuation of one suppression system. Specifically, in the event suppression coverage could reach equipment of both safe shutdown trains, the analyst should assess the susceptibility of the safe shutdown equipment to damage from suppressant. (FIVE, page 7-6, 2nd and 3rd paragraph)

By letter dated 8/21/91 (Ref.xvii), the NRC found the FIVE Methodology adequate for use in the IPEEE. The NRC provided their final acceptance of FIVE in a letter dated 7/26/93 (Ref. xviii) with one requested clarification that was unrelated to FRSS issues.

B.9.3 Response

The response to this question is prepared based on review of the submittals that reviewers considered adequately addressed the issue, simply those that did not receive this question. The submittal by Browns Ferry was selected for this purpose.

B.10 RAI Question 10 – Special Accident Initiators

B.10.1 Review of Generic Question

Generic question 10 is related to selection of the fire-induced accident initiator in general and special initiators (e.g., those resulting from failure of the support systems) in particular. The reviewers acknowledge that the Guide recognizes the need for this task but comment that the Guide does not provide a systematic evaluation approach for the identification of these initiators.

Reviewers also criticize the Guide for suggesting a threshold for the special initiators with non-recoverable frequency of 1E-4/yr.

B.10.2 Guidance

The Guide provides instructions for selection of accident initiators in step 2.3 (page 4-2), including table 4-1, and Step 2.4e (pages 4-4 and 4-5). The recommended approach first uses the available cable/raceway information to determine the accident initiators that result from a fire. And provides instructions to minimize the need for extensive cable search for non-Appendix R plant systems, e.g., Balance-of-Plant, Instrument Air, HVAC, etc. In cases where cable/raceway location is known, the information can be used to define these initiators. For example if location of both trains of Service Water, Component Cooling Water, or DC are known as part of the Appendix R data, loss of SW, loss of CCW or loss DC can be determined and modeled (Page 4-2). In cases that cable/raceway information is not readily available the guide suggests use of judgement to select a bounding initiator or a cutoff non-recoverable initiator frequency of 1E-4/yr.

The guide relies on the IPE for identification of these initiators for the plant. The guide also provides detailed instructions on one such special initiator, namely fire-induce containment bypass, in pages 4-46 and 4-47.

B.10.3 Response

The Guide provides systematic instruction for selecting of fire-induced accident initiators. The guidance provided suggests use of the IPE model to calculate fire-induced sequences. Accident initiators (special or otherwise) are the result of one or more equipment failures that result in plant trip. Use of the full IPE model will ensure that the cut set involving these failures will be represented whether their location is known (and they are affected by the fire) or unknown (and they are set to failed per instruction on page B-9, 2nd item from the top).

B.11 RAI Question 11 - Screening of Enclosed Ignition Sources

B.11.1 Review of Generic Question

Generic Question 11 deals with two issues associated with how the Guide treats electrical cabinet fires; in particular:

- The Review concluded that the Guide assumes that all enclosed ignition sources cannot lead to fire propagation or other damage. The concern is that this assumption would be optimistic for oil-filled transformers and high-energy cabinets.
- The Review also concluded that the Guide assumes that fire spread to adjacent cabinets cannot occur if a double wall with an air gap separates the cabinets or if the cabinet in which the fire originates has an open top. The concern is that an explosive fault within a high-energy cabinet may breach the integrity of the cabinet, and allow fire spread to combustibles located above the cabinet.

B.11.2 Guidance

<u>Issue 1: Enclosed Ignition Sources:</u>

The Implementation Guide (Ref. iii) makes the following statement regarding fully enclosed ignition sources:

- Page 4-18 (Step 5.2 – Screening Walkdown) states: “Eliminate from further consideration situations where ignition sources are fully enclosed, making them unable to ignite other combustibles.”

The Implementation Guide provides the following guidance specific to transformers:

- Page 4-5 (4.2 Fire Scenario Development – Phase 2) provides detailed guidance for determining ignition sources and developing fire scenarios. Table 4-2 identifies generic fire frequencies and includes transformers as ignition sources.

- Page 4-16 (Fixed Ignition Sources) identifies transformers inside plant areas as important ignition sources and provides guidance for development of fire scenarios.
- Appendix C, Guidance for Fire Ignition Frequency Calculation, provides specific guidance for the transformers to be counted as ignition sources.
- Appendix D, Guidance for Estimating Fire Severity, provides guidance specifically for transformers, particularly oil filled transformers in the plant.
- Appendix E, Guidance for Selection of Heat Release Rates, provides guidance specifically for transformers (both dry type and oil filled).

The Implementation Guide provides the following guidance specific to electrical cabinets:

- Appendix D, Guidance for Estimating Fire Severity, provides guidance specifically for electrical cabinets including Control Room electrical cabinets and Switchgear Room electrical cabinets.
- Appendix E, Guidance for Selection of Heat Release Rates, provides guidance specifically for electrical cabinets.

<u>Issue 2: Fire Spread to Combustibles Located above the Cabinet:</u>

The Implementation Guide (Page E-14) provides the following guidance specific to explosive electrical faults:

> "However, an electrical fault in a switchgear or MCC is likely to produce an explosive fire with significantly more damage resulting from the explosion than from the ensuing fire. The severity factors developed for the switchgear and MCCs (Appendix D) should provide a basis for what fraction of these fires could result in explosive and damaging fires. An explosive switchgear/MCC fire is likely to have the following distinct characteristics, which may be applicable to indoor transformers as well:
>
> - Initiates automatic suppression systems with fast response detectors before a high heat release rate is expected;
> - Damages the cabinet internals and adjacent cubicles;
> - Opens the cabinet door and allows for spread to adjacent cabinets; and
> - Creates life safety concerns and delays fire brigade response.
>
> These factors should be considered when modeling high energy electrical cabinet fires."

B.11.3 Response

Three concerns have been raised about the guidance provided for screening of enclosed ignition sources:

- Damage mechanisms associated with an energetic fault are not adequately addressed in the guidance. In particular, they cited the possibility of damage due to hot projectiles or a very high temperature "cloud" of vaporized copper.

- A fault breaching the cabinet boundaries could lead to damage or ignition of cables above the ignition source.
- Opening of a cabinet door by electricians or fire brigade members could lead to release of hot gases and flames into the compartment, and re-flash of a nominally suppressed fire.

Damage from energetic faults not addressed in the guidance.

The NRC's informal review of this issue in January of 1999 raised concerns about hot projectiles an a very high temperature cloud of vaporized copper. We performed a thorough search of the data we have available, to ascertain whether there was evidence of such failures. Our search considered 85 cabinet fire events in EPRI's Fire Events Database (NSAC 178L, data to 1988) [Ref. xv], 53 cabinet fire events in as-yet-unpublished EPRI data (fire events to 1992), and 42 cabinet fire events in the AOED fire events database, NRC Plant Daily Reports, Licensee Event Reports, Preliminary Notifications of Occurrences, NRC Inspection Reports, licensee internal investigation reports and other information provided to us by the licensees. In total, we reexamined 180 cabinet fire events. This search uncovered no evidence of damage that cannot be adequately addressed with the currently available fire damage models used by the licensees in their IPEEE analyses. None of the events, including the Waterford fire in 1995, after review of numerous internal and external event reports and discussions with the utility, showed clear damage to external circuits and equipment resulting from the initial explosive event. Re-screening and possibly reanalysis of cabinet fires by the licensees is not warranted based on the evidence available at this time. If more substantial evidence is brought forward, it should be carefully examined to ensure that both the frequency and consequences of such events warrant the same level of concern as the effects of sustained fires, before requesting additional analyses from the licensees.

Accounting for faults breaching the boundaries of electrical cabinets.

Our January draft proposed limiting consideration of energetic panel faults to the first switchgear downstream of a major station transformer. In light of the staff's comments we reexamined this recommendation. We searched the 180 cabinet fire events described in the preceding paragraph for events that could have been explosions or energetic faults. The results of the reexamination are as follows:

- We found nine candidate events. Five events are described in the sources as explosions, one is described as an extremely high energy fault, two are described as fireballs, and one is described as a "loud noise" and "flash".
- Seven of the nine events involved switchgear cabinets. The exceptions are a 1998 event at Surry, which occurred in a DG excitation cabinet, and one of the fireball events, which involved a 480V motor control center. The Surry event resulted in no fire or smoke, and damage was limited to the cabinet, which was described as "blown outward". The MCC fireball event resulted in no fire and no damage as a result of the fireball, and terminated when the MCC tripped.
- Three switchgear events, well known in the industry (Waterford, 1995; Oconee, 1989, and Yankee Rowe, 1984) resulted in sustained fires and damage to overhead cables. The remaining four events terminated with the initial energy release, resulting in damage to the

breaker and other cabinet internals, and in some cases the cabinet structure, but without sustained fires or damage outside the cabinets.

- No fault occurring in an MCC resulted in damage to a target or ignition of combustibles beyond the original ignition source.
- We found 22 cabinet fire events that we could associate with switchgear cabinets in all locations in the plant (switchgear rooms, auxiliary buildings, turbine buildings, reactor buildings, diesel generator buildings). There are probably more, but the level of detail in some of the data sources do not allow us to bin all of the cabinet events with a high level of confidence.
- Based on the published EPRI fire events data (which is the only source sufficiently detailed to allow us to determine the relative numbers of switchgear and MCC fire events) about 2.5 times as many of the reported fire events occurred in MCCs than in switchgear.

For purposes of screening, we are interested in ignition sources capable of damaging a target or igniting combustibles beyond the original ignition source. Based on the data we examined, only about one-third of the events involving a high-energy faults meet this criteria, and in all three cases the damage beyond the original ignition source resulted from a sustained fire following the initial energy release.

Conclusions:

1. The potential for very high-energy faults to breach the integrity of an electrical cabinet does exist. We found that explosions in electrical cabinets are strongly associated in the operating experience with switchgear cabinets. However, the potential for such faults to occur in other electrical cabinets fed from high energy sources, such as DG exciters should also be addressed. While we cannot demonstrate that such an event could not occur in an MCC, the data we examined included only one high-energy event (but not an explosion) associated with an MCC, and that event did not result in a sustained fire or damage beyond the original source.
2. The currently available fire damage models used by the licensees in their IPEEE analyses adequately address the significant mechanisms by which damage could occur as a result of a fire in an electrical cabinet. Concerns about damage due to hot projectiles and clouds of very high temperature vapor were not substantiated by the data we examined.
3. Reflash of a nominally suppressed fire could occur and is reflected in the historical data or manual suppression of electrical cabinet fires (EPRI Fire PRA Guide, Figure K-1).

B.12 RAI Question 12 - Electrical Cabinet Heat Release Rate

B.12.1 Review of Generic Question

Generic Question 12 deals with the heat release rates recommended in the Implementation Guide for analysis of cabinet fires. The reviewer cites experimental work resulting in heat release rates ranging from 23 Btu/s to 1171 Btu/s, and recommends a value in the mid-range (e.g. 550 Btu/s) for use in the analysis. The 65 Btu/s heat release rate recommended in the Guide appears to be of particular concern.

B.12.2 Guidance

Appendix E of the Guide provides guidance for selecting heat release rates for electrical cabinets. Appendixes H and M provide guidance for modeling control room cabinets.

The Guide recommends heat release rates for analysis of cabinet fires based on the characteristics of the cabinet of interest. Significant characteristics cited in the Guide include qualified vs. non-qualified cable; fuel loads (in cabinets with unqualified cable), and whether the cabinet is open or closed (for cabinets with unqualified cable). Based on these characteristics, the Guide recommends the range of values shown in Table 3-3.

Table 3-3 Cabinet Fire Heat Release Rates Recommended in the Fire PRA Implementation Guide

CABINET TYPE	GUIDE RECOMMENDED VALUE	RANGE OF THE EXPERIMENTAL DATA
Vertical cabinets, qualified cable	65 Btu/s	23 – 90 Btu/s (1)
Vertical cabinets, unqualified cable		100 – 918 Btu/s
Screening Values		
Open door	850 Btu/s	
Closed door	400 Btu/s	
Final Values		
Open door	Based on fuel load (2)	
Closed door	Based on fuel load (2)	
Benchboard cabinets, qualified cable	170 - 1140 Btu/s	*170 - 1140 Btu/s*
Benchboard cabinets, non-qualified cable	750 – 1200 Btu/s	750 – 1200 Btu/s

(1) Includes a nominal 25 Btu/s ignition source

(2) But not less than 95 Btu/s

B.12.3 Response

As the review points out, there is considerable spread in the data for heat release rates for cabinet fires. A median value (e.g., 550 Btu/s), as recommended by the reviewer, could be overly conservative for some configurations, and non-conservative for others.

A careful evaluation of the data in the report referenced by the reviewer (Ref. xix), as well as its companion report (Ref. iv) describing additional tests, forms the basis for the values recommended in the Guide. In all, the referenced reports present data from a total of 24 tests. There were nineteen tests in which cable was the combustible material (2 tests used gas burners and 3 tests used heptane, with no cable in the cabinet). Peak heat release rates for the tests involving cable ranged from 23 Btu/s (24 kW) to 1232 Btu/s (1300 kW). Tests encompassed a variety of conditions:

- Cabinet footprints ranged from 7-1/2 ft2 to 26 ft2;
- Combustible loads ranged from 110,000 Btus to 1,470,000 Btus;

- Combustibles consisted of either qualified or unqualified cable
- Cabinet doors were both open and closed;
- Cabinets were both vertical and benchboard types;
- Electrical and transient ignition sources were used;
- Room ventilation rates ranged from 1-8 room changes per hour.
- One test included an internal barrier in the cabinet.

Tests performed by the Technical Research Center (VTT) of Finland (Refs. xx and xxi), measured heat release rates for electronic cabinets with unqualified cable in seven tests. Measured heat release rates ranged from 9 kW to 380 kW (8 to 360 Btu/s). The VTT tests encompassed the following conditions:

- Cabinet footprints were approximately 0.31 m2 to 0.35 m2
- Combustible loads ranged from 20 kg to 71 kg of mixed materials (the total heat content in kilojoules is not reported).
- Combustible loads included relays and circuit boards in addition to unqualified cable
- Cabinet doors were closed. Ventilation was provided by louvers in the lower one-third of the door and an opening in the cabinet ceiling.
- Cabinets were vertical electronics type cabinets
- A propane burner ignition source was used

The Guide recognizes differences in cabinet configurations, but only where it is possible to discern the influence of cabinet features, with reasonable confidence, based on the experimental data. As such, cabinet configurations recognized by the Guide are limited to the type of cable (qualified or unqualified), type of cabinet (vertical or benchboard), and whether the cabinets are open or closed (only for vertical cabinets with unqualified cable). The Guide's recommendations are a significant improvement over the reviewer’s recommendation of a single median value for all cabinet and cable types.

NUREG/CR-4527 reports 11 cabinet fire test with qualified cables. In two of the tests the transient ignition source did not cause ignition of the cabinet combustible load. The peak heat release rate for 7 of the remaining 9 is reported between 23 and 65 Btu/s. These test were all in vertical cabinets with both open and closed doors and combustible loads of varying configuration ranging from 110,000 to 1,000,000 Btu. Two tests involving benchboard-type cabinets with 1,470,000 Btu loading and configurations similar to the vertical cabinet tests produced peak heat release rates of 175 Btu/s (Test PCT6: cabinet with open door) and 1148 Btu/s (Test 23: cabinet with front ventilation grill & open backdoor). The NUREG offers no explanation for the significant increase particularly in the case of Test 23.

A series or cabinet fire tests were conducted in Finland with unqualified cables that produced heat release rates between 48 and 360 Btu/s. These tests are used to derive the recommended 190 Btu/s value. Test 23 is taken into account as one-in-nine evidence.

B.13 RAI Question 13 - Fixed Ignition Source Screening, Non-Combustible Shield

B.13.1 Review of Generic Question

Generic Question 13 deals with one statement in the Guide regarding the screening walkdown; in particular:

- The concern is that the Guide allows screening of ignition sources if ignition sources are separated from targets by a non-combustible shield. The concern is that ignition sources could be improperly screened.

B.13.2 Guidance

The Implementation Guide (page 4-18, Step 5.2 – Screening Walkdown) states:

"Ignition sources with no targets overhead, with targets above the damage height and more than the damage radius to the side, or ignition sources separated from targets by a non-combustible shield can also be screened."

B.13.3 Response

The current wording is potentially misleading if taken out of context. A clarification would remove the potential for misinterpretation.

B.14 RAI Question 14 - Fixed Ignition Source Screening, Consideration of Transients

B.14.1 Review of Generic Question

Generic Question 14 deals with one statement in the Guide regarding screening ignition sources; in particular:

- The concern is that the Guide allows screening of compartments based on the contribution from fixed ignition sources alone. The concern is that transient ignition sources could be significant and the compartment could be improperly screened.

B.14.2 Guidance

The Implementation Guide (page 4-15, Step 5.1 – Scoping Evaluation) states:

> "If all fixed ignition sources in a compartment screen, the compartment *PROBABLY* will screen."

The guidance merely suggests that fixed ignition sources be considered first for their potential damage ability. If this consideration results in screening enough of the fixed ignition sources from the compartment fire CDF that brings the TOTAL compartment CDF below the screening cutoff, then the compartment can be screened. The aim of the guidance is to eliminate the need for defining and evaluating transient fire scenarios if possible. This is in part due to the fact that transient scenarios are harder (than fixed scenarios) to define without getting into open ended what-if questions.

B.14.3 Response

The basis for the concern identified in the Review was not specifically identified. It is assumed that the Review failed to recognize the *PROBABLY* in the statement identified above and erroneously concluded that the Guide suggests screening compartments without consideration of transient ignition sources.

Supplemental Guidance is provided in section 3 of this report to reduce chances of misinterpretation.

B.15 RAI Question 15 - Automatic Suppression Dependency

B.15.1 Review of Generic Question

Generic Question 15 deals with the adequacy of the guidance in defining scenario suppression unreliability, in particular:

- The Review concluded that the Guide appears to consider suppression efforts successful if fires involving the ignition source or any subsequently ignited targets are suppressed.
- Since both the ignition source and all ignited targets must be suppressed for suppression to be considered successful, analyses based on the premise above could result in flawed analysis results

B.15.2 Guidance

The statement of concern is in the next to last paragraph on page 4-39 (Step 6.3 – Evaluate Manual Detection and Suppression Reliability). In particular, the last sentence “The product of the two suppression unreliability gives the appropriate scenario unreliability” appears to be the basis for the concern.

The statement in question appears to be inconsistent with the first paragraph in Appendix K, Section K.1, Manual Suppression Time Reliability Curves, which states “Suppression curves for the ignition source are used unless another combustible (i.e., cable) becomes involved. Then, cable fire suppression is assumed to be the limiting factor once the cable is ignited.”

B.15.3 Response

The statements on page 4-39 require clarification to make them consistent with the guidance of Appendix K, Guidance on Effectiveness of Detection and Suppression.

B.16 RAI Question 16 - Piloted Cable Ignition Temperature

B.16.1 Review of Generic Question

Generic Question 16 deals with the cable ignition temperature, in particular, the basis for 932°F as the piloted ignition temperature for both qualified and non-qualified cable. The question has arisen as a result of testing performed by Sandia to investigate the effects of thermal aging on electrical cables [Ref. xxii]. The tests concluded that cable failure could occur at temperatures lower than 932°F under specific test conditions that could occur in a fire.

B.16.2 Guidance

The Implementation Guide (Ref. iii, page 4-27, <u>Cable Ignition in Horizontal Trays</u>) states:

"The EPRI Fire PRA methodology recommends a piloted ignition temperature of 932°F based on a variety of sources including FMRC test summary (NUREG / CR-4840) and the Fire Protection Handbook."

B.16.3 Response

Testing conducted by Sandia (Ref. xxii) identified a piloted ignition temperature of energized electrical cable that can occur at temperatures of approximately 700°F (lower than the 932°F currently suggested in the Guide). The temperatures can occur under conditions involving high convective flux such as could be encountered in plume or ceiling jet fire scenarios.

The basis for acceptance of the lower ignition temperature (700°F) is that the testing performed by Sandia in 1991 may reflect in-plant conditions during a fire. The 932°F value for cable ignition temperature has basis and is documented in a number of references [Ref. ii and iii]. The following describes the key technical differences between the two ignition temperature values and the conditions for use of 700°F.

<u>700°F Ignition Temperature</u>

This is an approximation of the values determined by Sandia in relatively recent tests. The tests involved energized electrical cable subjected to rapid heating by a high convective flux as well as radiant heating. The key differences from earlier tests appear to be the high convective heat flux and the impact of the energized cable.

Cable ignition was observed shortly after the electrical characteristics of the cable insulation degraded. Degradation of the insulation resulted in a localized heating of the material, followed by a spark and subsequent ignition of the cable. The observed ignition is attributed to electrical failure in the presence of a high convective heat flux such as would be experienced in a fire plume.

932°F Ignition Temperature

This value was determined by tests, documented in Reference ii. The test specimen was a segment of insulated electrical cable which was typically not energized. Piloted ignition of the cable occurred when the cable jacket and insulation are heated sufficiently to produce combustible gases that were ignited by an open flame.

Conclusion

The 1991 Sandia tests are representative of plant conditions involving energized electrical cable subjected to sustained high convective heat flux in the plume or ceiling jet regions of a fire. For scenarios modeling such exposures, a cable ignition temperature of 700°F is indicated.

For scenarios without a high heat flux (i.e., targets in the hot gas layer but outside the plume or ceiling jet region) use of 932°F is considered to be appropriate.

B.17 References

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