# TECHNICAL BASIS

# FIRE PROTECTION SIGNIFICANCE DETERMINATION PROCESS
(SUPPLEMENTAL GUIDANCE FOR IMPLEMENTING IMC 0609, App F)

## AT POWER OPERATIONS

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## 1.0 ENTRY CONDITIONS AND APPLICABILITY

SECY-99-007A describes the need for a method of assigning a risk characterization to inspection findings. This risk characterization is necessary so that inspection findings can be aligned with risk-informed plant performance indicators (PIs) during the plant performance assessment process. An attachment to the SECY describes in detail the staff's efforts to date for the risk characterization of inspection findings, which have a potential impact on at-power operations, affecting the initiating event, mitigating systems, or barrier cornerstones associated with the reactor safety strategic performance area. This significance determination process (SDP), discussed in the SECY, focuses on risk-significant issues that could influence the determination of the change in core damage frequency ()CDF) at a nuclear power plant (NPP). In this context, risk significance is based on the )CDF acceptance guidelines in Regulatory Guide (RG) 1.174.

A performance issue that leads to an increase in core damage frequency ()CDF) larger than $10^{-4}$ /ry is risk significant and therefore the highest risk category (red) is given to this frequency range in Table 1.1. Lower frequency ranges are allocated different colors (and hence risk significance categories) in one order of magnitude decrements. The Fire Protection SDP is based on changes in CDF, rather than changes in the large early release frequency (LERF).

**Table A9.1- Risk Significance Based on )LERF vs )CDF**

| Frequency Range/ry | SDP Based on )CDF | SDP Based on )LERF |
|---|---|---|
| $\$ 10^{-4}$ | Red | Red |
| $< 10^{-4} - 10^{-5}$ | Yellow | Red |
| $< 10^{-5} - 10^{-6}$ | White | Yellow |
| $< 10^{-6} - 10^{-7}$ | Green | White |
| $<10^{-7}$ | Green | Green |

The Fire Protection SDP methodology consists of three phases:

1. Phase 1: Characterization and initial screening of findings
2. Phase 2: Initial approximation and basis of risk significance
3. Phase 3: Finalized determination and basis of risk significance

The initial screening of findings in the Phase 1 process should lead to an identification of those findings that require Phase 2 or Phase 3 assessments.

### 1.1 Entry Conditions

The entry conditions for the Fire Protection SDP are defined for inspection findings of:

- Degraded conditions associated with the plant fire protection program.

The as-found degraded conditions are assumed to result from deficient licencee performance during full power operation of the plant (see IMC 0609 Appendix A). This may involve findings associated with fire protection features, fire protection systems, post-fire safe shutdown (SSD) systems, procedures, and equipment, or any other aspect of the fire protection program.

Appendix F provides a simplified risk-informed methodology that estimates the increase in core damage frequency (CDF) associated with inspection findings of deficient licencee performance in assuring fire protection during full power operations. Guidance for assessing risk significance of fire protection issues during low power or shutdown operations are currently not addressed in this Appendix. If the inspection finding(s) is judged not to be related to deficient performance, no SDP evaluation would be performed.

Nominally, each inspection finding is initially screened using the guidance in IMC 0612, Appendix B to determine whether or not the finding is a greater than minor issue. If the finding is greater than a minor issue, the IMC 0612 guidance directs the analyst to perform a Phase 1 SDP assessment. Since all inspection findings related to the fire protection program are referenced to Appendix F for further consideration, the screening of all fire protection program findings are performed using the guidance provided in Appendix F.

A detailed Phase 3 analysis may be recommended for any finding evaluated in Phase 2 as greater than Green. In general, a Phase 3 analysis would be appropriate for a complex finding. A complex finding (or special finding) is defined as:

- A finding with a number of correlated (or dependent) findings of performance deficiencies[1],
- A finding assessed in Phase 2 whose approximate risk significance appears to be driven by contentious assumptions and/or over-conservatism, or appears to be substantially affected by uncertainties associated with simplifying assumptions, or
- A finding judged to be potentially risk significant that is not covered by the guidance provided in this Appendix (see Section 2.0).

## 1.2 Applicability

The Fire Protection SDP is designed to provide NRC analysts and management with a risk-informed tool for identifying potentially risk-significant issues that involve degradations in the plant fire protection program. All such findings are evaluated in terms of the impact of the degradation finding on the change in fire-induced CDF. The Fire Protection SDP also helps to facilitate communication of the basis for significance between the NRC and regulated licensees. In addition, the SDP identifies findings that do not warrant further NRC engagement, due to very low risk significance, so that these findings are entered into the licensee's corrective action program.

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[1] Since the figure of merit for the SDP analysis is an increase in the average annual CDF, inspection findings are considered simultaneously in an analysis only when findings are due to a common cause. Otherwise, the coincidence of the findings would be considered as a random occurrence, and each finding is analyzed separately.

## 2.0 LIMITS AND PRECAUTIONS

This document provides supporting guidance for implementation of Phase 1 and 2 analyses under the Fire Protection SDP analysis process as described in Appendix F to IMC 0609 (referred to hereafter as "Appendix F"). The actual analysis procedure is documented in Appendix F. The current document is intended to serve as a supplemental resource to assist in implementation of, and to foster a greater understanding of, the Appendix F procedure. This document is considered a necessary companion to the procedure itself.

The Fire Protection SDP analysis process is a simplified tool that provides a slightly conservative, nominally order-of-magnitude assessment of the risk significance of inspection findings related to the fire protection program. The Fire Protection SDP is a tool that NRC analysts can easily use to obtain an assessment of the risk significance of a finding.

The Fire Protection SDP approach has a number of inherent assumptions and limitations:

- The Fire Protection SDP assesses the change in CDF, rather than LERF, as a measure of risk significance. The likelihood of early release of radioactive materials or long-term risk measures such as population dose (person-rem) and latent cancer fatalities are not addressed in this Appendix. Containment performance depends on the containment design, plant specific attributes and features, which have considerable variability and are beyond the scope of this simplified fire risk analysis tool.

- The quantification approach and analysis methods used in this Fire Protection SDP are largely based on existing fire PRA analysis methods. As such, the methods are also limited by the current state of the art in fire PRA methodology.

- The Fire Protection SDP focuses on risks due to degraded conditions of the fire protection program during full power operation of a nuclear power plant. This tool does not address the potential risk significance of fire protection inspection findings in the context of other modes of plant operation (i.e., low power or shutdown).

- The process strives to achieve order of magnitude estimates of risk significance. However, it is recognized that fire PRA methods in general retain considerable uncertainty. The Fire Protection SDP strives to minimize the occurrence of false-negative findings. In the process of simplifying existing fire PRA methods for the purposes of the Phase 2 Fire Protection SDP analysis, compromises in analysis complexity have been made. In general, these compromises have involved the application of quantification factors that may be somewhat conservative for specific applications. Hence, the objective of order of magnitude accuracy may not be uniformly achieved in the Fire Protection SDP Phase 2 analyses.

- The Fire Protection SDP excludes findings associated with the performance of the on-site manual fire brigade or fire department. A separate SDP methodology for the evaluation of such findings will be established.

- The Fire Protection SDP Phase 2 quantitative screening method includes an approach for incorporating known fire-induced circuit failure modes and effects issues into an SDP analysis. However, the SDP approach is intended to support the assessment of known issues only in the context of an individual fire area. It is not structured to support a systematic search for such issues, nor an assessment of the plant-wide risk significance of an identified issue. In practice, any given circuit failure modes and effects issue will likely impact the risk contribution arising from multiple fire areas. The SDP analysis approach could, in theory, be used to provide a screening estimate of the plant-wide risk significance of a particular circuit failure issue, but only if supported by a plant-wide search for relevant vulnerabilities (i.e., plant-wide routing information for all relevant cables and circuit, and an assessment of fire vulnerabilities for each relevant fire area). A systematic plant-wide search and assessment effort is beyond the intended scope of the fire protection SDP.

- This document does not currently include explicit treatment of fires in the main control room. The Phase 2 process can be utilized in the treatment main control room fires, but it is recommended that additional guidance be sought in the conduct of such an analysis.

- This document does not currently include explicit treatment of fires leading to main control room abandonment, either due to fire in the main control room or due to fires in other fire areas. The Phase 2 process can address such scenarios, but it is recommended that additional guidance be sought in the conduct of such an analysis.

# 3.0 ABBREVIATIONS, SYMBOLS AND DEFINITIONS

## 3.1 Abbreviations

| | |
|---|---|
| CCDP | Conditional Core Damage Probability |
| CD | Core Damage |
| CDF | Core Damage Frequency |
| CM | Compensatory Measure |
| CSR | Cable Spreading Room |
| DF | Duration Factor |
| DID | Defense in Depth |
| EPRI | Electric Power Research Institute |
| FDS | Fire Damage State |
| FPS | Fire Protection System |
| GDC | General Design Criterion |
| IMC | Inspection Manual Chapter |
| IPEEE | Individual Plant Examination for External Events |
| LER | Licensee Event Report |
| LERF | Large Early Release Frequency |
| MCR | Main Control Room |
| NEI | Nuclear Energy Institute |
| NPP | Nuclear Power Plant |
| NRC | Nuclear Regulatory Commission |
| NRR | NRC Office of Nuclear Reactor Regulation |
| NFPA | National Fire Protection Association |
| PNS | Probability of Non-Suppression |
| PRA | Probabilistic Risk Assessment |
| RES | NRC Office of Nuclear Regulatory Research |
| RG | NRC Regulatory Guide |
| ROP | Reactor Oversight Process |
| ry | Reactor Year (generally in the context of an event frequency) |
| SDP | Significance Determination Process |
| SER | NRC Safety Evaluation Report |
| SF | Severity Factor |
| SSCs | Structures, Systems, and Components |
| SSD | Safe Shutdown |
| TB | Turbine Building |

## 3.2 Mathematical Symbols

| | |
|---|---|
| $AF_{2.4}$ | Adjustment Factors for fire frequency - these factors may be applied in Tasks 2.4.2 and/or 2.4.3 |
| $CCDP_{2.1}$ | Screening CCDP developed in Phase 2 Step 2.1 |
| $CCDP_{Scenario}$ | Detailed CCDP for a specific scenario obtained from the USNRC Risk-Informed Inspection Notebooks |
| $\Delta CDF_{\#.\#}$ | Estimated change in CDF (a subscript indicate the specific analysis step during which the CDF change has been calculated and implies the level of detail incorporated into the change estimate) |
| DF | Duration Factor |
| F | Fire frequency - general representation |

| | |
|---|---|
| $F_{Area}$ | Fire frequency for a fire area in its entirety |
| $F_{Source}$ | Fire frequency for a specific fire ignition source or set of fire ignition sources |
| PNS | Probability of Non-Suppression - general representation |
| $PNS_{Scenario}$ | Probability of Non-Suppression for a specific fire growth and damage scenario |
| SF | Severity Factor - general representation |
| $SF_{Source}$ | Post-screening Severity Factor for a specific fire ignition source (applied only if fire screens out at expected fire intensity, but does not screen out at high confidence fire frequency during Step 2.3) |
| t | Time - general representation |
| $t_{Damage}$ | Time to damage |
| $t_{Detection}$ | Time to fire detection |
| $t_{Supp.}$ | Time to fire suppression |
| WF | Weighting Factor - equivalent to a partitioning factor, assigns a specific fraction of fires to a specific location within a fire area. Used in the analysis of transient fuel fires, hot work fires, and self-ignited cable fires. |

## 3.3 Definitions

Alternative Shutdown (or Alternate Shutdown): The capability to safely shut down the reactor in the event of a fire using existing systems that have been rerouted, relocated, or modified. See also: *Remote Shutdown*. (RG 1.189)

Compensatory Measure: Actions taken by a licensee to mitigate the potential impact of a known degradation of defense in depth, in this case, in some element of the plant fire protection program.

Compartment: A fire compartment is a well-defined volume within the plant that is not necessarily bounded by rated fire barriers or complete physical barriers but that is expected to substantially contain the adverse effects of fires within the compartment. Fire compartments are defined for the purposes of fire PRA analysis, and generally represent a subset of a plant fire area.

Exposed Fire Area: In the context of a multi-compartment, or room-to-room, fire scenario the exposed fire area is that fire area to which the fire may spread. An unsuppressed fire in the exposing fire area may spread through a fire barrier to the exposed fire area. (See *Exposing Fire Area*.)

Exposing Fire Area: In the context of a multi-compartment, or room-to-room, fire scenario the exposing fire area is that fire area where the fire is initiated or ignited. An unsuppressed fire in the exposing fire area may spread through a fire barrier to the exposed fire area. (See *Exposed Fire Area*.)

Fire Area: The portion of a building or plant that is separated from other areas by rated fire barriers adequate for the fire hazard. (RG 1.189)

Fire Barrier: Components of construction (walls, floors, and their supports), including beams, joists, columns, penetration seals or closures, fire doors, and fire dampers that are rated by approving laboratories in hours of resistance to fire, that are used to prevent the spread of fire. (RG 1.189)

Fire Brigade: A team of on-site plant personnel that have been qualified and equipped to perform manual fire suppression activities. (RG 1.189)

Fire Damage (or Fire-Induced Damage): A structure, system or component is no longer free of fire damage (see definition of Free of Fire Damage). That is, the structure, system, or component under consideration is no longer capable of performing its intended function without repair.

Fire Damage State: A discrete stage of fire growth and damage postulated in the development of Fire Protection SDP fire scenarios. Four fire damage states are defined as follows:

> *FDS0:* Only the fire ignition source and initiating fuels are damaged by the fire.
> *FDS1*: Fire damage occurs to unprotected components or cables located near the fire ignition source.
> *FDS2*: Widespread fire damage occurs to unprotected components or cables within the fire area of fire origin, to components or cables protected by a degraded local fire barrier system (e.g., a degraded cable tray fire barrier wrap), or to components or cables protected by a non-degraded one-hour fire barrier.
> *FDS3*: Fire damage extends to a fire area adjacent to the fire area of fire origin, in general, due to postulated fire spread through a degraded inter-area fire barrier element (e.g., wall, ceiling, floor, damper, door, penetration seal, etc.).

Fire Growth and Damage Scenario: That part of a fire scenario (see definition of *Fire Scenario*) that characterizes the potential that fires involving a particular fire ignition source (see definition of *Fire Ignition Source Scenario*) might ignite secondary combustible fuels, the subsequent spread of fire within and among any secondary combustible fuels, and the potential for fire-induced damage to fire PRA systems and equipment (see definition of *Fire PRA Systems and Equipment*).

Fire Hazard: The existence of conditions that involve the necessary elements to initiate and support combustion, including in situ or transient combustible materials, ignition sources (e.g., heat, sparks, open flames), and an oxygen environment. (RG 1.189)

Fire Ignition Source Scenario: That part of a fire scenario (see definition of *Fire Scenario*) that defines the early physical characteristics of the fire itself including factors such as the ignition source, the initially ignited combustible material(s), and the characteristics of the fire involving those initial combustible materials (e.g., heat release rate, location, duration, etc.).

Fire PRA Systems and Equipment: Structures, systems, components, and cables (power, instrumentation and control) credited for plant shutdown in the context of a fire PRA. The fire PRA systems and equipment will typically include all of the fire SSD systems and equipment, other systems and equipment credited in the internal events PRA, and other systems and equipment subject to unique fire-induced failure modes (e.g., components susceptible for fire-induced spurious actuation if such fault modes are included in the PRA model).

Fire Protection Defense in Depth (DID): "(Achieving) the required degree of reactor safety by using echelons of administrative controls, fire protection systems and features, and safe shutdown capability ... aimed at achieving the following objectives: to prevent fires from starting; to detect rapidly, control and extinguish promptly those fires that do occur; and to provide protection to systems, structures, and components important to safety so that a fire that is not promptly extinguished by the fire suppression activities will not prevent the safe shutdown of the plant." (taken from Regulatory Guide 1.189, Section B)

Fire Protection Feature: Administrative controls, fire barriers, means of egress, industrial fire brigade personnel, and other features provided for fire protection purposes. (NFPA 805)

Fire Protection Program: The integrated effort involving components, procedures, and personnel utilized in carrying out all activities of fire protection. It includes system and facility design, fire prevention, fire detection, annunciation, confinement, suppression, administrative controls, fire brigade organization, inspection and maintenance, training, quality assurance, and testing. (RG 1.189)

Fire Protection Program Element: Any individual system, feature, provision, analysis, procedure, requirement, training program, or plant practice that is a part of the overall fire protection program. The term "fire protection program element" is used in this document as the most general reference to individual aspects of the overall fire protection program.

Fire Protection System: Fire detection, notification, and fire suppression systems designed, installed, and maintained in accordance with the applicable NFPA codes and standards. (NFPA 805)

Fire Scenario: A sequence of events that begins with the ignition of a fire that has the potential to upset normal plant operations, and ends when the plants achieves, or fails to achieve, a safe and stable mode of plant operation, normally hot shutdown. A fire scenario is made up of a unique combination of a fire ignition source scenario, a fire growth and damage scenario, a postulated plant damage state, a fire suppression scenario, and a plant safe shutdown response scenario (see related definitions). Changes in any one of these five elements implies the introduction or identification of a new fire scenario.

Fire Suppression: Control and extinguishing of fires (firefighting). Manual fire suppression is the use of hoses, portable extinguishers, or manually actuated fixed systems by plant personnel. Automatic fire suppression is the use of automatically actuated fixed systems such as water, Halon, or carbon dioxide systems. (RG 1.189)

Fire Suppression Scenario: That portion of a fire scenario (see definition of *Fire Scenario*) that describes the process by which the fire is suppressed (see definition of *Fire Suppression*).

Fire Watch: Individuals responsible for providing additional (e.g., during hot work) or compensatory (e.g., for system impairments) coverage of plant activities or areas for the purposes of detecting fires or for identifying activities and conditions that present a potential fire hazard. The individuals should be trained in identifying conditions or activities that present potential fire hazards, as well as the use of fire extinguishers and the proper fire notification procedures. (RG 1.189)

Free of Fire Damage: The structure, system, or component under consideration is capable of performing its intended function during and after the postulated fire, as needed, without repair. (RG 1.189)

Non-Degraded: A fire protection system of feature that has no findings of degradation pending against it. A non-degraded system or feature is considered fully functional.

Phases of a Significance Determination:

> *Phase 1 -Characterization and Initial Screening of Findings:* Precise characterization of the finding and an initial screening of very low-significance findings for disposition by the licensee's corrective action program.

*Phase 2 - Initial Approximation and Basis of Risk Significance:* Initial approximation of risk significance of the finding and development of the basis for this determination for those findings that filter through the Phase 1 screening process.

*Phase 3 - Finalized Determination and Basis of Risk Significance:* Review and perform as-needed refinement of the risk significance estimation results from Phase 2, or perform any risk significance analysis outside of this guidance, by an NRC risk analyst (any departure from the guidance provided in this document for Phase 1 or Phase 2 analysis constitutes a Phase 3 analysis and must be performed by an NRC risk analyst).

Post-Fire Safe Shutdown Response Scenario: That part of a fire scenario that involves the plant response, including operator actions, to fire-induced damage to a specific and pre-determined set of plant components and systems. An analysis of the post-fire safe shutdown response scenario typically involves identification of one or more relevant plant accident sequence initiating events, application of plant system modeling event trees and/or fault trees, the assessment of automatic plant responses, the assessment of component and system failure modes and effects (circuit analysis), and the analysis of operator responses and actions, all intended to achieve a safe and stable plant shutdown state.

Qualified Cable: A cable that is certified for use in severe accident environmental conditions per the full suite of performance tests specified in IEEE-383 which includes a flame spread test.

Raceway: An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or bus-bars, with additional functions as permitted by code. Raceways include, but are not limited to, rigid metal conduit, rigid nonmetallic conduit, intermediate metal conduit, liquid-tight flexible conduit, flexible metallic tubing, flexible metal conduit, electrical nonmetallic tubing, electrical metallic tubing, underfloor raceways, cellular concrete floor raceways, cellular metal floor raceways, surface raceways, wireways, and busways. (RG 1.189)

Raceway Fire Barrier: Non-load-bearing partition type envelope system installed around electrical components and cabling that are rated by test laboratories in hours of fire resistance and are used to maintain safe shutdown functions free of fire damage. (RG 1.189)

Radiant Energy (Heat) Shield: A noncombustible or fire resistive barrier installed to provide separation protection of redundant cables, equipment, and associated non-safety circuits within containment. (RG 1.189)

Remote Shutdown: The capability, including necessary instrumentation and controls, to safely shut down the reactor and maintain shutdown conditions from outside the main control room (see GDC 19). See also: *Alternative Shutdown*. (RG 1.189)

Safe Shutdown (SSD) Systems and Equipment: Systems and equipment that perform functions needed to achieve and maintain safe shutdown regardless of whether or not the system or equipment is part of the success path for safe shutdown. (RG 1.189)

Screen to Green: If a finding satisfies established screening criteria, it is assigned a green color rating, and the SDP analysis is complete. Phases 1 and 2 of the Fire Protection SDP both include various qualitative and quantitative screening checks where a finding may Screen to Green.

Secondary Combustible: Any and all combustible materials that are separate and distinct from the initially ignited combustible material(s) associated with the fire ignition source scenario itself (see definition of Fire Ignition Source Scenario). Secondary combustibles may become involved in the fire if ignited. The ignition of secondary fuels implies a spreading fire has developed; i.e., the fire has spread beyond the fuels associated with the fire ignition source scenario.

Split Fraction: A conditional probability value reflecting the likelihood that one specific outcome from a set of possible outcomes will be observed. Example: When there are two possible outcomes, a split fraction is used to represent the likelihood that each specific outcome will be observed. A common example in the fire protection SDP is fire intensity. Each fire ignition source is characterized by two fire intensity values. The lower value is assumed to represent 90% of all fires involving that fire ignition source, the higher value represents the remaining 10% of fires. This would be a 90/10 (or 0.9/0.1) split fraction between these two outcomes - the smaller fire versus the larger fire.

Unqualified Cable: A cable that has not been certified for use in severe accident environmental conditions per the full suite of performance tests specified in IEEE-383.

# 4.0 GENERAL APPROACH FOR SIGNIFICANCE DETERMINATION

## 4.1 Road Map

The Fire Protection SDP as documented in Appendix F to IMC 0609 involves a series of qualitative and quantitative analysis steps for estimating the risk significance of inspection findings related to licensee performance in meeting the objectives of the fire protection defense-in-depth (DID) elements. The fire protection DID elements are:

- Preventing fires from starting,
- Rapid detection and suppression of fires that occur, and
- Protection of structures, systems, and components (SSCs) important to safety so that a fire that is not promptly extinguished by fire suppression activities will not prevent the safe shutdown (SSD) of the plant.

The Fire Protection SDP uses simplified fire PRA methods, tools, and approaches. The general philosophy of the Fire Protection SDP is to minimize the potential for false-negative findings, while avoiding undue conservatism. The duration (or exposure time) of the degraded conditions is considered at all stages of the analysis. Compensatory measures (CMs) that might offset (in part or in whole) the observed degradation are considered in Phase 2.

Phase 1 is a preliminary screening assessment intended to identify findings that can be quickly classified as Green and dispositioned into the licensee's corrective action program without further analysis. Findings that do not Screen to Green in Phase 1 pass forward to Phase 2.

Phase 2 of the Fire Protection SDP is quantitative and involves several analysis steps. Each step introduces greater refinement and detail. Quantitative screening checks are made each time new or refined analysis detail has been developed. The various screening steps are summarized in Table 4.1.1. Section 4.2 describes these screening steps more fully.

**Table A9.2 - Summary of Phase 1 and 2 Quantification/Screening Steps**

| **Step** | **Refined or New Information Added** | **Estimated change in CDF** *(unwritten terms assumed to have a value of 1.0)* **based on:** |
|---|---|---|
| 1.4 | First Screen | **Duration Factor (DF) X Area fire Frequency (AFF)** |
| 2.1 | Add ISSD Path | DF X AFF X **Independant SSD Path** |
| 2.4 | Refine Fire Frequency | DF X **Refined FF** X ISSD Path |
| 2.5 | Refine ISSD Path | DF X Refined FF X **Refined ISSD Path** |
| 2.7 | Add Probability of Non-Suppression | DF X Refined FF X Refined ISSD Path X **Probability of Non-Suppression(PNS)** |
| 2.9 | Refine Plant Response | DF X Refined FF X **Re-refine ISSD Path (CCDP)** X PNS |

## 4.2 General Approach

### 4.2.1 Phase 1 Qualitative Screening Analysis

Phase 1 of the Fire Protection SDP is a preliminary screening check intended for use by the Resident or Regional Office inspector(s) to identify fire protection findings of very low risk significance. If the screening criteria are met, the finding is assigned a preliminary risk significance ranking of Green and no Phase 2 analysis is required. If the Phase 1 screening criteria are not met, the analysis continues to Phase 2.

Phase 1 involves four analysis steps. A flow chart illustrating the Phase 1 process is provided in Appendix F. The Phase 1 steps are summarized as follows:

- Step 1.1: Categorize the finding based on the fire protection program element that was found to be degraded.

- Step 1.2: Assign a degradation rating based on the potential impact the degraded condition might have on the performance of the degraded fire protection program element.

- Step 1.3: Perform an initial qualitative screening check.

- Step 1.4: Perform an initial quantitative screening check considering room fire frequency and duration factor.

The Phase 1 analysis procedure is provided in Appendix F to IMC 0609.

### 4.2.2 Phase 2 Quantitative Analysis

A finding that does not meet the Phase 1 screening criteria is processed through Phase 2. Phase 2 involves a quantitative assessment of CDF increase given a finding. There are nine analysis steps in Phase 2 as discussed further below. The Phase 2 process is illustrated in a flow chart provided as a part of Appendix F itself. Each step introduces new detail and/or refines previous analysis assumptions and results.

The quantification process parallels fire PRA practice. In a fire PRA the fire-induced CDF is quantified as the product of the following three terms:

> Fire Frequency - the likelihood that a potentially challenging fire will occur in a specific location during a reactor operating year (ry).
>
> Fire Damage State Non-Suppression Probability - the likelihood that fire suppression efforts fail to suppress the fire before a pre-defined set of plant components/cables are damaged by the fire.
>
> Conditional Core Damage Probability (CCDP) - the likelihood that the fire-induced damage to plant components/cables leads to core damage (post-fire SSD efforts fail to achieve safe and stable hot shutdown conditions).

In addition to these three fire PRA quantification factors, the SDP also includes the duration factor associated with a finding. The value of the duration factor established in Phase 1 (see Step 1.4) is used in all Phase 2 quantification steps.

The procedure for a Phase 2 analysis is documented in Appendix F to IMC 0609. A Phase 2 analysis involves nine steps, each involving specific analysis tasks. The steps and tasks are summarized as follows:

Step 2.1 - Independent SSD Path First Screening Assessment:

- Task 2.1.1: Identify the designated post-fire SSD path for fires in the fire area under analysis
- Task 2.1.2: Assess the unavailability factor for the SSD path.
- Task 2.1.3: Assess the independence of the SSD path in light of the worst possible FDS fire scenarios.
- Task 2.1.4: If the independence criteria are met, credit the SSD path in a quantitative screening check. (The SSD path may also be credited in subsequent quantification calculations.)

Step 2.2 - Fire Damage State Determination:

- Task 2.2.1: Determine which FDSs will be considered.
- Task 2.2.2: Perform a screening check for retention of FDS3 fire scenarios.

Step 2.3 - Fire Scenario Identification and Ignition Source Screening:

- Task 2.3.1: Identify and count fire ignition sources.
- Task 2.3.2: Characterize each fire ignition source (fire severity and location).
- Task 2.3.3: Identify nearest fire ignition or damage target for each fire ignition source.
- Task 2.3.4: Screen fire ignition sources.
- Task 2.3.5: Screening Check - finding screens to Green if ALL fire ignition sources screened out (no credible fire scenario).

Step 2.4 - Fire Frequency For Unscreened Fire Ignition Sources:

- Task 2.4.1: Estimate nominal fire frequencies for each unscreened fire ignition source.
- Task 2.4.2: Increase hot work and/or transient fire frequencies if finding is against administrative controls.
- Task 2.4.3: Reduce hot work and/or transient fire frequencies if compensatory measures will reduce likelihood of fire occurrence.
- Task 2.4.4: Perform a screening check using updated room fire frequency.

Step 2.5 - Independent SSD Path Second Screening Assessment:

- Task 2.5.1: Identify fire growth scenarios for unscreened fire ignition sources and each applicable FDS (fixed ignition sources).
- Task 2.5.2: Identify fire growth scenarios for unscreened fire ignition sources and each applicable FDS (self-ignited cable fire, transients. hot work).
- Task 2.5.3: Identify fire damage scenario (i.e., fire damage target sets) for each fire growth scenario.
- Task 2.5.4: Re-assess post-fire SSD path independence in context of each fire damage scenario.
- Task 2.5.5: Perform screening using scenario-specific SSD credit.

Step 2.6 - Fire Growth and Damage Scenario Time Analysis:

- Task 2.6.1: Perform FDS time analysis for each FDS1 fire scenario.
- Task 2.6.2: Perform FDS time analysis for each FDS2 fire scenario.
- Task 2.6.3: Perform FDS time analysis for unscreened FDS3 fire scenarios.

Step 2.7 - Fire Non-Suppression Probability Analysis:

- Task 2.7.1: Estimate the time to fire detection.
- Task 2.7.2: Estimate performance time for fixed fire suppression systems

- Task 2.7.3: Estimate fire suppression time for manual fire fighting.
- Task 2.7.4: Estimate probability of non-suppression for each FDS fire scenario.
- Task 2.7.5: Perform screening check including non-suppression probability.

Step 2.8 - Plant Safe Shutdown Response Analysis:

- Task 2.8.1: Identify plant accident initiating event(s) worksheet(s) to be used.
- Task 2.8.2: Identify systems and functions that can be credited to support plant SSD response for each FDS scenario.
- Task 2.8.3: Identify manual actions included in the SSD procedures.
- Task 2.8.4: Assess failure probability of manual actions.
- Task 2.8.5: Assess the CCDP for each FDS fire scenario.

Step 2.9 - Final Quantification and Preliminary Significance Determination:

- Using all available information, calculate final estimate of CDF change and assign finding a preliminary color.

In order to optimize the efficiency of the analysis, Phase 2 includes five screening checks. These screening checks ensure that a low significance finding will screen to green as soon as the information developed is sufficient to support such a determination. A screening check is made each time a refined estimate of any one of the three fire risk quantification factors identified above is developed (duration factor remains constant once set in Phase 1). If at any time, the estimated CDF change meets the screening criteria, the finding is assigned a preliminary significance ranking of green, and the analysis is considered complete. Subsequent steps need not be performed. The Phase 2 screening checks are summarized as follows:

- Step 2.1 includes a screening check that considers the designated post-fire SSD path if that path meets the established physical independence criteria. If the SSD path is credited, a screening CDF change is calculated as follows:

$$\Delta \mathrm{CDF}_{2.1} \approx \mathrm{DF} \times \mathrm{F}_{\mathrm{area}} \times \mathrm{CCDP}_{2.1.2 \text{ or } 2.1.3}$$

- Step 2.3 screens a finding to green if <u>all</u> fire ignition sources screen out as non-spreading and non-damaging (no credible fire scenario).

- Step 2.4 includes a screening check that uses the refined room fire frequencies and fire severity factors where appropriate. The refined screening CDF is calculated as follows:

$$\Delta \mathrm{CDF}_{2.4} \approx \mathrm{DF} \times \left[ \sum \mathrm{F}_{\mathrm{Source}} \times \mathrm{SF}_{\mathrm{Source}} \right]_{\substack{\mathit{AllUnscreened} \\ \mathit{Sources}}} \times \mathrm{CCDP}_{2.1.2 \text{ or } 2.1.3}$$

- Step 2.5 re-assesses credit for the designated post-fire SSD path considering the worst FDS arising from each fire ignition source. If the physical independence criteria are satisfied for a given fire source, a refined screening CDF change is calculated as follows:

$$\Delta \mathrm{CDF}_{2.5} \approx \mathrm{DF} \times \left[ \sum \mathrm{F}_{\mathrm{Source}} \times \mathrm{SF}_{\mathrm{Source}} \times \mathrm{CCDP}_{2.1\text{-Source Limiting}} \right]_{\substack{\mathit{All\ Unscreened} \\ \mathit{Sources}}}$$

- Step 2.7 assesses the non-suppression probability values for each fire scenario. A refined screening CDF change is then calculated as follows:

$$\Delta \mathrm{CDF}_{2.7} \approx \mathrm{DF} \times \left[ \sum \mathrm{F}_{\mathrm{Source}} \times \mathrm{SF}_{\mathrm{Source}} \times \mathrm{PNS}_{\mathrm{Scenario}} \times \mathrm{CCDP}_{2.1\text{-}\mathrm{Scenario}} \right]_{AllScenarios}$$

Given completion of Step 2.8, all quantification steps of the Phase 2 analysis are complete. Step 2.9 involves final quantification and assignment of a preliminary color. The final color assigned in Step 2.9 may be green, but this is not considered a screening step; rather, it reflects final quantification results for the finding.

## 4.3 Analysis Procedures

The procedures for the Fire Protection SDP Phase 1 and Phase 2 analyses are provided in Appendix F to IMC 0609 including its associated attachments. These procedures are intended to serve as essentially stand-alone working application tools and guidance. The procedures include an expanded description of each analysis task and the supporting information required to complete each task. Attachments to the Appendix F procedures provide additional details and guidance required for completion of specific analysis tasks. Worksheets for managing and documenting the analysis are also provided.

The current document is intended to provide supplemental guidance to support implementation of the Appendix F procedures. In particular, the information in Chapter 5 provides additional discussion intended to enhance the practitioners understanding of the procedures. The text focuses on expanded discussions on the intent of each analysis step and task, and on the relationships between tasks. Chapter 6 of the current document provides basis discussions supporting each step in the analysis procedure.

## 4.4 Flexibility in Exercising the Analysis Procedures

### 4.4.1 Fire Protection SDP Process Flexibility

As discussed in Section 4.2, the Fire Protection SDP uses simplified versions of fire PRA methods, tools, and approaches. Fire PRA is, by design, a flexible analysis process. PRA analysts exercise judgement and tailor their analysis process to suit specific applications. It is intended that the Fire Protection SDP retain this flexibility.

The analysis procedures involve a series of steps and tasks. The order of the steps/tasks, as written, should optimize the analysis of most fire protection findings. However, situations will arise where the as written process flow path may not be the optimum path. In such cases, the procedures should viewed with flexibility and adjustments to either the order of analysis steps, or to the analysis depth in a specific step may be considered.

Chapters 5 and 6 provide additional information about the analysis process, its intent, and the inter-relationships between various steps and tasks. Chapter 5 provides additional explanatory material in the form of supplemental background and supporting information for each analysis task. Chapter 6 provides information on the underlying basis for the Fire Protection SDP approach. Reference to this information should support decision making with regard to process flexibility.

### 4.4.2 Flexibility Examples

This section provides examples where some adjustment of the analysis process may be appropriate. The examples are not exhaustive, but rather, are illustrative of the intent with regard to process flexibility. In general, flexibility may be exercised in the order of step/task performance and in the depth of a given step/task.

Specific task input assumptions should not be adjusted except as allowed by the as-written guidance. That is, no adjustments should be made to assigned values for factors such as screening criteria, fire frequency, fire intensity profiles, severity factors, damage criteria, damage times, suppression times, suppression reliability, etc., unless the possibility of an adjustment to suit case specific factors is called out in the procedures. Supplemental adjustments to input assumptions are deferred to Phase 3.

## Early Completion of a Later Step

The order in which analysis steps are performed may be adjusted if early completion of a later step might result in a finding screening to green with a reduced level of effort.

- Example 1: In Step 2.1 a designated safe shutdown path is identified but not credited. Step 2.4 provides a refined fire frequency for the fire area, and the screening CDF for the finding is already at 9E-6. Hence, one additional order of magnitude in risk reduction would result in a green color assignment. In this case, it may be more efficient to develop a refined CCDP value by completing Step 2.8 prior to the development and analysis of specific fire growth and damage scenarios (e.g., steps 2.5-2.7). Note that in this example, Step 2.8 must be entered assuming fire damage consistent with the limiting, or most severe, unscreened FDS scenario. This may limit the effectiveness of an early pass through Step 2.8. Should the analysis fail to demonstrate the anticipated risk reduction, the analysis can return to Step 2.5 for completion of the fire growth and damage analysis tasks.

- Example 2: A finding impacts a fire area with a minimal set of fire ignition sources. Further, it is expected that the fire ignition sources will likely screen out as non-threatening such that no credible fire scenario will be developed for the fire area. In this case, it may be appropriate to conduct Steps 2.3 and/or 2.4 prior to the execution of Steps 2.1 and 2.2. If, in hindsight, a credible fire scenario is developed, and the finding still does not screen to green (e.g., based on a refined fire frequency), the analysis can return to Step 2.1 and continue with the balance of the analysis.

In performing a later step earlier in the analysis process, the practitioner is essentially developing a more refined estimate for one of the three fire risk quantification factors described in Section 4.2.2 (fire frequency, probability of non-suppression, or CCDP) earlier in the analysis process. The refined risk quantification factor is then folded into the CDF formulas in place of the corresponding, and less refined, value that would have been used had the earlier steps been completed in their normal order.

Care must be exercised to ensure that no “double-counting” of the same risk quantification factor occurs. Replacing the nominal value with the refined value ensures that no double counting occurs.

In many cases, the nominal value for a factor that is being replaced by early completion of a later step may be an implied value of 1.0. For example, the term PNS does not appear in the risk quantification equations for Steps 2.1 through 2.5. Hence, the implied value of PNS is 1.0 for these steps; that is, Steps 2.1 through 2.5 assume that suppression efforts will fail to protect exposed components/cables in a timely manner with a probability of 1.0. A specific value of PNS is not calculated until step 2.7.

## Omission of Non-Productive Steps

Certain steps/tasks may not need to be performed if sufficient information has already been gathered to determine that no discernable risk reduction benefit will be gained.

- Example: Based on knowledge of the designated SSD path for a given fire area, a decision may be taken to not credit that path in the initial stages of analysis, but rather, to defer crediting the SSD path to Step 2.8. In this case, Step 2.1 might not be formally conducted and the analysis might proceed directly to Step 2.2 using a screening CCDP value of 1.0.

## Reducing Analysis Depth for a Given Step

The depth of analysis pursued in a given step may be reduced if additional depth is either not needed to conclude that the finding is green, or if additional depth will not provide any discernible risk reduction benefit.

- Example: The fire area impacted by a finding has full coverage sprinkler protection that is not impacted by the finding. Step 2.6 has been completed, and the actuation time analysis in Task 2.7.2 reveals that the sprinklers will actuate at least 10 minutes prior to the estimated fire damage time, even for the individual fire scenario with the shortest damage time (from Step 2.6). Hence, the sprinklers will be given maximum credit in all scenarios for suppressing the fire prior to damage (98% based on general system reliability).

  This result indicates that, at worst, a 0.02 non-suppression probability can be applied to all scenarios reflecting credit only for fixed suppression system. The added consideration of manual fire fighting can only improve this value (reduce the non-suppression probability). Hence, crediting only the fixed suppression system would be conservative.

  When combined with previous factors (i.e., fire frequency, duration factor, screening CCDP) a non-suppression probability of 0.02 may be sufficient to conclude the finding is green. In this case Step 2.7 can be completed without a formal analysis of sprinkler actuation time for each individual fire scenario, and without an analysis of manual fire fighting for any fire scenarios (i.e., without completing task 2.7.3). The finding can be screened to green based on Task 2.7.5 using a bounding non-suppression probability value of 0.02.

# 5.0 SUPPORTING GUIDANCE AND EXPLANATORY MATERIAL

This chapter provides supporting guidance and additional explanation of the various steps and tasks in the Fire Protection SDP analysis procedure. The material includes additional discussion of the relationship between steps and tasks, PRA methods background information, and historical perspectives relating to the Fire Protection SDP analysis approach. The information in this section is not required for completion of a SDP Phase 1 or Phase 2 analysis; rather, it is intended to enhance the practitioners understanding of the analysis approach.

## 5.1 Phase 1 Analysis Supporting Information

### 5.1.1 Step 1.1 - Categorization of Inspection Findings

The categorization of an inspection finding supports several aspects of the Phase 1 and Phase 2 analyses. The finding categories are defined based primarily on how findings will be handled using the simplified fire PRA approach. That is, quantification of a finding's risk importance involves modifications to the basic or nominal input values and assumptions used in specific steps/tasks of the analysis. For each finding category, the required modifications will be associated with one or more specific steps as follows:

- Findings in the cold shutdown category are screened to green in Phase 1.
- Findings in the Fire Prevention and Administrative Controls category will require changes in the fire frequency estimates for transients and hot work (Step 2.4).
- Findings in the Fixed Fire Protection category will require changes to the detection and suppression analysis (Step 2.7)
- Findings in the fire Confinement category will impact the identification of FDS damage states that need to be considered (Step 2.2), and will impact the fire damage time analysis for FDS3 fire scenarios (Step 2.6).
- Findings in the Localized Cable or Component Fire Barrier category will result in changes to the fire damage time analysis for FDS1 and FDS2 scenarios (Step 2.6)
- Findings in the Post-Fire SSD category will result in changes to the SSD analysis (Step 2.8).

The screening criteria applied in Steps 1.4, 2.1, and 2.4 also depend on the finding category. The basis for this approach is discussed further in Section 6.1.

### 5.1.2 Step 1.2 - Assign a Degradation Rating

At the current time, no supplemental guidance regarding this step is provided.

### 5.1.3 Step 1.3 - Initial Qualitative Screening Check

At the current time, no supplemental guidance regarding Task 1.3.1.

With regard to Task 1.3.2, the intent of this task is to screen to green some moderate degradation findings against inter-compartment fire barrier elements (fire confinement category findings). Note that Low degradations will screen to green in Task 1.3.1, and High degradations are always passed on to Step 1.4 for additional analysis.

In general, the likelihood of a fire spreading from one fire area to another is considered low for nuclear power plants in the U.S. given the multiple layers of defense in depth. The analysis of multi-compartment or room-to-room fire scenarios remains an area of technical challenge and high uncertainty for fire risk. The established screening criteria consider whether or not there are sufficient levels of defense in depth remaining that would render the inter-compartment fire scenarios of low risk even given the degraded barrier conditions.

### 5.1.4 Step 1.4 - Initial Quantitative Screening Check

The screening check in Step 1.4 considers only the duration factor (DF) and the fire area fire frequency ($F_{area}$). In the context of the three-term risk quantification framework (see Section 4.2.2) this screening step gives no credit to fire suppression nor to post-fire safe shutdown. In mathematical terms, the probability of non-suppression (PNS) and the CCDP are, in effect, both set to 1.0 in this step. All three of the fire PRA risk quantification terms will be refined in Phase 2, although DF remains constant at the value set in Step 1.4. DF <u>is</u> credited in all subsequent quantification calculations.

## 5.2 Phase 2 Analysis Supporting Information

### 5.2.1 Step 2.1: Independent SSD Path First Screening Assessment

A key aspect of fire PRA analysis approaches is to estimate the conditional probability (or likelihood) that fire-induced damage to plant components/cables will lead to core damage (CCDP). Said another way, the PRA estimates the probability that given fire-induced damage, post-fire safe shutdown efforts will fail to achieve safe and stable hot shutdown conditions.

The assessment of CCDP is done at two levels: Steps 2.1 and 2.5 represents the first level of analysis; Step 2.8 represents the second level of analysis. In the first level of analysis, only the designated post-fire SSD path is credited. In the second level of analysis, all available means for achieving SSD are credited.

Step 2.1 involves the identification and assessment of the post-fire SSD path for the fire areas examined during an inspection. If the SSD path is independent of any FDS fire scenarios that might be developed as a part of the finding assessment, then it will be credited at a nominal level in Steps 2.1 through 2.4. If the SSD path might be damaged given at least one possible FDS fire scenarios that could be developed in subsequent steps, then credit for the SSD path will be deferred until Step 2.5 when specific fire damage scenarios have been defined. Credit for the SSD path is re-considered on a scenario specific basis in Step 2.5.

The post-fire SSD path is documented in the licensee's fire protection program documentation for each fire area in the plant. The initial identification tasks (Tasks 2.1.1 and 2.1.2) can be completed based entirely on plant documentation.

Once the areas to be examined during the inspection have been identified, the following licensee documents should be requested and reviewed to support this task including:

- The licensee's fire hazards analysis for the fire areas to be evaluated.
- The post-fire safe shutdown analysis for the fire areas to be evaluated.
- The licensee's lists of required and associated circuits.
- Post-fire operating procedures applicable to the fire areas to be assessed.
- Documentation for any USNRC approved deviations or exemptions relevant to the fire areas to be assessed.

#### 5.2.1.1 Task 2.1.1: Identify the Designated Post-Fire SSD Path

Fire protection regulations require that licensees identify, analyze, and protect a designated post-fire safe shutdown path that will remain free of fire damage given a fire impacting any single fire area in the plant. In Task 2.1.1, the analyst is asked to identify this designated SSD path. The task also involves gathering basic information to characterize this SSD path.

The SSD path should be documented in the licensees post-fire SSD analysis. The designated post-fire SSD path may vary by plant location, and should be identified for each fire area to be inspected.

As a part of the SSD path identification effort, the corresponding Appendix R Section III.G.2 compliance strategy should also be determined. Section III.G.2 requires the separation and protection of the SSD capability. If an exemption or exception to III.G.2 has been granted by the USNRC for the fire area of interest, the exemption should also be carefully reviewed so that the separation strategy is clearly understood prior to entry into the fire area.

The analyst should also obtain and review the corresponding procedures for execution of post-fire SSD. Particular note should be taken of any credited human actions. The location where these actions take place is important to the analysis, especially if the process includes any human actions that require entry into, or passage through, the fire area under analysis.

Finally, the functions and systems that are required to support the SSD path should be identified. The analyst should also review the corresponding circuit analysis results for the designated SSD path. This review may include an assessment of the completeness of the SSD required and associated circuit component lists. Again, this step may be completed prior to entry onto the plant site for the inspection. Note that findings against the Post-Fire SSD program may arise from these reviews.

#### 5.2.1.2 Task 2.1.2: Assess the Unavailability of the Identified SSD Path

In task 2.1.2, a total unavailability factor is assigned to the post-fire SSD path. The value used is either 1.0 (no credit - assigned when the SSD path fails to meet the independence criteria), 0.1, or 0.01. The unavailability factors are based on the characteristics of the SSD path. The assessment criteria are described in a table in Appendix F. In general terms, the unavailability factor is based on the failure probability for the weakest link in the SSD path, including manual actions.

#### 5.2.1.3 Task 2.1.3: Assess the Independence of the Identified SSD Path

The intent of Task 2.1.3 is to determine if the designated SSD path is independent of <u>all</u> fire damage scenarios that might be developed in later steps of the analysis. If the SSD path might be damaged in one or more fire scenarios, then crediting the SSD path at this early stage of analysis could lead to false-negative findings.

It is, in fact, likely that the SSD path could be credited in some fire scenarios, even if it cannot be credited in all possible scenarios. However, at this stage of analysis, specific fire damage scenarios have not been defined. This does not take place until Step 2.4 has been completed Hence, a conservative assessment of SSD path independence is necessary. Credit for the SSD path is reassessed in Step 2.5 once the specific fire damage scenarios have been defined.

#### 5.2.1.4 Task 2.1.4: Finding Screening Check

The previous screening check (Step 1.4) only considered the duration factor and the room fire frequency. As discussion in Section 5.1.4, Step 1.4 inherently assumes a CCDP value of 1.0 for all fires. Having completed Task 2.1.3, a first level estimate of the fire-induced CCDP has been calculated based on the potential to credit the post-fire SSD path. This value is now substituted into the risk quantification equation for the implied 1.0 failure probability value of Step 1.4.

If the SSD path does meet the independence criteria, then a revised CDF change estimate is calculated. The duration factor (DF) and fire area fire frequency ($F_{area}$) as estimated in Step 1.4 are retained.

As a final note, the screening CDF formula used in Step 2.1 still gives no credit to fire suppression prior to critical damage. As a result, the implied value for PNS remains at 1.0.

## 5.2.2 Step 2.2: FDS Determination and FDS3 Screening

### 5.2.2.1 Task 2.2.1: Initial FDS Assignment

The initial assignment of FDS scenarios is intended to focus the analysis on those fire scenarios that may change as a result of a finding.

> Example: If the finding is a degraded fire barrier element separating two fire areas (category: fire confinement) then only fire scenarios leading to the spread of fire between these to fire areas are relevant to the risk change calculation. Any fire scenario that impacts only one fire area or the other will not change as a result of the observed fire barrier degradation.

The initial FDS assignment is broadly inclusive of potential fire scenarios.

### 5.2.2.2 Task 2.2.2: Screening Assessment for FDS3 Scenarios

**Screening Criteria**

In general, fire barriers that separate fire areas are expected to display high reliability so long as they are not degraded. Fire PRAs assume that fire barrier elements are both intact and effective. As a result, fire PRAs often find that most potential inter-compartment fire scenarios are not significant contributors to fire risk. For an inter-compartment fire scenario to be a visible risk contributor, all of the following factors will likely apply:

- The exposed fire area must contain risk-important component/cable damage targets that are unique from the components/cables that are located in the exposing fire area. This could include either post-fire safe shutdown components, or other plant components whose failure would create a demand for safe shutdown (e.g., a plant trip). However, if the damage targets in the exposed fire area impact the same functions as do the damage targets in the exposing fire area (i.e., they are not unique), no risk increase is expected due to fire spread to the exposed fire area.

- It must be plausible that an unsuppressed fire in the exposing fire area could threaten the integrity of the inter-compartment fire barrier. This generally will require a high-hazard fire source (e.g., a large supply of flammable or combustible liquid), a fire that could spread along combustible materials passing through the barrier (e.g., cables), or a fire that could cause direct flame impingement on the fire barrier itself (a severe fire directly under of adjacent to the barrier). In most situations, the fire must also be sustained for a period exceeding the fire barrier's fire endurance rating.

- Fixed automatic fire suppression systems must either be absent from both the exposing and exposed fire area, or if present must fail to suppress the fire in a timely manner.

- The damage targets in the exposed fire area must be damaged by the fire or fire effects (heat, smoke) spreading from the exposing fire area. This generally means that the targets must be relatively close to the fire barrier <u>and</u> exposed. If target damage requires extensive fire spread in the exposed fire area, or if the damage targets in the exposed fire area have passive fire barrier protection (such as a raceway fire wrap), damage becomes far less likely.

The FDS3 screening criteria are designed to identify exceptions to at least one of these conditions. If an exception is identified, the FDS3 scenarios are screened out from further consideration.

<u>Additional Discussion of FDS3 Scenarios</u>

Given the screening criteria applied in Tasks 1.3.2 and in 2.2.2, FDS3 scenarios will be retained only under a limited set of configurations. Hence, the analysis of the FDS3 scenarios becomes relatively simple because the analysis procedure is tailored to suit each of the specific conditions under which an FDS3 scenario might have been retained. The conditions under which FDS3 fire scenarios might need to be analyzed are summarized as follows:

- If the finding is not related to fire confinement, FDS3 scenarios are only retained if:
    - There are unique targets in the exposed fire area that are not provided with passive fire barrier protection, and are located relatively near the boundary between the two fire areas,
    - There is effectively no functional fixed automatic fire suppression capability in either fire area so that only manual fire suppression will be credited,
    - There are one or more fire scenarios in the exposing fire area that could challenge the fire barrier, and
    - The rating of the fire barrier is less than two hours.

- If the finding is moderate degradation of the fire area fire barrier:
    - There are unique targets in the exposed fire area that are not provided with passive fire barrier protection, and are located relatively near the boundary between the two fire areas,
    - There is effectively no functional fixed automatic fire suppression capability in the exposing fire area so only manual fire suppression will be credited for that fire area,
    - There are one or more fire scenarios in the exposing fire area that could challenge the fire barrier, and
    - The rating of the fire barrier is less than two hours.

- If the finding is a high degradation of the fire area fire barrier, that barrier will be given no credit as confining the fire or fire effects.

### 5.2.3 Step 2.3: Fire Ignition Source Scenario Identification, Characterization and Screening

#### 5.2.3.1 Task 2.3.1: Identify and Count Fire Ignition Sources

The identification and counting of fire ignition sources is intended to include only those fire scenarios relevant to the calculation of risk change. That is, if the risk contribution for a fire scenario is the same with or without the observed degradation, then the corresponding fire ignition source should not be counted in this step. Several specific cases where the scope of the fire ignition source counting exercise is sharply limited are discussed in Appendix F. Below are additional illustrative examples:

- Example 1: The finding being evaluated is a partial-coverage sprinkler system installed where a full coverage system is required. As installed, the system provides adequate fire protection for those fire sources within the coverage zone, but not all of the fire sources in the fire area are within this coverage zone. Extending the coverage zone to the full fire area would not alter the risk contribution for fire sources already provided with adequate fire protection (i.e., those fire ignition sources within the existing coverage zone). Hence, the SDP Phase 2 analysis of risk change should focus only on those fire sources outside the system's coverage zone.

- Example 2: The finding being evaluated involves a violation of the combustible controls program. In this case, only transient fuel fires are relevant, and fixed fire ignition sources need not be evaluated. (A transient fire may still spread to fixed combustibles, but the only fire ignition source that needs to be considered is a transient fire.)

- Example 3: The finding being evaluated involves a degraded raceway fire barrier - a small un-patched hole was left in the barrier after maintenance work. In this case, the SDP Phase 2 analysis only needs to consider those fire ignition sources that have the potential to threaten the cables within the degraded fire barrier. Because the hole is highly localized, a fire that might threaten the protected cables would generally need to be directly below the point of degradation. In this case, the Phase 2 analysis would focus primarily on growth and damage scenarios involving those fire ignition sources located directly below the point of degradation. A bounding assessment of the potential hot gas layer effects for other fire ignition sources in the fire area would also be needed.

#### 5.2.3.2 Task 2.3.2: Characterize Fire Ignition Sources

Characterization of a fire ignition source means that the initial fire intensity (before fire spread) is set, and a specific location is assigned to the fire. For purposes of characterization, fire ignition sources are identified as either simple or non-simple.

## Simple Fire Ignition Sources

Most fixed fire ignition sources are characterized using pre-defined fire characteristics. These are referred to as the simple fire ignition sources. The fire intensity values are set using pre-defined values that are provided in a corresponding table in Appendix F (see Task 2.3.2).

## Non-Simple Fire Ignition Sources

The non-simple fire sources involve either more complex fire characteristics (e.g., arcing faults), or sources that cannot be pre-defined for all cases (e.g., liquid fuel spills). These ‘non-simple’ fire ignition sources include the following:

- Self-ignited cable fires,
- Energetic arcing electrical faults leading to fire,
- Transient fuel fires when the as-found conditions exceed the nominal fire intensity values,
- Hot work fires,
- Oil or other liquid fuel spill fires
- Severe fires involving the main turbine generator set, and
- Hydrogen fires.

Specific guidance is provided for these non simple fire sources in Attachment 5 to Appendix F. In many cases, the non-simple fire ignition sources are mapped to one of the fire intensity bins established for the simple fire sources. However, the non-simple fire cases will require that additional fire behaviors and characteristics be considered beyond setting a fire intensity (e.g., selecting fire location for a transient or hot work fire, or dealing with the initial energy release in an arcing fault).

The available guidance should be sufficient to treat most of the non-simple fire sources in most circumstances. If difficulties arise in a particular situation, additional guidance from either Regional or Headquarters Fire Protection Staff should be sought.

## Treating Fire Intensity/Severity

In most cases, each fire ignition source is assigned two potential fire intensity values. In Step 2.4, some fire ignition sources may screen out in whole (i.e., given either intensity value) or in part (i.e., given the lower value but not the higher intensity value). It is through this treatment of two fire intensity values for each fire ignition source that the concepts of fire severity are included in the analysis.

The expected and high confidence fire intensity values are associated with a “split fraction” as follows:

- The lower fire intensity is assumed to represent 90% of fires involving that fire ignition source. This is shown in the corresponding table in Appendix F as the 75th percentile fire intensity value.

- The higher fire intensity is assumed to represent the remaining 10% of fires. This is shown in the corresponding table in Appendix F as the 98th percentile fire intensity value.

This split fraction (see definition in Section 3.3) ultimately leads to a severity factor applied to each fire scenario. The severity factor is specific to each scenario because it depends on the screening results as follows:

- If the “anticipated” value leads to fire spread or damage, then clearly the higher intensity fire will also lead to spread or damage. In effect, all fires are assumed to be potentially damaging, and the effective severity factor is 1.0 (0.9 for the “anticipated” fire case plus 0.1 for the “high confidence” fire case).
- If only the high confidence fire can lead to fire spread or damage, then this will be reflected through a severity factor of 0.1.
- If neither the anticipated or high confidence value leads to fire spread or damage, then the fire source is screened out from further consideration.

### Grouping of Fire Ignition Sources:

In some applications it is both more efficient and appropriate to group fire ignition sources. The most common example is electrical panels. It is quite common to encounter a “bank” of like electrical panels. In such a panel bank, each individual panel is essentially identical to its neighbors and will be assigned the same fire characteristics. In such cases, fires involving each individual panel may be represented by one (or more) fire ignition source scenario(s) that conservatively bound(s) the conditions of the entire panel bank. That is, fires involving all members of the group are treated using one (or more) representative bounding case(s).

A group of like fire ignition sources may be treated, in effect, as a single fire ignition source scenario in subsequent analyses. Grouping is appropriate when all of the following criterial are met:

- All of the individual fire ignition sources are of the same type and hence have the same fire intensity characteristics (e.g., a row of breaker panels).
- All of the individual fire ignition sources have a similar proximity to the nearest secondary combustible fuels and/or fire damage targets (e.g., a stack of cable trays running directly above a row of electrical panels). This means that a fire involving any one individual source will behave similarly to the other individual sources in the group with regard to fire growth, spread, and damage.
- Each of the individual fire ignition sources will represent a roughly equivalent challenge to fire detection and suppression given that a fire does occur (e.g., none of the sources is located in an especially challenging location, or in a location with different levels of fire detection and/or suppression coverage, in comparison to other sources).

Grouping of ignition sources may still be appropriate even given some variation in the features noted in the above criteria. It is appropriate to group individual ignition sources if the group can be conservatively bounded by one or more representative cases. Again, judgement is required in making such decisions.

### Assigning a Location to Fire Ignition Sources:

Fixed fire ignition sources are assigned to their actual physical location:

- The fire location for a fixed fire ignition sources is the physical center of the fire ignition source itself, unless this choice is in obvious conflict with the likely location of a fire involving the source. The width of the fire ignition source (for use in screening with the ball and column diagrams) is based on the source's physical footprint.

In other cases, the choice of fire ignition source location is more complex. For example, choosing one or more representative locations (i.e., one or more representative fire ignition source scenarios) to represent a grouped set of ignition sources requires the application of judgement. Examples of these and other similar cases include:

- Choosing one or more representative locations for a bank of electrical panels of the same general type
- Choosing the location for a transient fuel fire
- Choosing the location for a self-ignited cable fire
- Choosing the location for a transient oil spill fire

The assignment of source location will drive aspects of the fire ignition source scenario screening process (Task 2.3.4) and the fire damage time analysis for unscreened fire ignition source scenarios (Step 2.6).

For a grouped fire ignition source set, and for non-fixed fire ignition sources (transients, hot work, liquid fuel spills), the location chosen should conservatively bound the potential for fire spread and damage. This often means choosing the specific ignition source or location that is nearest secondary combustibles, or is nearest a thermal damage target. For radiant heat exposure, nearest means line of site. For plume exposure nearest means the first target directly above the source (directly above the source's physical "footprint").

> Example 1: A fire area contains multiple fire ignition sources of a similar type; in this example, two rows of breaker panels located on opposite sides of the room. Proximity to secondary combustibles (e.g., overhead cables) and fire protection features and coverage are all found to be similar regardless of which individual panel is considered. Cable locations are not well characterized (e.g., certain cables are known (or assumed) to be in the fire area but their specific locations within the area are not known). A single bounding location is used to represent all of the individual breaker panels and the fire is located within the individual electrical panel that is closest to secondary combustibles and/or damage targets (see Step 2.2.3).
>
> Example 2: The physical situation is similar to Example 1, but in this case there is detailed information on component and cable locations within the fire area. Consistent with a FDS1 type scenario, fires involving one row of the breaker panels may damage a train A function, while fires involving the second row of breaker panels may damage a Train B function. Consistent with FDS2, fires involving any panel might damage both the Train A and B functions. In this case, at least three fire scenarios are developed, one representing each row of breaker panels for FDS1, and a third representing any panel fire leading to FDS2 level damage. Each scenarios requires that a representative location be identified.

In the case of transients, the fire is always located on the floor, unless specific conditions observed during an inspection suggest otherwise. The exact location of the fire may eventually prove critical to the fire spread and damage potential if, for example, there is a cable pinch point where multiple target cables cross.

- For the purposes of this screening task, it is only necessary to determine whether or not a transient fire in some plausible location might spread or cause damage.

That is, if all combustible materials or targets are located well above the floor, then any floor level transient fire may not cause damage. In this case, transients screen out. However, if there is any location in the fire area where combustible materials or damage targets are low enough to be within the transient fire's damage zone, then the transients are retained. The analyst may use judgement to determine if a transient existing in such a location is plausible. If the identified location is not plausible, then the transients could still be screened out.

### 5.2.3.3 Task 2.3.3: Identify Nearest Ignition and Damage Targets

No supplemental guidance for this task is currently provided.

### 5.2.3.4 Task 2.3.4: Screen Fire Ignition Sources

Zone of influence charts (also called the "ball and column" chart) have been pre-calculated for the five fire intensity values specified for simple fire sources using the fire modeling correlations described below. If recalculation for a specific fire intensity is required, the correlations can be re-applied to estimate the proper stand-off distances.

If the fire characteristics do not conform to those established for the 'simple' fire ignition source types (e.g., oil fires, revision to the transient fuel fire, etc.) it may be necessary to re-calculate the ball and column diagrams for a specific fire intensity value. It is recommended that additional guidance be sought from either the Regional or Headquarters staff if re-calculation is necessary.

A hot gas layer temperature analysis is also performed to ensure that general heating of a room by a fire ignition source, in and of itself, cannot lead to component damage. Few fire sources will be of sufficient intensity, in and of themselves, to cause widespread damage in a room. Exceptions will be encountered given either a relatively small room and/or particularly challenging fire sources (e.g., oil-filled transformers or the turbine generator set). A correlation for hot gas layer temperature prediction is provided in the Fire Dynamics Tools Quantitative Fire Hazards Analysis for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program, NUREG-1805.

#### Plume temperature analysis correlation

The plume temperature correlation used in the SDP is described in detail in Chapter 9 of NUREG-1805. The following spreadsheet from the associated CD is used to calculate centerline temperature of a buoyant fire plume:

- Plume_Temperature_Calculations.xls

The plume calculations used in the SDP assume a convective heat release rate fraction of 0.7. This value is appropriate for most solid fuel fires.

The plume correlation is dependent on the fire location, and in particular, must be adjusted for fires located adjacent to a wall or corner as follows:

- For fires in an open area away from walls or corners the nominal fire intensity/HRR is used in the plume temperature calculation directly.

- For a fire located directly next to a wall, the nominal fire intensity/HRR is multiplied by two in the plume temperature calculation.
- For a fire located directly next to a corner, the nominal fire intensity/HRR is multiplied by four in the plume temperature calculation.

For the purposes of the phase 2 analysis, a fire is considered to be “near” a wall if its outer edge is within two feet of a wall, or is “near” a corner if within two feet of each of the two walls making up the corner.

**Radiant heating correlation**

The correlation for estimating fire radiant heating effects is described in detail in Chapter 5 of NUREG-1805. The Phase 2 SDP uses the Wind Free Condition correlation and assumes a point source:

- Heat_Flux_Calculations_Wind_Free.xls (Click on Point Source Tab) or
- Heat_Flux_Calculations_Wind_Free_Given_HRR.xls

The wind-free condition is appropriate for all indoor fires. For outdoor fires, wind can substantially increase heat flux exposure levels for a target down-wind of the fire. If the application involves an outdoor fire scenario where wind may be a factor, it is recommended that additional guidance be sought from either the Regional or Headquarters fire protection staff.

The SDP radiant heating calculations assume a radiant heat release rate fraction of 0.3. This value is appropriate for most solid fuel fires.

**Hot gas layer temperature analysis correlation**

The correlation to be applied in the analysis of hot gas layer temperature response is documented in Chapter 2 of NUREG-1805. The following spreadsheets from the associated CD that may be applied are:

- Fire with Natural Ventilation: Temperature_NV.xls
- Fire with Forced Ventilation: Temperature_FV.xls

In most cases, the thermally thick correlation will apply. Additional guidance is provided within the electronic spreadsheet.

Using the spreadsheet, the predicted hot gas layer temperature will rise with increasing time. Screening should consider the temperature at 30 minutes. By this time, conditions will be approaching steady state, and the likelihood of fire suppression is relatively high for most scenarios. This is taken as a representative estimate of the hot gas layer temperature likely to be observed during an extended fire involving the fire ignition source.

#### 5.2.3.5 Task 2.3.5: Screening Check

No specific guidance for this task is currently provided.

### 5.2.4 Step 2.4: Fire Frequency Analysis

#### 5.2.4.1 Task 2.4.1: Nominal Fire Frequency Estimation

An electronic worksheet is available for calculating fire frequencies based on the fire ignition source counting results. While hand calculations can be performed to duplicate the spreadsheet functions, It is strongly recommended that this worksheet be exercised in its electronic format.

For most fire ignition sources, the fire frequency is provided on a per component basis. However, for non-qualified cables, transients, and hot work a relative ranking of fire areas as low, medium, or high is required. The guidance for assigning these rankings is provided below.

## Cable Fuel Load Assessment

Cables can be found practically at every part of a nuclear power plant and are the primary focus of a fire risk analysis. For the purposes of fire frequency calculation, each area is ranked according to the quantity of non-qualified cables located in the area. The following three levels are defined:

- Low is used for areas that have a few cable trays that are generally less than half full. For example, this level may be used for a fire area where there are four vertical cables attached to one wall and each cable tray carries no more than 10 cables. Areas that will typically be assigned a low cable loading include pump rooms.

- Medium is used for areas that have several cable trays that are generally more than half full. For example, this level may be used for a fire area where there are four vertical cable trays attached to one wall and all four trays carry large number of cables. Typical rooms that will likely be assigned a medium cable load are areas such as a switchgear room.

- High is used for areas that have a large concentration of cable trays (e.g., the cable spreading room, cable vaults, cable tunnels, other areas used for general routing of cables).

For those plant areas where the only cables that are not enclosed are small sections of cables (i.e., a few feet long) that provide the power to the electrical equipment in the plant area, it may be assumed that cables have no contribution to the fire frequency of the area. For example, the room where a residual heat removal pump is located may contain no cables except for a 3 feet length of a power cable between the pump motor and the floor.

Most cable trays have ladder-type construction and are therefore open on both sides. Some trays may have a solid bottom or a sheet metal cover on top or both (i.e., solid bottom and sheet metal cover). In the latter case, the trays are not hermetically sealed. Therefore, a fire inside the cable tray may impact other adjacent cables. The analyst may elect to include such fully enclosed cable trays in the fire frequency calculation. However, some cable trays may be fully wrapped or boxed in a fire retardant material and construction. For such cases, the analyst may ignore the influence of those cable trays on the fire frequency.

## Assignment of a Relative Transient Fire Likelihood Rating

Criteria for assigning a relative transient fire likelihood rating focus on the following factors:

- Extent of general plant personnel traffic passing through an area - higher traffic tends to be indicative of a higher likelihood rating.
  - Exception: a roving fire watch or routine security patrols passing through an area will not be taken as indicative of a higher transient fire likelihood.
- Normal occupancy during at-power operations - higher occupancy levels and rates is taken as indicative of a higher likelihood rating.

  - Exception: continuous occupancy of the main control room will not be taken as indicative of a higher transient fire likelihood because extraordinary vigilance is expected for this fire area.
  - Exception: a continuous fire watch in a fire area will not be taken as indicative of a higher transient fire likelihood.
- The frequency of maintenance activities undertaken in the area - maintenance activities may introduce transient fuels and/or ignition sources and increases the likelihood rating.
- Storage practices for transient materials - areas will be assigned a higher likelihood rating if, by plant practice, they are use to store transient materials such as trash, maintenance materials, flammable liquids, packing materials, etc., or to stage materials in anticipation of an outage or other maintenance activity. Storage may be occasional and temporary (generally indicative of a medium rating) or continuous (generally indicative of a high rating).
- Restrictions imposed by administrative controls - less restrictive combustible materials and/or activity-related administrative controls are taken as indicative of a higher transient fire likelihood.

Given these factors, the relative transient fire likelihood rating is assigned as follows:

- Low - applies to fire areas that are normally closed for any type of traffic, are not visited often (no more than once per week), are not occupied during normal plant operations, and where maintenance activities would generally be disallowed during normal at-power plant operations. Furthermore, the fire area is subject to administrative controls that disallow leaving transient fuel sources unattended in the area (e.g.: no storage of transient materials is allowed; maintenance materials may not be left unattended). Examples:
  - Pipe tunnels that contain nothing but pipes, that are accessible but are not generally visited by plant personnel can be regarded as "low" transient combustible level areas.
  - Low can also be assigned to a cable spreading room with cables only assuming that access to the room is strictly controlled and administrative controls are in place as described above. Low may also apply to other similar areas such as cable vault and tunnel areas.
  - Low will generally apply to main control rooms.
  - Low will generally apply to the containment structure.
- Medium - used for areas that either have occasional to frequent foot traffic (no more than once per shift and the area is not a regular access/transit pathway) or are occasionally, but not continuously, occupied during normal plant operations. Modest storage of transients may be allowed. Medium would also apply to a fire area where maintenance activities are allowed during at-power plant operation, but these activities are subject to strict administrative controls such as activity-specific permit and/or combustible controls program, <u>and</u> are a relatively rare occurrence (e.g., not more than once per operating year). Examples:
  - A fire area that is not normally locked but is not used as a passage to other parts of the plant may be regarded as "medium" transient combustible level area. A DC Power distribution panel room at the end of a corridor can be regarded as such a room.
  - The room is not locked, but only a few plant personnel may enter the room once or twice per shift.
  - Normal plant operations may, infrequently, involve plant personnel occupying the area for up to several hours.
  - Medium can also be assigned to a cable spreading room that contains components other than cables.

  - Items may be stored in the room on a temporary basis, for example, to conduct repair work on equipment nearby. Such storage should be infrequent rather than routine.
  - Repair/maintenance work that may result in introduction of transient fuels or ignition sources (e.g., pump oil change-out activities or routine maintenance on motor bearings) is relatively common (e.g., two or more times per year) while the plant is at power.
  - Most pump rooms and areas within the Reactor Building or Auxiliary Building would likely fall into this category (case specific exceptions are possible).
  - Most switchgear rooms would typically be ranked medium.
  - Batteries rooms would generally be ranked medium depending on the frequency of battery maintenance activities.

- High - used for areas that have heavy foot traffic, are frequently or continuously occupied, where transient items are typically stored, where plant refuse is routinely gathered in substantive quantities for eventual collection, where ignition sources are often brought into the area, and/or where maintenance activities during normal operation are relatively common. Examples:
  - Those parts of a power plant with characteristics similar to an office can be regarded as "high". In such an area, personnel are present for a large fraction of the time. Paper based items (i.e., letters, reports, computer printouts, etc.) are brought in and maintained in the area. Small electrical tools or appliances (e.g., hot plates, portable heaters, microwave ovens, coffee pots) may be used in the area once every few weeks or more frequently. Health physics access control areas, break room areas, any area used for food preparation, and security stations are examples. Note that this category is not intended to apply to the main control room itself, but may apply to kitchen or security areas associated with or adjacent to the main control room.
  - Any area where smoking is not prohibited or where there is evidence of smoking.
  - An area with an open trash can that routinely contains substantive quantities of general trash.
  - An area where rad protection gear (e.g., jump suits, gloves, boots, etc.) are stored or collected including turn-out/change-out areas.
  - Any area used for the storage (permanent or temporary) of flammable or combustible fluids.
  - A staging area where items are repaired or constructed before they are taken to other parts of the plant for installation.
  - An area where materials are pre-staged in anticipation of a planned outage.
  - A truck loading and unloading bay.
  - An area where hot work is relatively common during at-power plant operations.
  - For most plants, areas within the turbine building, service building, diesel generator rooms, intake structure, and rad waste areas would typically be categorized as high for transient combustible fire potential.

## <u>Assigning a Relative Likelihood Rating for Hot Work Fires</u>

Each fire area is rated as either Low, Medium, or High for hot work activities, and a fire frequency assigned accordingly.

As a starting point, the same likelihood rating assigned to the fire area for transient fires is also used as the hot work fire likelihood rating. However, plant specific conditions may be considered if such information is readily available, and an alternate hot work likelihood rating may assigned as appropriate.

- Example: A fire area is rated as High for transient fires due to the storage of substantial quantities of maintenance materials. The fire area is therefore initially rated as High for hot work fires as well. However, plant personnel demonstrate that plant procedures preclude the conduct of hot work in this fire area (e.g., perhaps due to the storage configuration itself). In this case, the hot work likelihood category is re-assigned to Low to reflect the case-specific conditions.

The hot work fire likelihood ratings are representative of the following conditions:

- Low - fire areas where hot work is precluded during at-power plant operations.
- Medium - fire areas where hot work activities might be undertaken during at-power operation, but would only be expected to occur only rarely (e.g., on the order of once per operating year).
- High - fire areas where hot work activities are allowed and likely to occur during at-power operation (e.g., on the order of two or more times per operating year).

Note that the above rating categories presume that all hot work activities within the plant would be subject to administrative controls (e.g., hot work permit programs and fire watches) regardless of their location.

### 5.2.4.2 Task 2.4.2: Findings Quantified Based on Increase in Fire Frequency

#### High Degradation Findings against the combustible controls program

Recall that combustible control program findings are ranked as either high or low degradation. Low degradation findings screen to green in Phase 1. Hence, this step only applies to high degradation findings.

If the finding being evaluated involves a violation of the combustible controls program, then the fire frequency for transient fires may be increased to reflect an increased likelihood that improperly stored or inappropriate transient fuels might be ignited. Fire areas are ranked using a low/medium/high likelihood ranking scheme for transient fires as described in Task 2.4.1.

The increase in fire frequency for a given fire area is reflected by increasing the likelihood ranking by one level from what would normally be assigned. Thus, an area that would normally be ranked as low becomes medium, a medium area becomes high. For a fire area already ranked as high likelihood for transient fires, the base fire frequency is multiplied by 3.

#### High Degradation Findings Against a Hot Work Fire Watch

If the finding is associated with hot work permitting and/or hot work fire watch provisions of the fire protection program, then Task 2.4.2 will increase in the hot work fire frequency. Hot work findings are ranked as either high or low, and low degradation findings screen to green in Phase 1. Hence, this step only applied to high degradation hot work findings.

As with the transient fire case, fire areas are ranked as low/medium/high likelihood for hot work fires. A violation of hot work requirements in a fire area automatically results in a fire area being ranked as high likelihood for hot work fires.

However, the base fire frequency values for hot work fires already credit an effective hot work fire watch. A high degradation means that the fire suppression function of the fire watch is compromised. The fire event data show that at least 2 out of 3 hot work fires are suppressed promptly by the fire watch. This has been credited in the base fire frequency estimates. That is, the base fire frequency reflects only those fires where prompt suppression did not occur. If the fire watch is not functional for fire suppression purposes, then removal of this credit is appropriate.

For a high degradation of hot work administrative controls, the base hot work fire frequency for a high likelihood fire area is multiplied by a factor of 3.

#### 5.2.4.3 Task 2.4.3: Credit for Compensatory Measures that Reduce Fire Frequency

The base fire frequency estimates include at least a nominal fire frequency for hot work and transient fires in all fire areas. In Task 2.4.1, the fire area must be ranked at least as low and hence is assigned some fire frequency. Task 2.4.3 credits administrative controls which prevent the introduction of combustibles or performance of hot work in a fire area during normal plant operations or during the exposure time of the finding if the plant-specific conditions merit this adjustment. If hot work and/or transient fuels can be shown to never exist in the fire area, either during at power operations in general or during the exposure period associated with the finding, then no further development of the corresponding fire scenarios is required to complete the Phase 2 analysis.

The following criteria are used to credit measures which may reduce fire frequency are:

- The revised transient combustible fire frequency is set to zero, and transient fire scenarios are dropped from further analysis, if there is a combustible control system supported by frequent surveillance patrols (at least once per shift) that would preclude transients from a fire area. It is expected that a review of surveillance reports would be performed to identify any cases of improperly stored combustibles. If surveillance reports indicating improperly stored materials during the finding exposure period are found, then the transients are retained.
- The revised hot work fire frequency is set to zero if it can be shown that no hot work has been performed in the area during the exposure period associated with the finding. This could if hot work has been precluded under a compensatory measure, or if by normal practice hot work is explicitly prohibited during normal plant operations. It is expected that hot work permits would be reviewed to confirm that no hot work occurred.

#### 5.2.4.4 Task 2.4.4: Finding Screening Check

No specific guidance is currently provided for this task.

### 5.2.5 Task 2.5: Fire Scenario Definition and Independent SSD Path Second Screening Determination

At this stage of the analysis, it is necessary that each of the fire scenarios that will be analyzed in the subsequent analysis steps be clearly defined. Recall that a fire scenario (see Definition in Section 3.2) is a unique combination of the following elements:

- Fire ignition source scenario,
- A fire growth and damage scenario,
- A postulated plant damage state,

- A fire suppression scenario, and
- A plant safe shutdown response scenario.

In order to complete the analysis, each of these five aspects of each fire scenario to be analyzed must be clearly defined:

- With the completion of Task 2.3, fire ignition source scenarios have already been screened (the first element of a fire scenario).
- In Step 2.5, the next two elements of the specific fire scenarios will be defined; namely, fire growth and damage scenarios, and the corresponding plant damage state scenarios.
- The fire suppression scenario is addressed in Step 2.7.
- The SSD response scenario is addressed in Step 2.8.

Also recall that in Step 2.1 the post-fire designated SSD path was only credited if it was shown to be physically independent of both the fire area under analysis and the specific finding being evaluated. In Step 2.5 the independence of the designated SSD path is assessed in the context of the specific fire scenarios being evaluated, and credit for the SSD path may be applied on a somewhat more scenario-specific basis. That is, once the plant damage state scenarios have been clearly defined, the survival or loss of the designated post-fire safe shutdown path is no longer in question. The plant damage state will need to clearly define the systems and functions that are assumed to survive. Using this new information, a screening check is made.

In crediting the SSD path, the emphasis is placed on crediting the path for a given fire ignition source scenario. Recall that a given fire ignition source can give rise to multiple scenarios. At worst, one fire ignition source may lead to one FDS1, one FDS2, and one FDS3 scenario. For this ignition source, the worst-case damage state must be considered in crediting the SSD path; in this case, the FDS3 scenario. Hence, it is most likely that the SSD path will be credited when the potential damage from a given fire source is limited to FDS1 and/or FDS2 type scenarios.

### 5.2.5.1 Task 2.5.1: Identify Fire Growth and Damage Scenarios

Supplemental guidance supporting Task 2.5.1 has been included as Attachment 3 to Appendix F.

### 5.2.5.2 Task 2.5.2: Identify Fire Growth and Damage Scenarios for Transients, Hot Work, and Self-Ignited Cable Fires

Collectively, transients, hot work fires, and self-ignited cable fires are referred to as non-fixed fire sources because they are not tied to a specific plant location, but rather, may be postulated to occur in most any location in the plant. Fire scenarios involving the non-fixed fire ignition sources will only be risk important under particular circumstances. Hence, the recommended practice is to develop and analyze fire scenarios arising from these sources only in those circumstances where their contribution is likely risk-important. Under other circumstances, the risk associated with fixed fire ignition source is assumed to be dominant, and scenarios involving the non-fixed sources need not be developed.

In general, the non-fixed fire ignition sources will only be risk important if the fixed fire ignition sources hold little or no potential to damage the risk-important damage targets in a fire area. If the fixed fire ignition sources are found to hold the potential to damage the risk-important cable and component targets, then it is likely that those fixed fire ignition sources will dominate the final fire risk estimates. This is largely due to the relatively low likelihood for non-fixed in comparison to fixed fire ignition source, particularly as location partitioning factors are applied to reflect a critical location within a fire area where damage to risk important damage targets is plausible.

However, if there are unique targets in the fire area that will not be damaged given fires in the fixed sources, but that may be damaged in a scenario initiated by a non-fixed source, then the non-fixed fire ignition sources should be considered. In this context, the non-fixed fire ignition sources can be viewed as a “back pocket item”. The specific treatment of fire scenarios involving these sources may be held in reserve for risk characterization should the fixed fire sources in the room prove to be non-threatening to one or more of the damage targets of interest.

### 5.2.5.3 Task 2.5.3: Identify Plant Damage State Scenarios

In order to analyze the plant post-fire safe shutdown response, fire damage to components and cables must be translated to impacts on plant systems and functions. Task 2.5.2 involves this translation task. This can be a challenging task, especially when circuit failure modes and effects issues (e.g., spurious operation) or manual actions are involved.

The real output or results of task 2.5.2 that is carried forward is actually the inverse of the plant damage state. That is, the key output is a list of those systems and functions that will survive the fire. This problem is approached by defining what is lost, and crediting what remains. The surviving systems and functions will be credited in Step 2.8.

The SDP procedure follows general fire PRA practice in that systems and functions are assumed to be lost unless it can be verified that they will survive. In particular, cable routing information often excludes cables not associated with the Appendix R safe shutdown systems. Hence, it may be impractical to determine whether or not the cables associated with a system not on the Appendix R safe shutdown list are threatened in a given fire scenario. If it cannot be verified that the FDS excludes cables associated with a system, then that system is assumed to be damaged.

The guidance provided in Appendix F includes an extended discussion of this task. Several examples illustrate how plant damage state scenarios are defined. If additional guidance is required, it is recommended that the Regional or Headquarters staff be consulted. In particular, this task requires a working knowledge of plant safety systems, their interactions and dependencies, and may require knowledge of circuit analysis issues.

### 5.2.5.4 Task 2.5.4: Assess Scenario-Specific Independence of Post-Fire SSD Path

If the SSD path has not been credited in previous analysis steps, then it is appropriate to re-evaluate the independence of the SSD path in the context of the individual fire scenarios being developed.

The criteria applied to the assessment of scenario-specific SSD independence are based entirely on the postulated damage state for each fire scenario. If the designated post-fire SSD path is not damaged in the scenario (none of its cables or components are included in the fire damage target set), then the SSD path can be credited for that scenario.

Recall that in Step 2.1 the SSD path was only credited if it could be shown to be physically independent of both the fire area and the specific finding being evaluated. In Task 2.5.3, the independence of this SSD path is re-evaluated in the context of the fire ignition source scenarios and the corresponding plant damage state scenarios (as defined in Task 2.5.2).

Example 1: If a FDS1 fire scenario involves damage to only one train of plant safety equipment, and the designated SSD path relys on an undamaged redundant train of plant safety equipment, the survival of the SSD path can be credited for that FDS1 scenario even if the cables for the redundant train are also located in the impacted fire area.

Example 2: Given a similar physical arrangement to that of example 1, a FDS2 fire scenario might involve damage to both equipment trains. In this case, the SSD path might survive given an FDS1 scenario, but might fail given an FDS2 or FDS3 scenario.

#### 5.2.5.5 Task 2.5.5: Finding Screening Check

Recall that at this stage of the analysis, fire frequencies are available to characterize each unscreened fire ignition source scenario (Step 2.4). Furthermore, each fire ignition source can potentially lead to one or more FDS, one or more fire growth and damage scenarios (Tasks 2.5.1 and 2.5.2), and therefore to one or more plant damage state scenarios (Task 2.5.3). In Task 2.5.4, the designated post-fire SSD path independence assessment was based on each unique plant damage state scenario. The net result is that the applicability of the screening CCDP value is dependent first and foremost on the plant damage state, rather than the given fire ignition source.

For example, assume a case where a single fire ignition source (e.g., a pump) has been associated with one FDS1, one FDS2 and one FDS3 scenario. The critical piece of information that remains lacking at this stage is the likelihood that the pump fire might actually continue its development from FDS1 to FDS2, and ultimately to FDS3. Hence, in order to credit the SSD path for the pump as an ignition source, the SSD path must be independent of the worst-case plant damage state associated with the pump. In this case that would be the FDS3 scenario.

For this reason, the analyst only applies the screening CCDP value to a given fire ignition source scenarios if the SSD path was found independent of the worst-case credible FDS scenario arising from each fire ignition source scenario. This result will be further refined once the analyst has completed Steps 2.6 and 2.7 and has determined how likely it is that a fire will actually progress from FDS1 to FDS2 and potentially to FDS3.

Example: A particular fire ignition source is found capable of generating one FDS1 and one FDS2 fire scenario. Given the corresponding plant damage states, the SSD path was found to survive given the FDS1 scenario, but was compromised given the FDS2 scenario. The FDS2 scenario is limiting, and becomes the basis for the screening check in Task 2.5.5; hence, the SSD path is not credited for this fire ignition source.

NOTE: The results from Task 2.5.4 for each of the individual scenarios (i.e., both the FDS1 and FDS2 scenarios in the above example) will be used in the screening check for Step 2.7 below.

NOTE: If the designated SSD path met the independence criteria of Step 2.1, then it has already been credited for all fire scenarios; hence, there is no additional screening benefit to be gained. In this case, Task 2.5.4 need not be performed. The original SSD path failure probability is carried forward as a screening CCDP for all individual scenarios.

### 5.2.6 Step 2.6: Fire Growth and Damage Analysis

**General caution regarding complex fire growth scenarios**

The fire modeling tools provided to support the Phase 2 fire growth and damage time analysis are relatively simple correlation-based modeling approximations. These tools cannot handle all fire growth conditions accurately. Hence, an analysis that encounters complicated fire growth conditions is a potential candidate for a Phase 3 assessment.

**Treatment of components protected by a highly degraded raceway fire barrier**

If the finding being evaluated involves a highly degraded localized fire barrier system (e.g., a raceway fire barrier), then the FDS1 and/or FDS2 scenarios scenario may involve damage targets (components or cables) within the degraded barrier. In these cases, the damage targets are treated as fully exposed. The fire barrier is assumed to provide no protection against fire damage.

NOTE: Damage to components or cables protected by a fire barrier found to be moderately degraded is considered in the FDS2 fire scenarios. See Section 5.2.6.2 for further information.

**Treatment of cables in conduit**

Cables located in a metallic conduit are not considered to contribute to the spread of fire, but are considered as exposed damage targets. It is assumed that the conduit will not delay the onset of thermal damage.

**Cables with a fire retardant coating applied**

The Phase 2 analysis does not credit fire retardant coatings on cables. That is, in the Phase 2 analysis, it is assumed that coatings will not prevent the spread of fire nor delay the onset of thermal damage. If this assumption proves critical to the Phase 2 analysis results, the situation is a potential candidate for a Phase 3 analysis.

### 5.2.6.1 Task 2.6.1: Fire Growth and Damage Time Analysis - FDS1 Scenarios

The time to damage for FDS1 scenarios is based on the effects of direct radiant heating and/or heating in the fire plume. Fire spread to secondary combustibles may also be a concern.

Additional supporting guidance for completion of Task 2.6.1 is included as Attachment 7 to Appendix F. Limited discussion of the basic modeling correlations used to support this task are provided in the following.

**Plume heating**

For fire plume exposures, the plume temperature is estimated at the target location using the NRC Fire Dynamics Tools (NUREG-1805). The plume temperature correlation gives a single value result based on the height above the fire source and fire intensity (HRR). Another factor that must be input is the convective fraction of the heat release:

- For plume temperature calculations assume 70% of the heat is released convectively (convective fraction = 0.7).

Note that for certain specific physical configurations, the HRR utilized in the fire plume correlation must be adjusted. In particular, close proximity of the fire ignition source to a wall or corner amplifies the effects of the plume as follows:

- To adjust plume temperature for fire geometry - i.e., fires against a wall or in a corner:
    - For a fire in an open area (away from walls or corners) the nominal fire heat release rate (HRR) is used,
    - For the same fire next to a wall, multiply the nominal HRR by two,
    - For the same fire in a corner, multiply the nominal HRR by four.

Given an exposure temperature, the time to damage is estimated using pre-defined reference tables. These tables are presented in Section 6.2.6, and are also repeated in Appendix F itself.

**Radiant heating**

The approach for radiant heating is similar to that for plume heating. An exposure heat flux is calculated using the appropriate fire modeling correlation from the USNRC Fire Dynamics Tools. The damage time is estimated based on the intensity of the exposure. The analyst must establish the line of sight distance from the fire to the target. A second factor required is the fraction of the total fire heat output that is released as thermal radiation.

- For evaluating damage due to radiant heat, assume 30% of heat released by fire is radiant energy (radiant fraction = 0.3).

Once the exposure heat flux has been estimated, pre-defined reference tables provide estimates of the time to cable failure versus exposure heat flux. These tables are shown in Section 6.2.6, and are also presented in Appendix F itself.

#### 5.2.6.2 Task 2.6.2: Fire Growth and Damage Time Analysis - FDS2 Scenarios

Supplemental guidance required for completion of Task 2.6.2 has been included in Attachment 7 to Appendix F. If additional guidance is required, it is recommended that support be sought from the Regional or Headquarters fire protection staff.

#### 5.2.6.3 Task 2.6.3: Fire Growth and Damage Time Analysis - FDS3 Scenarios

Supplemental guidance required for completion of Task 2.6.3 has been included in Attachment 7 to Appendix F. If additional guidance is required, it is recommended that support be sought from the Regional or Headquarters fire protection staff.

### 5.2.7 Step 2.7: Fire Non-Suppression Probability Analysis

The analysis of fire suppression also involves the analysis of the fire detection response. Fire detection is important in the SDP context only because it triggers the manual fire brigade response. All of the manual fire fighting probability curves assume that fire detection has occurred. Hence, the total fire duration when following a manual suppression path is the sum of the detection time plus the manual suppression time. It is this total fire duration that is compared to the fire damage time to assess damage likelihood.

With regard to fire detection, the analysis approach credits the dominant path to fire detection only. That is, while there are multiple paths to achieving fire detection, only one path needs to succeed. In practice, only the path that leads to the shortest fire detection time is credited. If there is a continuous fire watch, the detection time is zero. In other cases, a fixed fire detection system, if installed, will be assumed to be the predominant means of detection. Failing these two features, roving fire watches and detection by general plant personnel are credited.

With regard to fire suppression, all fire areas are covered by the manual fire brigade, but many plant areas will also have fixed fire suppression systems. In general, if a fixed fire suppression system is in place and functional, it is presumed to be the first line of defense. If the fixed system fails on demand, then the fire brigade is credited as a back-up means of fire suppression. If there is no fixed suppression present, or if the fire suppression system is highly degraded, the fire brigade is credited as the primary means of fire suppression.

Supplemental guidance supporting the specific tasks under Step 2.7 is included as Attachment 8 to Appendix F.

### 5.2.8 Step 2.8: Analysis of Plant Safe Shutdown Response

All guidance required for the completion of Step 2.8 is provided in Appendix F. If additional guidance is needed, consult the Regional or Headquarters staff. Step 2.8 involves the analysis of post-fire safe shutdown. Hence, expertise in plant systems and PRA plant response modeling are needed.

### 5.2.9 Step 2.9: Final Quantification and Color Assignment

No supplemental guidance in support of Step 2.9 is currently provided.

# 6.0 BASIS

## 6.1 Phase 1 Analysis Basis

### 6.1.1 Step 1.1: Assignment of a Finding Category

The finding categories are assigned primarily as a tool for guiding aspects of the analysis. The finding categories map directly to the fire protection DID elements. Certain tasks in the analysis are only relevant to specific types of findings, and other tasks are skipped for specific types of findings.

### 6.1.2 Step 1.2: Assignment of a Degradation Rating

Degradation ratings are defined in a context explicitly consistent with the fire PRA approach consistent with the overall objective of the SDP as a risk-informed analysis tool. The generic definitions are explicitly tied to the level of credit that will be given to a degraded fire protection program element in the subsequent PRA-base analyses. All case specific degradation ratings have been established consistent with the generic definitions of High, Moderate, and Low Degradation as discussed in Section 4.3.2. Specific basis for the degradation ratings assigned to specific types of findings are discussed in the subsections that follow.

#### 6.1.2.1 Fire Prevention and Administrative Controls Programs

The fire prevention and administrative control program degradations focus on issues related to hot work fire watches and combustible materials controls.

Hot work fire watch degradations rated as high focus on those issues which might render hot work fire watches ineffective at promptly suppressing hot work fires. The available experience demonstrates that a hot work fire watch is an effective means of mitigating hot work fires. At least 2 out of 3 hot work fires in the fire event database (NSAC-178) were promptly suppressed through actions of the fire watch. Degradations to the hot work fire watch fire suppression capability will be taken as indicative of a high degradation and the fire frequency will be increased accordingly.

The items identified as low degradation are primarily related to the hot work fire watch function as a fire detection mechanism, or relate to documentation and training issues associated with the hot work activities.

In the case of transient fuels control programs, a similar approach is taken. That is, the focus is placed on degradations that could lead to a substantial increase in fire frequencies. In this case there are no industry-wide standards against which to weigh a given situation. Each licensee sets its own requirements for administrative controls. Hence, the licensee’s performance must be weighed against their requirements.

#### 6.1.1.2 Fixed Fire Detection & Suppression Degradation

The degradation ratings for fire detection and suppression systems are intended to reflect the general functionality of the system in light of the noted degradation. Many minor deviations from the code of record are possible that would not substantially degrade the system performance. These types of degradations are assigned to the low category.

The moderate degradation category reflects more significant degradations that could either delay the systems actuation, render the system less effective in fighting one or more fire ignition sources in the fire area, or adversely impact system reliability. However, the expectation is that even given the moderate degradation, the system should function with some substantial degree of reliability and effectiveness.

The high degradation category is reserved for those degradations that render the system ineffective. Consistent with the generic definition of degradation ratings, high implies that the system will not be credited in the risk quantification.

#### 6.1.2.3 Fire Barrier Degradation

The fire barrier degradation ratings are tied to the expected performance time of the degraded barrier as compared to the nominal or rated fire endurance performance time. Indeed this is how the degradations are reflected in risk quantification.

The various degradation categories were developed to reflect 35%, 65% and 100% degradation of a barrier's performance. Hence a 3 hour barrier could be assumed to have the effectiveness of either a 2 hour or 1 hour, or may be assumed to be non-functional. The examples are taken from the experience of field inspectors, NRC headquarters staff, research, and the plants themselves.

#### 6.1.2.4 Safe Shutdown Findings

The SSD finding degradation levels are intended to align with the generic definitions. However, in this context the interpretation focuses somewhat more sharply on ‘reliability’ issues. For example, a fire suppression system can be compared to a code of record and deviations can be readily identified. SSD provisions rarely have such a definitive yardstick against which they can be measured. SSD findings are more likely to hinge on qualitative factors. For example, issues likely to arise could include the timing of manual actions, the adequacy of post-fire safe shutdown procedures, the reliability of a proposed safe shutdown path, unavailability of required functions, likelihood of spurious equipment operations, etc. The criteria as written reflect the qualitative nature of these findings. It is expected that considerable judgment on the part of the practitioner will be required to properly assess SSD findings.

### 6.1.3 Step 1.3: Initial Qualitative Screening Check

#### 6.1.3.1 Task 1.3.1: Qualitative Screening for All Finding Categories

The first question in the qualitative screening check asks if a Low degradation rating was assigned to the finding. By design, the definition of Low degradation implies that the performance and/or reliability of the fire protection feature is not substantially impacted by the noted degradation finding. Hence, the feature would be given essentially full credit in the PRA-based analysis. In this case, the risk change is essentially zero, and the finding should be screened to Green. Question 1 accomplishes this action.

The second question screens findings to green that impact only the ability of the plant to achieve cold shutdown. This is consistent with the common risk analysis practice of defining hot shutdown as success. That is, both fire PRAs and Internal Events PRAs typically assume that achieving a safe and stable hot shutdown state constitutes success and the end stat for accident sequence analyses. Note that this screening step applies only to findings against 10CFR50 Appendix R, Section III.G.1.b. All other regulatory provisions are considered to involve, in part or in whole, measures provided for preservation and protection of the post-fire hot shutdown capability and will not be screened in this step (e.g., fire prevention, fire suppression, fire brigade, fire barriers, etc.).

#### 6.1.3.2 Task 1.3.2: Supplemental Screening for Fire Confinement Findings

The supplemental screening questions included in Task 1.3.2 are intended to identify cases where a finding against an inter-compartment fire barrier (i.e., a fire confinement finding) will have low risk significance. The screening questions are derived from common fire PRA practices as exercised in the IPEEE analyses. In particular, the questions are similar to, but somewhat more restrictive than, the screening criteria applied in the EPRI FIVE methodology Fire Compartment Interaction Analysis.

The screening criteria give credit to various fire protection features that past fire PRAs have shown will minimize the potential risk significance of the inter-compartment fire scenarios. Fire protection features credited are:

- Barriers with a minimum two hour fire endurance capacity
- Fixed automatic fire suppression systems that are functional
- A lack of unique fire PRA damage targets in the exposed fire area, and
- Fire barriers with a minimum 20 minute fire endurance rating when the physical conditions are not conducive to direct flame impingement on the barrier element.

### 6.1.4 Step 1.4: Initial Quantitative Screening Check

Entry into Step 1.4 implies the following two conditions have been met:

- The finding was assigned either a Moderate or High degradation rating (low degradation findings Screen to Green in Step 1.3). Hence, one element of the fire protection program will be given either substantially degraded performance credit (moderate degradation) or no credit (high degradation) in subsequent analysis steps.

- The finding is not limited to cold shutdown functions only; rather, hot shutdown functions may be impacted given the degradation noted. Hence, it may not be appropriate to credit SSD functions without further assessment.

On this basis a quantitative screening check is performed based on the product of duration factor and a conservative estimate of room fire frequency.

#### 6.1.4.1 Task 1.4.1: Duration Factor

The duration factor used in the Fire Protection SDP is identical to duration factors as established by the USNRC staff for other SDP applications.

#### 6.1.4.2 Task 1.4.2: Generic Fire Area Fire Frequency

The generic fire frequencies used in Step 1.4 are based on a review of past fire PRA practice and insights gained from evaluations of fire event data. Generic fire area designations from these studies, and the corresponding fire event frequency estimates were compiled. The values recommended for use in the Fire Protection SDP were based on a conservative interpretation of the cited values. The sources considered are:

- Typical IPEEE practice as documented in the EPRI Fire-Induced Vulnerability Evaluation (FIVE) method (EPRI TR-100370) and the Fire PRA Implementation Guide (EPRI TR-105928);
- USNRC staff evaluations as documented in RES/OERAB/S02-01 (Jan. 2002);
- The reactor safety studies documented in NUREG-1150;
- The Risk Methodology Integration and Evaluation Program (RMIEP) analysis of the LaSalle Nuclear Power Station (NUREG/CR-4832); and
- The Diablo Canyon NPP Fire Risk Analysis.

In general, the sources all agreed as to the approximate order of magnitude associated with fire area-specific fire frequency values. The variation between one analysis and another was generally no more than a factor of 4, and was often less. In the case of the most significant variation, a review revealed that the value reported in one specific analysis included application of a fire severity factor. The Fire Protection SDP explicitly applies fire severity factors, and so this particular source was discounted.

Given the general agreement between the studies, the final Fire Protection SDP values represent an aggregate conservative value based on the specific sources reviewed.

### 6.1.4.3 Task 1.4.3: Quantitative Screening Criteria

The quantitative screening criteria utilized in Task 1.4.3 (as well as in Steps 2.1, 2.3, and 2.5) are based on the finding category assigned in Step 1.2.

In the case of a high degradation finding, the implication is that some aspect of the fire protection program is considered non-functional. For such findings, the screening criteria is set a 1E-6 which is the general criteria for a Green finding in any event. Any time that the analysis can demonstrate a risk significance of less than 1E-6, the finding is by definition Green. This is consistent with that broader practice and criteria.

In the case of a moderate degradation, the degraded fire protection program element is not deemed to be non-functional, but rather, will be given some substantial credit in the subsequent quantification element. The screening criteria represent a conservative assessment that gives some inherent additional PRA credit to other non-degraded elements of the fire protection program. All licensees have implemented the USNRC-mandated fire protection DID approach. Given a moderate degradation, some substantial credit will still be given to the degraded program element (the element remains functional, but its performance or reliability may be substantially degraded). Further, multiple levels of defense exist against any fire that might occur at the plant, even given a finding of moderate degradation against one element of the fire protection program. The general elements of a fire protection DID program will include, but are not necessarily limited to, the following features and systems:

- Measures to minimize the occurrence of fires in the plant;
- Fixed fire detection systems in most plant areas and in virtually all safety significant plant areas;
- The plant manual fire brigade;
- Fixed fire suppression and/or localized three-hour rated fire endurance barriers protecting a post-fire SSD path in any fire area that contains redundant trains of SSD equipment;
- Barriers to fire spread and damage including both inter-compartment barriers and local barriers as applicable; and,

- Provisions for post-fire SSD given loss of unprotected equipment in the entire fire area up to and including SSD provisions that are independent of the main control room.

The quantitative screening begins with a duration factor for the finding reflecting the time that the degradation was present. The second factor is a conservative assessment of the total fire frequency in the entire fire area impacted by the finding. Given these two entry values, and the DID features and systems listed above, the following assessments have been made:

- It is conservatively anticipated that given a moderate degradation to a fixed fire protection system (detection or suppression), an inter-compartment fire barrier element, or a local fire barrier element, the PRA approach will assess a minimum of one order of magnitude reduction to reflect other non-degraded DID elements.

- It is conservatively anticipated that given a moderate degradation against the post-fire SSD provisions, circumstances might arise in which the PRA approach might not assess any additional risk reductions given a fire that creates a demand for SSD. The Step 1.4 screening criteria have been set accordingly.

## 6.2 Phase 2 Analysis Basis

### 6.2.1 Step 2.1: Independent SSD Path First Screening Assessment

#### 6.2.1.1 Task 2.1.1: Identify the Designated Post-Fire SSD Path

For each fire area in the plant, the licensee is required by the USNRC fire protection regulations to establish a post-fire SSD path that will remain free of fire damage given the fire-induced failure of all unprotected cables and components within the fire area. In Task 2.1.1, the analyst is simply asked to identify this SSD path for the fire area under analysis.

#### 6.2.1.2 Task 2.1.2: Assess the Unavailability of the Identified SSD Path

Those values used for the mitigating system failure probabilities in the screening CCDP calculation are consistent with the data used in the plant specific worksheets for determining Phase 2 CCDP values which are documented in the internal events SDP Plant Notebooks. In the internal SDP Plant Notebooks, simple reliability models and generic data have been used to estimate the failure probabilities of plant equipment. These failure probabilities are based on the licensee's Individual Plant Examination (IPE) submittal, the updated Probabilistic Risk Assessment (PRA), and system information obtained from the licensees during site visits as part of the review of earlier versions of the internal SDP notebook.

Approaches used to maintain consistency within the SDP, specifically within similar plant types, resulted in sacrificing some plant specific modeling approaches and details. A benchmarking of the plant-specific internal SDP notebook was conducted, comparing and analyzing the risk significance of inspection findings using the notebook and the plant-specific PRA. When the results were compared, areas of differences were recognized (either conservative or non-conservative), and reasons for the differences were understood. These differences can result in either changes to the notebook or updates to the plant-specific PRA model. Overall, these probability values have been determined to provide realistic to conservative estimates of risk during the benchmark exercises.

#### 6.2.1.3 Task 2.1.3: Assess the Independence of the Identified SSD Path

The independence assessment is based primarily on the Appendix R III.G.2 compliance strategy for achieving physical protection of the designated post-fire SSD path. At this stage of the analysis, specific fire scenarios have not been developed nor screened. Hence, a very stringent basis for independence of the designated post-fire SSD path is established.

The SSD path will be credited given one of three III.G.2 compliance strategies as outlined in Table 4.4.1 (see Section 4.4.1, Task 2.1.3). The credit is based on the following bounding assessments of the likelihood that each of these compliance strategies might fail given a fire in the fire area:

- Separation by fire area: Fire area boundaries as applied in the regulatory complex will generally have a minimum fire endurance rating of 2 hours, and often are rated at 3 hours. The likelihood that any given fire might last two hours or more, and thereby potentially challenge the non-degraded barrier element, is approximately 0.01 (based on statistical analysis of all fires in the 2000 version of the EPRI Fire Events Database that occurred interior to plant structures). This value generally reflects the overall performance of the manual fire brigade because the vast majority of fires are manually suppressed. This statistic probably overestimates the actual likelihood that any given fire might challenge an inter-area fire barrier element and fail a redundant train on the protected side of the barrier. Other factors to be considered include the actual location of the fire (it would need to occur near, or spread to, the barrier element to be challenged), and the potential for a fire to actually become substantially threatening to the fire barrier (not all fires in the database had the potential to grow to such challenging proportions). Furthermore, the fire must also fail the redundant train of SSD equipment once the barrier is breached. Given these factors, a conservative assessment is that not more than 1 in 1000 fires (0.001) will result in breaching of a fire barrier and failure of redundant SSD equipment in an adjacent fire area. It is worth noting that in all the years of experience for the U.S. nuclear power industry, only one fire (Brown's Ferry, 1975) has resulted in breaching of an inter-area fire barrier element, and in that case the barrier element was not complete. The most optimistic random failure probability estimate allowed in crediting the SSD path in this step is 0.01. This value is clearly dominant in the overall assessment of the likelihood of SSD path failure. Hence, the SSD path can be credited with high confidence at the higher failure probability (0.01 given the most optimistic assessment as in this example).

- Separation by a 3-hour rated localized fire barrier: The argument for this case is similar to that presented above for an inter-area fire barrier. In this case the likelihood of a three hour duration fire is even lower (about 0.005). The balance of the case follows as above.

- Separation by a 1-hour barrier plus automatic detection and suppression: For this case three features are of particular importance: passive protection by the 1-hour barrier; active protection by the automatic fire suppression system; and active protection by the fire brigade with a high probability of early fire detection. The probability of an indoor fire lasting one hour is nominally on the order of 0.05 (5%). The vast majority of the fires in the database are manually suppressed, so this can be taken as the nominal reliability of manual suppression within one hour for interior space fires. If additional credit is taken for the fixed fire suppression system, in a non-degraded condition, activation of the fire suppression system should achieve fire control and prevent breaching of the localized fire barrier. Nominal failure probabilities for fixed suppression systems are on the order of 0.02. The product of these two values ($0.05 \times 0.02 = 0.001$) represents a nominal estimate of the conditional likelihood that both the manual fire brigade and the fixed suppression system will fail to control the fire within one hour. Note that no credit is taken in this for potential recovery of the failed fire suppression system or other factors that might reduce this further.

Again, the random failure probability dominates in even the most optimistic assessment allowed in the task (0.01).

Other protection schemes will not be credited at this stage of the analysis. For example, if the protection scheme involves spatial separation, hot gas layer or radiant heating effects might cause failure of the redundant train, e.g., should fire suppression fail or given a high-intensity fire exposure source. At this stage of the analysis (Step 2.1) fire scenarios have not been developed to a sufficient level of detail to assess the likelihood that such effects will be observed given a fire in the area. Hence, credit for survival of the SSD path will be deferred pending further refinement of specific fire scenarios.

#### 6.2.1.4 Task 2.1.4: Finding Screening Check

The screening check performed in Step 2.1 is essentially identical to that performed in Step 1.4, and its basis remains largely unchanged. In Step 2.1, the analyst is potentially providing some limited credit to a robust and designated SSD path that meets stringent independence criteria. This is not expected to change the assessment of subsequent PRA risk reductions reflecting other elements of the fire protection program as discussed in Section 6.1.4.4.

### 6.2.2 Step 2.2: FDS Determination and FDS3 Screening

#### 6.2.2.1 Task 2.2.1: Initial FDS Assignment

The initial FDS assignment of Task 2.2.1 is broadly inclusive of potential risk scenarios. The selection of FDSs applicable to a given finding is limited only by the nature of the finding itself. That is, an FDS is not required to be considered if and only if the finding itself inherently implies that any scenario corresponding to that particular FDS would be unaffected by the finding.

The first exclusion involve findings against fire confinement. Fire confinement refers to those fire barrier elements that segregate one fire area from an adjacent fire area. These inter-compartment fire barriers will only be relevant to the analysis of inter-compartment fire scenarios - i.e., the FDS3 scenarios. Any fire scenario that remains confined within the fire area of fire origin (i.e., any FDS1 or FDS2 scenario) would be unaffected by a finding associated with fire confinement. Therefore, the risk change for FDS1 and FDS2 scenarios is by definition zero, and need not be analyzed. Hence, Task 2.2.1 requires that only the FDS3 scenarios be considered.

The only other exclusion from the initial FDS assignment is the exclusion of FDS1 scenarios for a moderate degradation of a localized cable or component fire barrier. In this case, the cables or components protected by the degraded barrier is, by definition, postulated only in the FDS2 and FDS3 scenarios. Therefore, FDS1 scenarios are unaffected and need not be analyzed.

#### 6.2.2.2 Task 2.2.2: Screening Assessment for FDS3 Scenarios

A broad insight gained from past fire risk analyses is that inter-compartment fire scenarios are commonly found to be insignificant contributors to fire risk, although exceptions to this general observation do exist. The screening rules applied in Task 2.2.2 give nominal credit to those fire protection features and systems that have been found to be key to minimizing the risk associated with such inter-compartment fire scenarios. That is, the exceptions that have been identified in past PRAs are generally associated with cases where these features and/or systems were absent.

It should also be noted that the screening criteria used in Task 2.2.2 are broadly consistent with, although a bit more conservative in some specific aspects, than the screening rules applied widely by licensees in the IPEEE fire analyses. In particular, the FDS3 screening criteria are based in large part on the Fire Compartment Interaction Analysis (FCIA) screening criteria from EPRI's FIVE methodology.

## 6.2.3 Step 2.3: Characterize and Screen Fire Ignition Sources

### 6.2.3.1 Task 2.3.1: Identify Fire Ignition Sources

The list of fire ignition sources to be considered by analysts is broadly consistent with similar lists applied in general PRA practice. In particular, the list used for the SDP process were aligned with the fire ignition source bins defined for the RES/EPRI Fire Risk Requantification Study. For SDP various individual ignition sources were combined in order to simplify the process (the pumps and electrical panel categories were the most significant in this respect). The fire frequencies for each individual member of such combined sets as used in the Requantification Study were compared to the SDP values, and the differences were found to be small. The fire frequencies generally agreed to within a factor of less than 2, and in no case did the value change by more than a factor of 3.

### 6.2.3.2 Task 2.3.2: Characterize Fire Source Severity and Location

The general approach to fire severity being applied has been adapted from the methods being developed in the Fire Risk Requantification Study. The Fire Protection SDP approach is simplified in that two discrete values of fire intensity are applied (an expected and a high confidence value), whereas the Requantification Study treats fire intensity as a distribution. The approach ensures that the risk evaluation includes consideration of the low-likelihood, high intensity fire.

The fire source severity levels were established based on input from an expert panel. The values are broadly consistent with those being applied in the Requantification Study. The set of unique fire intensities applied in the SDP was limited to five values by consolidating similar fire types as defined in the Requantification Study. In essence, the fire intensity values for individual fire ignition source types were “rounded up” to achieve a limited set of discrete values for use in SDP. This substantially simplifies the subsequent fire modeling tasks.

The guidance provided for locating the fire source is also consistent with past practice (e.g., FIVE and the Fire PRA Implementation Guide).

### 6.2.3.3 Task 2.3.3: Identify Nearest Ignition and Damage Targets

At this stage the analyst is asked to identify the nearest fire ignition and damage targets without regard to the specific importance of these targets in a PRA context. For example, the nearest damage target may not be a safety-related damage target, and its loss may have no measurable risk impact. However, by screening fire ignition sources based on the nearest targets, optimistic screening results are precluded. Additional consideration is given to the identification and behavior of scenario-specific target to the extent allowed by the available cable and component routing information in later steps of the analysis.

It is anticipated that the fire and ignition targets will generally be electrical cables. Electrical cables typically represent the most vulnerable element of major plant components. For example, a large pump is itself relatively invulnerable to fire-induced damage due to its shear mass and the lack of specifically vulnerable parts. However, the power cable that supplies power to the pump motor, and/or the control cables that control operation of the pump are typically exposed, and are known to be vulnerable to fire-induced failure. Hence, the SDP focus on cables is both appropriate and consistent with common PRA practice.

It is anticipated that some specific applications might involve thermal damage targets that are more fragile that the cables. An example would be solid state signal conditioning or control switching equipment. Provisions for such cases have been allowed in the guidance. However, the guidance also specifies that given a fire in an electrical panel, including a control panel, that all of the components in that panel be assumed to fail. Hence, it is likely that most SDP analyses will continue to focus on electrical cables as both the ignition and damage targets.

## Basis for Cable Failure Thresholds

### Temperature Thresholds - Thermoset Cables

Thermoset represents a very broad class of cables. Of the thermoset cables, cross-linked polyolefin (XLPO) insulated cables are generally the weakest in terms of susceptibility to thermal damage (see discussion of Kerite FR below). Of the general class XLPO, the specific material cross-linked polyethylene (XLPE) is the most widely used. XLPE insulated cables are used extensively in the US nuclear power industry. For example, based on surveys of nuclear industry practices conducted in support of the USNRC Equipment Qualification research programs, one of the most popular cable products is the widely used Rockbestos Firewall III line of nuclear qualified cable products. In general, the XLPO and XLPE cables can be taken as representative of the weaker thermoset materials. Fairly extensive evidence for thermal damage to thermoset cables in general, and the XLPO and XLPE materials in particular, exists based on a number of public sources.

Perhaps the earliest source of direct evidence on thermal failure thresholds for thermoset cables is provided in NUREG/CR-5384 which reports thermal damage test results from the early 1980's for a XLPE insulated cable. The tested cable was specifically IEEE-383 qualified, including the flammability testing protocol. The samples were taken from excess stocks of cables purchased to support USNRC-sponsored testing in the late 1970's. Hence, these cables are a very early vintage IEEE-383 qualified cable given that the flame spread test was first introduced in IEEE-383 in the 1975 revision. During high temperature exposure tests, electrical failures were observed at temperatures as low as 270°C (518°F). At this temperature damage times were relatively long ranging from 30 to 82 minutes, and averaging 56 minutes. At an exposure temperature of 350°C (662°F) the damage times ranged from 7 to 28 minutes, averaging 13 minutes.

Direct evidence is also provided in NUREG/CR-5546 (1991) which reports thermal damage results for a XLPE insulated Rockbestos Firewall III cable, an extremely common cable in the US nuclear industry. At a temperature of 325°C (617°F) no failures were observed for two samples during exposures lasting approximately 80 minutes. At 330°C (626°F) failures were observed in all four samples tested. The failure times ranged from 33 to 79 minutes, and averaged 55 minutes. At a temperature of 335°C (635°F), damage times ranged from 16 to 30 minutes and averaged about 20 minutes.

A third source of direct evidence is gained from superheated steam exposure tests conducted under severe accident simulation tests in the equipment qualification (EQ) domain (e.g., NUREG/CR-5655, 1991). The dry superheated steam environments look much like the dry hot environment of a fire, and a previous study has concluded that these results might be applied as indicators of fire damage thresholds as well (SAND92-1404C). A direct correlation has been made between the damage criteria applied in fire testing to those applied in the EQ tests. All products tested were explicitly qualified for use in US nuclear industry applications. Interpretation of the EQ test results requires selection of a failure criteria. NUREG/CR-5655 reports results for four separate failure criteria, each representing a progressively more severe level of degradation. Using the worst case failure threshold (i.e., that indicative of the highest level of degradation), the failure threshold for an XLPE cable was estimated at about 320°C (610°F). For the more general class of XLPO materials, failures at the same threshold were noted at temperatures as low as 300°C (572°F).

A fourth source for direct evidence on the electrical performance of XLPE insulated cables is a series of test performed in 1984 by TVA[2]. The TVA tests involved six different cable types each insulated with XLPE. The maximum temperature reached by the cables during the test was 299°C (570°F) at the end of a one-hour exposure protocol. None of the XLPE cables experienced electrical failure at these temperatures.

A fifth source of direct evidence regarding failure for thermoset cables is the recently completed NEI/EPRI Cable Failure Modes and Effects Tests. As a part of an expert panel activity (EPRI TR1006961) some panel members examined the cable failure data in the context of temperature, and estimated the minimum failure threshold for the thermoset cables tested. Each panelist was left to their own approach to analysis and interpretation of the test data, and each reached somewhat different conclusions. Furthermore, the cable types (insulation material in particular) are not identified beyond thermoset versus thermoplastic. Nonetheless, the results do provide some insights into cable failure thresholds for at least some cable types as follows:

- Mowrer noted thermoset cable failures at a minimum temperature of 680°F (360°C). (See pg. B-21 of the EPRI TR1006961.)
- Funk concluded that, for thermoset cables, 550°F (288°C) was a “reasonably conservative” estimate of the “threshold of thermal insult below which cable failure (either partial or complete) does not occur, or is extremely unlikely.” (pg. B-3, ibid.)
- Salley noted at least one thermoset cable that failed at a temperature of 591°F (311°C) and others in the range of 660-680°F (349-360°C). (pg. B-64, ibid.)

The Fire Performance of Electrical Cables (FIPEC) study provides indirect evidence based on the piloted ignition thresholds. The reported ignition temperatures for a range of XLPE cable products

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[2] As reported in: M.H. Salley, “An Examination of the Methods and Data Used to Determine Functionality of Electrical Cables when Exposed to Elevated Temperatures as a Result of a Fire in a Nuclear Power Plant,” University of Maryland, MS Thesis, 2000.

ranged from 220-474°C (429-885°F). The average ignition temperature reported was 332°C (630°F). The results again illustrate a wide variability in performance. However, ignition behavior is dominated by the outer jacket material, rather than the cable insulation material. The FIPEC cable samples involved a range of jacket materials, and many of these were PVC-based thermoplastic materials. Hence, the lower threshold values cited might be more an indication of the performance of the thermoplastic jackets than of the thermoset insulation. Note that in the US nuclear industry it is not common practice to utilize thermoplastic or PVC jackets on a thermoset insulated cable. Rather, thermoset cables will typically have neoprene, rubber-based, or chloro-sulfanated polyethylene (hypalon) jackets. These materials are all thermoset.

It is worth noting that in the IPEEEs, a commonly applied screening failure threshold for IEEE-383 qualified cables applied by licensees was 370°C (700°F). Note that IEEE-383 involves both LOCA electrical performance testing and a flame spread test. Virtually all cables fully qualified to both aspects of the IEEE-383 test standard are thermoset materials.[3] The 700°F value is recommended in the EPRI FIVE method (EPRI TR-100370), and appears again in the EPRI Fire PRA Implementation Guide (EPRI TR-105928). The original source cited for this value is the EPRI cable damage tests reported in a series of Factory Mutual Research Corp (FMRC) studies from the early 1980's (see in particular EPRI NP-1767, March 1981). The method used to estimate the cable “critical” threshold values cited in the original FMRC work, and repeated in FIVE, has since been discredited, and has been disavowed by FMRC (see letter, A. Tewarson of FMRC to R. Kasawara of EPRI, May 10, 1995). There appears little basis for the continued reliance on 700°F as a screening threshold for thermoset/qualified cables given the direct evidence of failures at substantially lower temperatures for a broad and common class of thermoset/qualified cable products.

<u>Recommended SDP Practice:</u> A failure threshold of 330°C (625°F) is recommended for the generic class of thermoset cables.

<u>Summary of Basis</u>

- The recommended SDP practice <u>does not</u> bound all of the data on cable failure thresholds for all thermoset cable types. In particular, it does not bound the performance of some XLPO cable types (e.g., Polyset) and it does not bound one specific test data point related to XLPE. It also does not bound the proprietary material “Kerite FR” (see discussion below).
- Given their widespread use in the US nuclear industry, failure thresholds for thermoset materials are based on XLPE insulated cables.
- 330°C is representative of clearly demonstrated and documented test results showing failures within an average time of well under one hour for a widely used specific XLPE insulated cable product, Rockbestos Firewall III.
- The lower threshold values implied by the earlier tests in NUREG/CR-5384 are not recommended for this application given the relatively long failure times reported (average time of nearly one hour) and the very early vintage of the cables tested. The TVA results also provide evidence that the failure thresholds for most XLPE cables should be expected to exceed 299°C (570°F).
- The lower threshold values associated with the specific XLPO cable product tested in NUREG/CR-5655 is not recommended as a general criteria because this particular material/product is not widely used as an insulation material in the US nuclear industry.

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[3] Various thermoplastic materials will pass the flame spread portion of the IEEE-383 test, but not electrical performance requirement of the LOCA portions of the testing protocol. Such cables would not be considered “IEEE-383 qualified” in this context.

- It is recommended that the consideration of higher threshold values based on knowledge of a specific cable product being used in a specific case should be deferred to the Phase 3 analysis should such an analysis be pursued.

SPECIAL EXCEPTION: There is a particular proprietary cable insulation material called "Kerite FR". While this material is a thermoset, experimental evidence suggests it is substantially more vulnerable to thermal damage than are other thermoset materials. In particular, NUREG/CR-5655 reports substantial degradation of the cable's insulation value at temperatures as low as 153°C (307°F). Testing by SCE&G cites average temperatures at failure of 237°C (458°F) (as reported by Salley). Hence, it is recommended that the material Kerite FR should be analyzed using the failure criteria for a thermoplastic cable, not the values reported for a thermoset material.

Temperature Thresholds - Thermoplastic Cables

The typical thermoplastic cable is polyethylene insulated (PE) often with a polyvinyl-chloride (PVC) jacket. This configuration is also considered representative of the weaker members of the thermoplastic group. The evidence for thermal failure threshold for PE insulated cables can be taken from a number of sources.

Direct evidence of thermally induced electrical failure is provided in NUREG/CR-5384 (see Figure 6.3 in that reference). The failures for this cable were observed at temperatures as low as 250°C (482°F). At this exposure temperature, failure times ranged from 1.5 to 23.5 minutes and averaged about 9 minutes. At exposures of 180°C (356°F) no failures were observed in six test samples during two separate tests with exposures lasting approximately two hours. Given the relatively short failure times observed in some of the 250°C exposure tests, the actual failure threshold likely lies somewhat below the cited 250°C value, but certainly above 180°C.

Direct evidence of functional failure is also provided by testing conducted by Tennessee Valley Authority (TVA). Two samples of a PE/PVC (dual layer) insulated cables tested. The failure temperature in the first test was estimated as 175°C (346°F), and in the second test as 227°C (440°F). During the TVA tests, weights were placed on top of the sample cables to simulate the weight of a load of cables in a raceway. The first test utilized a load approximately 4 times larger than the second test. During the second test, the cables were examined immediately following the initial failure, and showed signs of substantial melting. A second series of test in 1996 demonstrated satisfactory electrical performance for the same cable type exposed to temperatures peaking at 139°C (282°F) at the end of a one-hour exposure protocol.

A third source of direct evidences is testing by VTT Finland. Failures of a PVC insulated cable were reported at temperatures as low as 196°C (385°F). These results might be discounted to some extent by the fact that these are tests of a European cable formulation, and likely a Russian formulation (given its use in the Finish nuclear industry). Hence, its formulation in comparison to typical US material would be unknown. It is also uncommon to encounter a PVC insulated cable in the US nuclear industry. This result is take as a general indication of marginal performance for these materials at temperatures exceeding 200°C

A fourth source of direct evidence is the above cited EPRI expert panel report (TR1006961). The following damage insights are noted:

- Mowrer noted thermoplastic cable failures at a minimum temperature of 400°F (205°C). (See pg. B-21 of the EPRI TR1006961.)

- Funk concluded that, for thermoplastic cables, 400°F (205°C) was a "reasonably conservative" estimate of the "threshold of thermal insult below which cable failure (either partial or complete) does not occur, or is extremely unlikely." (pg. B-3, ibid.)
- Salley noted at least one thermoset cable that failed at a temperature of 390°F (200°C) and recommended a threshold value of 400°F (205°C) for " 'garden variety' thermoplastic cables." (pg. B-64, ibid.)

Indirect evidence is provided based on the FIPEC piloted ignition thresholds. The minimum temperature reported for piloted ignition of a PE/PVC cable was 197°C (388°F) for one sample. All other samples showed ignition temperatures of 246°C (476°F) or greater. The average temperature for piloted ignition for the six cable types tested was 253°C (487°F).

It is worth noting that the EPRI FIVE method (EPRI TR-100370) recommended use of a failure threshold for non-qualified cables[4], generally corresponding to thermoplastic cables, of 218°C (425°F)[5]. This value was widely used by licensees in their IPEEE analyses. The basis for the value is not explicitly cited in the FIVE documentation. The value appears in Reference Table 1E (pg. 10.4-47).

Recommended SDP practice: Continue the use of the commonly applied IPEEE failure threshold of 205°C (400°F) for non-qualified or thermoplastic cables.

Summary of Basis:

- The recommended value is based on the available experimental evidence for PE and PVC insulated cables.
- A value of 250°C is known to yield damage times of on the order of 2-20 minutes.
- The TVA results for the heavily weighted cables in their first test can be discounted to some extent as being a grossly conservative loading configuration. However, the observation of cable failure at 175°C (346°F) does provide evidence of marginal performance at these temperatures.
- The loading configuration in the second TVA test cannot be discounted and yielded failures at 227°C (440°F) in an exposure of well under one hour duration.
- The recommended value is largely consistent with the piloted ignition results for the FIPEC study excluding only one test sample with a disproportionately lower ignition threshold.

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[4] In this context, "qualified" refers a cable shown to pass all aspects of the IEEE-383 performance standard. An "un-qualified" or "non-qualified" cable is a cable that does not meet one or more aspects of the IEEE-383 standard. Note that a cable that has been shown to pass the IEEE-383 flame spread test but has not been shown to pass the LOCA electrical performance tests in IEEE-383 is considered "un-qualified" in this context.

[5] See FIVE Reference Table 1E, (pg. 10.4-67).

Radiant Heating Failure Criteria - Cables

The available data for the electrical failure of cables under radiant heating conditions remains relatively sparse. While substantive data is available for higher heat flux conditions, the threshold conditions in particular have only been explored directly in a handful of cases.

The primary source of direct evidence is EPRI-sponsored tests conducted at Factory Mutual Research Corp. during the late 1970's and early 1980's (see for example, EPRI NP-1200). These tests involved a fairly wide range of NPP cable products. Unfortunately, the threshold exposure levels were only explored in a limited number of cases, and were extrapolated for most tests. The extrapolation method used in the data analysis has since been discredited.

There was also a limited set of early NRC-sponsored radiant exposure tests at Sandia National Laboratories in the late 1970's (see NUREG/CR-5384). These tests were conducted in a manner similar to the EPRI tests, but at a more representative scale using a loaded cable tray.

Some additional insights were gained from the FIPEC study. The FIPEC study involved primarily thermoplastic cables and focused on ignition properties with no direct monitoring of electrical failure. However, the ignition of a cable is taken as indirect evidence that electrical failure is imminent. Hence, these data are taken as indicators of threshold, but not timing (see discussion of failure timing in section 6.2.6).

Finally, current PRA practice as documented in the EPRI *FIVE* methodology and in the more recent EPRI *Fire PRA Implementation Guide*, was considered.

Based on the available information, threshold heat flux damage limits of 6 kW/m$^2$ (0.5 BTU/ft$^2$s) have been recommended for thermoplastic cables. For thermoset cable the recommended damage threshold is 11 kW/m$^2$ (1.0 BTU/ft$^2$s).

### 6.2.3.4 Task 2.3.4: Screen Fire Ignition Sources

The approach defined for the screening of fire ignition sources is based on practices that were commonly applied in the IPEEE analyses, and in other fire PRA approaches. The zone of influence charts combined with the hot gas layer consideration covers the three major modes of fire damage that are considered in fire modeling. The correlations used to estimate fire plume temperatures, radiant heating effects, and hot gas layer temperatures are all well-established handbook correlations.

The damage/ignition threshold values used to establish cable damage and ignition temperatures are bounding values representative of the weakest members of the two major cable groups. The values used (400°F and 625°F) reflect commonly applied screening values for the damage thresholds for minimum damage/ignition thresholds for thermo-plastic and thermo-set cables respectively.

The ignition temperatures have been assumed equal to the damage temperature based on USNRC-sponsored testing from the late 1980's (NUREG/CR-5546) which showed piloted ignition concurrent with failure of an energized electrical cable. For the SDP, piloted ignition conditions are assumed without explicit analysis of the flame zone location or extent in order to simplify the analysis modestly. This may be a source of some modest conservatism for some cases.

### 6.2.3.5 Task 2.3.5: Screening Check

The screening check in Step 2.3 only screens a finding to green if the analyst was unable to identify a fire ignition source with a potential to ignite the nearest secondary combustible material or damage the single most vulnerable thermal damage target. This indicates that there are no fire ignition sources in the fire area, including hot work and transient fires, capable of creating a credible fire scenario. This is taken as a very strong indication of low fire risk based on a demonstrated lack of fire hazards.

## 6.2.4 Step 2.4: Fire Frequency Analysis

### 6.2.4.1 Task 2.4.1: Nominal Fire Frequency Estimation

In many ways the fire frequency is estimated in exactly the same manner used in most current fire PRAs. The most significant extension applied in the SDP is the used of component or fire ignition source specific fire frequencies for all sources.

The generic plant-wide fire frequency is based on the analysis of fire event data using common methods of data analysis. The fire event database used is an up-to-date version of the EPRI fire event database (e.g., NSAC-178). Of the available databases, the EPRI database provides the most complete descriptions of the recorded fire events.

The data were culled and analyzed using Bayesian analysis. The culling process eliminated fire events judged to be irrelevant to at-power operations (e.g., fires uniquely associated with a shutdown activity). Culling also eliminated fire events judged to be “non challenging,” that is, events reported in the database that had no potential for either fire spread or fire damage even if postulated to occur in a different plant or plant location. The definition of a non-challenging fire was based directly on the Fire Risk Requantification Study approach. Based on USNRC staff recommended approaches, only fire data after January 1, 1986, has been used for most fire ignition sources. In a small number of cases where there was very sparse data (i.e., self-ignited cable fires, main control room fires, battery fires), data prior to 1986 was included to create a statistically valid event set.

For the SDP process, the nominal fire frequency estimates are based on a component level analysis. This is expected to substantially simplify the inspection process. The SDP often focuses on a very narrow set of fire ignition sources, those sources whose risk contribution is changed by the finding under analysis. Hence, it is often necessary to estimate the fire frequency for a one or more specific ignition sources. The component level fire frequencies allow for this without the need to resort to cumbersome or difficult to calculate frequency partitioning factors.

The SDP approach assigns a fire frequency to each individual fire ignition source (generally the electrical equipment). The total fire frequency for a fire area is the sum of the frequencies for the individual sources in the area. This approach makes it quite simple for the analyst to estimate the room fire frequency, or the frequency of a specific fire ignition source scenario. This approach is broadly consistent with the approaches being applied in fire PRAs. For example, the FIVE method, the EPRI Fire PRA Implementation Guide, and the Fire Risk Requantification Study all recommend a similar approach.

Implementation of this approach did require on significant simplification to the application process. The major difference for the Fire Protection SDP is that the analyst is not asked to count fire sources throughout the plant, only those in the fire area under analysis. In the other cited PRA analysis methods, it is assumed that the analyst will have a complete count of fire ignition sources throughout the plant. Hence, the generic plant-wide fire frequency is partitioned to individual components based on the plant-specific total component count. In SDP a generic or representative component counts are applied, and the generic plant-wide fire frequency is partitioned to individual components based on these generic component count values.

The table provided below illustrates the process used to estimate the component level fire frequencies. Included are the plant wide fire frequencies, the assumed generic component counts for a “typical” plant, a brief description of the how the counting units were defined, and the final per-counting-unit fire frequencies.

The generic component counts were generated using information for several plants. The EPRI *Fire PRA Implementation Guide* provided counts for seven plants based on work performed during the IPEEE analyses. NEI provided counting information for four additional plants as a part of their efforts to support and comment on this revision of the process guidance. These results contained substantial plant to plant variability in some categories. Discussions with individuals knowledgeable of the counting process revealed that much of the variability was due to differences of interpretation of the EPRI IPEEE guidance. A individual plant volunteered to provide component counts using the SDP guidance directly. These counts were relied upon heavily in establishing the final generic count values.

**Table A9.3 - Calculation of Component Specific Fire Ignition Frequencies Based on Plant Wide Fire Frequency and Generic Component Counts**

| Ignition Source Bin | Plant-wide Fire Freq (/ry) | Plant-wide Count (avg.) | Counting Unit | Fire Sub-Type | Fire Frequency per Counting Unit (/ry) |
|---|---|---|---|---|---|
| **Cables – Non-Qualified:**** | | | | | |
| Cables – Low Loading | 2.9E-03 | ~1% of total fire frequency | | n/a | 1.6E-05 |
| Cables – Medium Loading | | ~25% of total fire frequency | | | 4.8E-04 |
| Cables – High Loading | | ~74% of total fire frequency | | | 1.4E-03 |
| **Electrical Cabinets:** | | | | | |
| Switchgear Cabinets | 4.5E-02 | 750 | # distinct vertical sections | Thermal | 5.5E-05 |
| | | | | Energetic | 4.7E-06 |
| General Electrical Cabinets | | | | n/a | 6.0E-05 |
| General Control Cabinets | | | | n/a | 6.0E-05 |
| MCR and MCR Service Cabinets | 4.8E-03 | 1 | # control rooms per unit | n/a | 4.8E-03 |
| **Electric Motors:** | | | | | |
| Electric Motors – (< 100HP) | 2.6E-03 | 4 | # motors <100 HP | n/a | 6.5E-04 |
| Electric Motors – ($ 100HP) | | | # motors $ 100 HP | n/a | 6.5E-04 |
| **Generators – General:** | | | | | |
| Diesel Generators | 1.1E-02 | 2 | # diesel generators | n/a | 5.6E-03 |
| Gas Turbine Generators | 6.5E-04 | 2 | # gas turbine generator sets | n/a | 3.2E-04 |
| Reactor Protection System MG Sets | 2.0E-03 | 3 | # RPS MG sets | n/a | 6.7E-04 |
| **Hydrogen Sources:** | | | | | |
| H2 Recombiner (BWR) | 1.7E-02 | 3 | # H2 recombiners | n/a | 5.5E-03 |
| H2 Storage Tanks | 6.5E-04 | 1 | # H2 tanks | n/a | 6.5E-04 |
| H2 - Normally Charged Piping | 2.9E-03 | 3 | # fire areas with charged piping | n/a | 9.7E-04 |
| **Hot Work:**** | | | | | |

**Table A9.3 - Calculation of Component Specific Fire Ignition Frequencies Based on Plant Wide Fire Frequency and Generic Component Counts**

| Ignition Source Bin | Plant-wide Fire Freq (/ry) | Plant-wide Count (avg.) | Counting Unit | Fire Sub-Type | Fire Frequency per Counting Unit (/ry) |
|---|---|---|---|---|---|
| Hot Work – Low | 1.5E-02 | 10 | # Low fire areas | n/a | 2.3E-05 |
| Hot Work – Medium | | 30 | # Moderate fire areas | | 6.9E-05 |
| Hot Work – High | | 10 | # High fire areas | | 6.9E-04 |
| **Main Turbine-Generator Set:** | | | | | |
| TG Exciter Fire | 2.8E-03 | 2 | # exciters | Electrical | 1.4E-03 |
| TG Oil Fires | 8.3E-03 | 5 | # lube oil systems | Oil | 1.7E-03 |
| TG Hydrogen Fires | 4.2E-03 | 3 | # H2 systems | Gas | 1.4E-03 |
| **Miscellaneous Components:** | | | | | |
| Air Compressors (< 100HP) | 2.6E-03 | 10 | # air compressors | Electrical | 1.6E-04 |
| | | | | Oil | 1.0E-04 |
| Air Compressors ($ 100HP) | | | | Electrical | 1.6E-04 |
| | | | | Oil | 1.0E-04 |
| Battery Banks | 1.1E-03 | 6 | # interconnected battery sets | n/a | 1.9E-04 |
| Boiler Heating Units | 9.7E-04 | 1 | # boilers | n/a | 9.7E-04 |
| Electric Dryers | 1.6E-03 | 3 | # dryers | n/a | 5.4E-04 |
| Ventilation Subsystems | 9.0E-03 | 150 | # major ventilation systems | n/a | 6.0E-05 |
| **Pumps:** | | | | | |
| Reactor Coolant Pump (PWR) | 2.8E-03 | 3 | # reactor coolant pumps | Electrical | 6.2E-04 |
| | | | | Oil | 3.1E-04 |
| Reactor Feed Pump (BWR) | 2.8E-03 | 3 | # reactor feed pumps | Electrical | 8.4E-05 |
| | | | | Oil | 8.4E-04 |
| Main Feedwater Pumps | 8.8E-03 | 3 | # main feedwater pumps | Electrical | 2.7E-04 |
| | | | | Oil | 2.7E-03 |
| Other Pumps (< 100HP) | 9.0E-03 | 90 | # other pumps < 100HP | Electrical | 5.0E-05 |
| | | | | Oil | 5.0E-05 |
| Other Pumps ($ 100HP) | | | # other pumps $100HP | Electrical | 5.0E-05 |
| | | | | Oil | 5.0E-05 |
| **Transformers:** | | | | | |
| Outdoor/Yard | 2.5E-02 | 6 | # outdoor transformers | n/a | 4.2E-03 |
| Indoor Dry | 6.5E-03 | 60 | # indoor dry trans. | n/a | 1.1E-04 |
| Indoor Oil-Filled | | | # indoor oil-filled trans. | n/a | 1.1E-04 |
| **Transient Fuels:**** | | | | | |
| Transients – Low | 2.2E-02 | 10 | # Low fire areas | n/a | 5.5E-05 |
| Transients – Medium | | 30 | # Moderate fire areas | | 1.7E-04 |
| Transients – High | | 10 | # High fire areas | | 1.7E-03 |

Table Notes:
** See text for discussion of how the high/medium/low likelihood categories are assigned.
*** Bus bars use the same fire frequency as that calculated for energetic faults/fires in an individual switchgear electrical panel.

For some fire ignition sources, fires of more than one type are considered. Switchgear are assumed to have general thermal fires and energetic fires initiated by an arcing electrical fault. Pumps are assumed to have either electrical motor type fires or oil spill/leak fires. In these cases, a split fraction was calculated based on the event data, and the fire frequency apportioned to each fire type accordingly. In the case of main turbine generator set fires, frequency values for the three types of fires identified (exciter, oil, gas) were calculated directly based on the event data (each was treated as a unique fire ignition source).

**Treatment of Transient Fuel Fire Frequency**

Estimating the frequency of transient fires for a given fire area involves the process of fire frequency partitioning[6]. For fires involving transient fuels (e.g., trash, general materials storage of solids or liquids, maintenance materials, materials staged in anticipation of maintenance activities, etc.) the partitioning process is based on four assumptions.

- Assumption 1: The plant wide fire frequency for transient fires is approximately 2.3E-2/ry. This value is derived from analysis of the fire event database.

- Assumption 2: Each fire area will be assigned a relative transient fire likelihood rating. Three likelihood ratings will be used (Low, Medium, and High). Guidance for assigning a likelihood rating to a given fire area is provided below.

- Assumption 3: On a fire area by fire area basis, the relative likelihood of a transient fire occurring in a "medium" fire area is three times the likelihood of a fire occurring in a "low" fire area ($f_{med}=3\times f_{low}$). In the same manner, the likelihood of a transient fire in a "high" fire area is ten times the likelihood of a fire occurring in a "medium" fire area ($f_{high} = 10\times f_{med} = 30\times f_{low}$ ).

- Assumption 4: A typical plant would have a total of approximately 10 fire areas that would be designated "low", 30 fire areas designated "medium", and 10 fire areas designated "high".

Using these assumptions, the fire frequency for any given fire area can be established based on the assignment of a "low", "medium", or "high" rating. Using the relative fire frequency ratios, and the assumed number of fire areas in each category, the plant wide fire frequency is reconstructed based on the following simple equation:

$$f_{PlantWide} = (n_{low} \times f_{low}) + (n_{med} \times 3 f_{low}) + (n_{high} \times 30 f_{low})$$

where $f_{PlantWide}$ = 2.3E-2/ry (per assumption 1), $f_{low}$ is the fire frequency for a fire area rated as low (unknown), and 'n' represents the number of fire areas in each likelihood category ($n_{low}$=10, $n_{med}$=30, and $n_{high}$=10 per assumption 4). The fire frequencies for medium ($f_{med}$) and high fire areas ($f_{high}$) have already been substituted for using assumption 3.

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[6] "Partitioning" refers to the PRA practice of apportioning the plant-wide fire frequency to individual fire areas or fire scenarios.

Solving this equation yields the following (rounding to one significant figure):

| Table A9.4 - Transient Fire Frequency (per Fire Area) | |
|---|---|
| **Low** | $f_{low}$ = 5.5 E-5 /ry |
| **Medium** | $f_{med}$ = 1.7 E-4 /ry |
| **High** | $f_{high}$ = 1.7 E-3 /ry |

**Treatment of Hot Work Fire Frequency**

The estimation of hot work fire frequency parallels the treatment of transients as described above. Using the same approach as documented above, the plant wide fire frequency is partitioned (assigned) to specific fire areas. The nominal plant-wide fire frequency for hot work fires[7] is estimated at 9E-3/ry. The fire area specific fire frequency is based on the hot work fire likelihood rating based on the following table.

| Table A9.5 - Hot Work Fire Frequency (per Fire Area) | |
|---|---|
| **Low** | $f_{low}$ = 2.3 E-5 /ry |
| **Medium** | $f_{med}$ = 6.9 E-5 /ry |
| **High** | $f_{high}$ = 6.9 E-4 /ry |

### 6.2.4.2 Task 2.4.2: Findings Quantified Based on Increase in Fire Frequency

Certain types of findings are quantified, in whole or in part, based on an increase in fire frequency. In particular, this approach is applied to findings related to hot work permitting and fire watch programs, and to findings against the plant fire prevention programs and the transient combustible controls programs in particular.

Hot Work Fire Frequency

The factors affecting hot work were primarily based on the requirements of NFPA 51B "Fire Prevention During Welding, Cutting, and Other Hot Work," 1999 and the description of events as provided in an Appendix B to the code "Significant Hot Work Incidents." Most of the degradations had to do with fire watch deficiencies based on the fact that the fire watch provides both early detection and early suppression of the incipient fire.

Deficiencies such as failure to implement a fire watch in positions to observe all areas of vulnerability, failure to implement a fire watch at all, or not having a proper or functional fire extinguisher were considered high degradations. A method of recovery from not having an

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[7] Note that the hot work fire frequencies cited here exclude fires promptly suppressed by a hot work fire watch. That is, these frequency values include full credit for prompt suppression by an effective hot work fire watch.

functional fire extinguisher is to be within 30 ft of a properly identified functional fire extinguisher of the proper type and size for the potential fire. If such conditions exist the deficiency may be considered a low degradation. The 30 ft criteria is the maximum allowable distance to a small extinguisher for Class B fire Hazards from NFPA 10 “Portable Fire Extinguishers.” A wet standpipe and hose station was considered as being equivalent to the fire extinguisher during an iteration of this document, however, because the operation of the hose can be more complex and time consuming than operation of a portable extinguisher and requires special training, the wet standpipe and hose station was excluded as a method of recovery. Another deficiency which should be considered a high degradation is failure by the licensee or fire watch to maintain safe conditions during hot work operations. Although such failures do not remove the fire watch as a means of detection and suppression, the probability of a fast growing fire which could challenge the effectiveness of the fire extinguisher increases. Low degradation were considered to be deficiencies observed by reviews of training records or interviews of fire watches. These are considered low because in an actual situation, it is likely that other members of the hot work crew would have the knowledge to compensate. The nominal hot work fire frequency values reported in the SDP frequency analysis tables excluded fire events that were promptly suppressed by the fire watch. A high degradation will be factored into the risk analysis by “removing” this prompt suppression credit. This is reflected by multiplying to nominal fire frequency by a factor of 3. The multiplication factor was based on an analysis of the event data. This analysis revealed that approximately 60% of the reported hot work fires are promptly suppressed (with rounding, a factor of 3 is applied for simplicity).

### Transient Combustible Fire Frequency

Findings for which degradations may be assigned for transient combustible fire frequency will be based on the requirements in the plant’s written policies regarding transient combustible storage. Items of interest in regard to transient combustible fire frequency are considered to be relatively low flashpoint flammable and combustible liquids, self igniting combustibles, evidence of smoking in a non-smoking area, and unapproved heaters or heat sources. The relatively low flashpoint flammable and combustible liquids are those liquids with flashpoints below 200°F and include class I liquids (flashpoint 73°F - 100°F, class II liquids (flashpoint 100°F - 140°F), and class IIIA liquids (140°F - 200°F). The selection of 200°F was based on limiting the flammable/combustible liquids to those liquids which could result in a flash fire because of their proximity to a heat or ignition source. Combustible liquids with flashpoints over 200°F are more likely to require actual contact or close proximity to an ignition source similar to ordinary solid combustibles. In addition, the “low flashpoint” liquids have to be in unapproved containers and unattended to qualify as a high degradation. Low flashpoint liquids above the amount specified in the plant’s storage policies but in approved containers will be considered a low degradation and will not affect the transient combustible fire frequency. However, such a finding may increase combustible loading assumptions for fire modeling.

Other findings which would result in high degradations are self-igniting combustibles in unapproved containers which are not being attended; evidence of smoking materials in a non-smoking area; and unapproved heaters and heat sources. All high degradations findings will increase the transient fire ignition frequency for the fire area in which they are found by a factor of 3.

Another type of finding that may be associated with transient combustibles is finding combustibles outside of approved locations or inside unapproved locations. However, if such findings do not involve combustible liquids with flashpoints under 200°F, they should be treated under combustible loading considerations and/or adding to the continuity of combustibles.

All of the possible degradations discussed above will have a dependence on the plant's combustible control procedures. In that these procedures vary from plant to plant, it must be assumed that the level of safety provided by adherence to the procedures also varies. This will require the consideration of the plant's combustible control program and potential compensating measures in the determination of the baseline transient combustible ignition frequency for different areas of the plant.

### 6.2.4.3 Task 2.4.3: Credit for Compensatory Measures that Reduce Fire Frequency

The purpose of Task 2.3.3 is to account for certain types of compensatory measures that will act to reduce fire frequency. In most cases, compensatory measures are credited with reducing the frequency of transient fuel fires in particular. The only example of compensatory measures which reduce the fire ignition frequency are administrative controls which prevent combustibles or hot work.

Under these circumstances, the frequency which accounts for transient combustibles or hot work is removed from the analysis for the fire area under consideration, and corresponding fire scenarios are not developed. It is expected that the practitioner will ensure that, during the exposure time of the finding, transient combustibles were not present in order to remove the transient combustible frequency, and hot work was not performed in order to remove the hot work fire frequency.

Note that hot work fire prevention measures are not treated as compensatory measures. Rather, these measures are assumed to be required. The base fire frequency for hot work fires has already credited prompt suppression by the hot work fire watch. Hence, no further reductions in hot work fire frequency are warranted.

### 6.2.4.4 Task 2.4.4: Finding Screening Check

The general approach to the screening check in Step 2.4 is the same as that applied in Step 1.4 as discussed in Section 6.1.4.4. The general basis for this approach is also the same. In this specific step, the screening criteria have been adjusted to reflect the fact the explicit application of severity factors on fire frequency. In previous steps, the fire frequency applied was the full fire area fire frequency as conservatively determined in Step 1.4. The refinement of these frequencies in Step 2.4 means that one aspect of potential risk reduction - the observation that not all fires are potentially challenging to nuclear safety - has been explicitly credited.

## 6.2.5 Step 2.5: Independent SSD Path Second Screening Determination

### 6.2.5.1 Task 2.5.1: Identify Fire Growth and Damage Scenarios

The process of identifying specific fire growth and damage scenarios is based primarily on long-standing practices in fire PRA. The identification of fire growth and damage scenarios is an integral part of most any quantitative fire risk analysis.

One unique aspect of this step as implemented in the Fire Protection SDP is the use of the discrete fire damage states as a basis for organization of the scenarios. The basis for this approach has been discussed in Section 6.2.2.

The second unique aspect of the SDP is the application of a rule-based approach to identification of fire growth scenarios. In particular, a set of fire spread rules has been developed based on expert panel input to guide the analyst in formulating fire growth scenarios.

This rule-based approach is necessary to simplify the process and to avoid the need to apply fire growth computer models in the assessment of fire growth potential. That is, in most fire PRAs the fire growth scenario would be assessed using a fire growth model such as COMPBRN or MAGIC. This is, however, impractical in the inspection context. The rule-base approach was selected by the panel as the alternative approach.

#### 6.2.5.2 Task 2.5.2: Identify Fire Growth and Damage Scenarios for Transients, Hot Work, and Self-Ignited Cable Fires

The treatment of the non-fixed fire ignition sources is based largely on past experience in fire PRA. In particular, these sources are rarely found to be risk important unless the fixed fire ignition sources are either absent, or those present are found to be non-threatening to one or more of the potential damage targets in the fire area. Hence, the non-fixed sources are typically found to be risk-important for areas such as a cable spreading room or cable vault/tunnel area where there are few, if any, fixed fire sources. The recommended practice recognizes this insight, and directs that the fixed fire ignition sources be considered first, and that the non-fixed sources should be held in reserve and considered only if the fixed sources are non-threatening to one or more of the unique targets located in the fire area.

#### 6.2.5.3 Task 2.5.3: Identify Plant Damage State Scenarios

The identification of the plant damage state scenario is a direct translation of component and cable damage into system faults.

#### 6.2.5.4 Task 2.5.4: Assess Scenario-Specific Independence of Post-Fire SSD Path

In this task, the designated post-fire SSD path is reassessed in the context of each individual scenario. In this case, the thermal damage targets and plant damage state have already been clearly defined. Hence, the survival or loss of the SSD path for each individual scenario is well characterized. This task merely represents a formalization of that result.

#### 6.2.5.5 Task 2.5.5: Finding Screening Check

In this step, the SSD path is credited on a fire ignition source scenario basis. That is, a single fire ignition source may lead to a range of fire damage scenarios and/or plant damage states. For some, the SSD may survive, while for others it may be assumed damaged. The SSD path is only credited for a fire ignition source if it survives all of the identified fire damage scenarios and the corresponding plant damage state scenarios. This ensures a conservative application of credit for the designated post-fire SSD path, pending additional information on the conditional probability that the more severe plant damage states will actually be observed for a given source. The remainder of the screening approach remains unchanged from the approach applied in Step 2.1.

## 6.2.6 Step 2.6: Fire Growth and Damage Analysis

**Basis for Cable Damage Timing Estimates**

The data sources available to support the assessment of cable damage times are essentially identical to those described in Section 6.2.4 (the discussion of cable damage thresholds). The specific objective here is to estimate the damage time for a given exposure condition at or above the damage threshold. The following describes how the recommended damage time estimates were developed.

Temperature Exposures - Thermoset Cables

Damage timing for thermoset cables is based primarily on the data reported in NUREG/CR-5546 for XLPE insulated cables (the Rockbestos Firewall III product). As discussed in Section 6.2.4, use of XLPE as representative of the thermoset class does not bound all of the thermoset products (see discussion of Polyset) but does bound the vast majority of thermoset products. XLPE is also the most popular single product used in the U.S. nuclear industry.

A review of the NUREG/CR data also showed that they were broadly consistent with more recent tests, including in particular the recent EPRI/NEI circuit failure tests (EPRI TR-1003326). The EPRI/NEI tests often involved temperatures very near the expected threshold of cable damage. Hence, the damage times were relatively prolonged, often in excess of 1 hour. This is consistent with the NUREG/CR data in that the damage times at the threshold temperature were also in excess of 1 hour. Hence, use of the specific information in the NUREG/CR appears appropriate.

These data are plotted in two figures. Figure 6.2.1 shows the direct time to failure versus exposure temperature as directly recorded in the tests. In order to extrapolate between the recorded data points, the data are re-plotted as shown in Figure 6.2.2.
In this second plot the exposure temperature is plotted against the inverse of the time to failure. This inversion provides a near-linear relationship between the exposure temperature and the

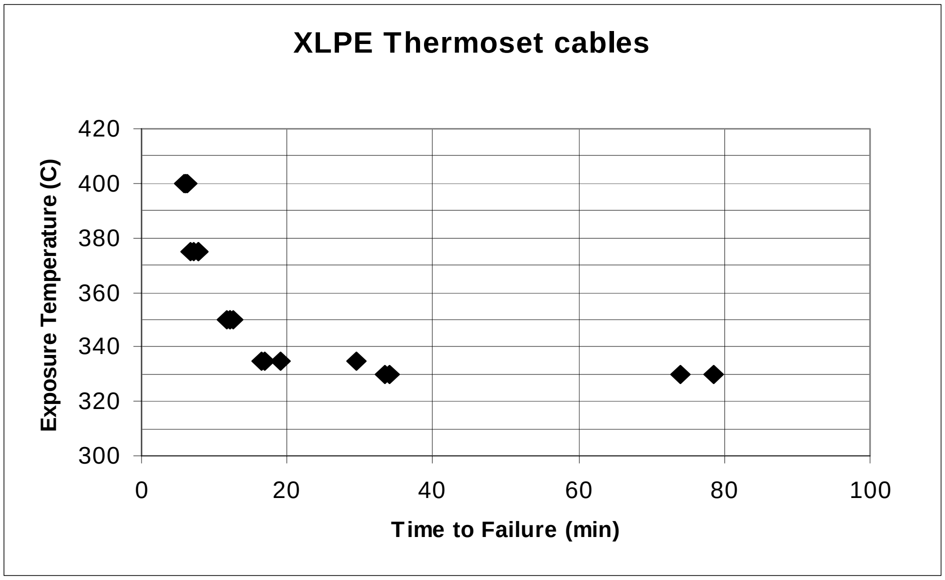

Figure 6.2.1: Raw time to damage chart for thermoset XLPE cables.

inverse of time to damage. This relationship is characterized by the following linear regression curve:

1/(time to damage : seconds) = 3.343E-05 ×(Temp: °C) - 1.044E-02
Using this relationship, a table of time to damage values was generated. Note that the results of the linear regression were adjusted modestly for values that fell outside the data range where extrapolation is necessary. Also note that for the purposes of SDP analysis, the maximum damage times (at the threshold) were limited to 30 minutes.

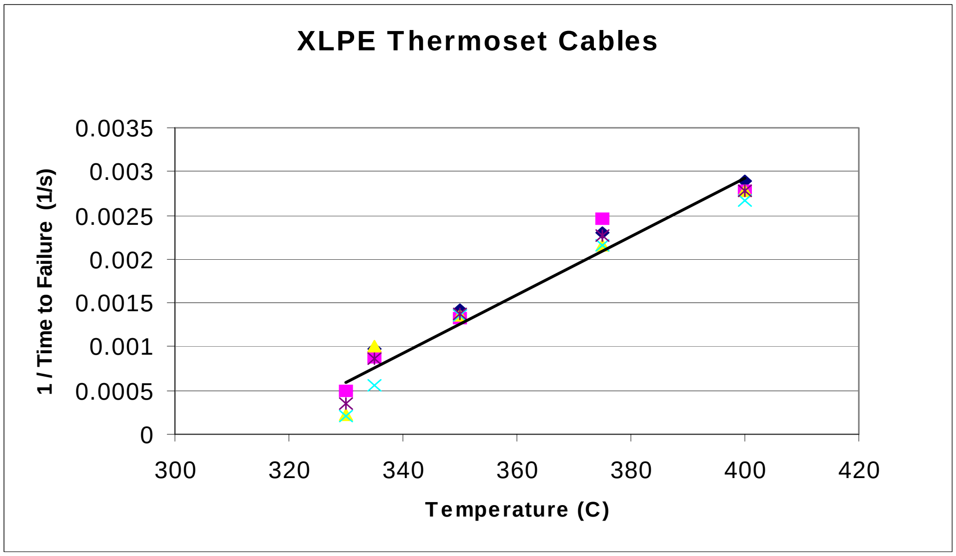

Figure 6.2.2: damage time plot for thermoset cables with linear regression curve shown.

| Table A9.6 - Failure Time-Temperature Relationship for Thermoset Cables | | |
|---|---|---|
| Exposure Temperature | | Time to Failure (minutes) |
| °C | °F | |
| 330 # T < 335 | 625 # T < 634 | 28 |
| 335 # T < 340 | 634 # T < 642 | 24 |
| 340 # T < 345 | 642 # T < 651 | 20 |
| 345 # T < 350 | 651 # T < 660 | 16 |
| 350 # T < 360 | 660 # T < 680 | 13 |
| 360 # T < 370 | 680 # T < 700 | 10 |
| 370 # T < 380 | 700 # T < 716 | 9 |
| 380 # T < 390 | 716 # T < 735 | 8 |
| 390 # T < 400 | 735 # T < 752 | 7 |
| 400 # T < 410 | 752 # T < 770 | 6 |
| 410 # T < 430 | 770 # T < 805 | 5 |
| 430 # T < 450 | 805 # T < 840 | 4 |
| 450 # T < 470 | 840 # T < 880 | 3 |
| 470 # T < 490 | 880 # T < 915 | 2 |
| T $ 490 | T $ 915 | 1 |

Temperature Exposures - Thermoplastic Cables

Damage timing for thermoplastic cables is based primarily on the data reported in NUREG/CR-5384 for PE insulated cables. These data were analyzed in a manner similar to that used in the analysis of the Thermoset cable response as discussed above. However, in the case of the thermoplastic cables, there was considerable scatter in the data. In particular, very short damage times are reported for some cases at the lowest exposure temperatures. The reasons for this scatter are not clear.

The data used in the analysis are again shown in two figures essentially identical to those discussed in the thermoset section above. Figure 6.2.3 shows the direct time to failure versus exposure temperature as directly recorded in the tests for those cases used in the analysis. Figure 6.2.4 shows the inverse of the time to failure - temperature relationship.
Using a similar analysis approach, the following linear regression curve was obtained:

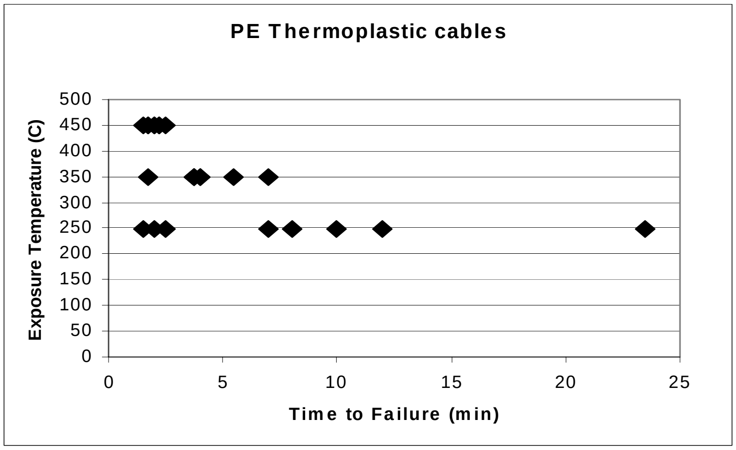

Figure 6.2.3: Raw time to damage plot for thermoplastic PE cables.

1/(time to damage : seconds) = 3.488E-05 ×(Temp: °C) - 7.467E-03
Using this relationship, a table of time to damage values was generated. Again, results of the linear

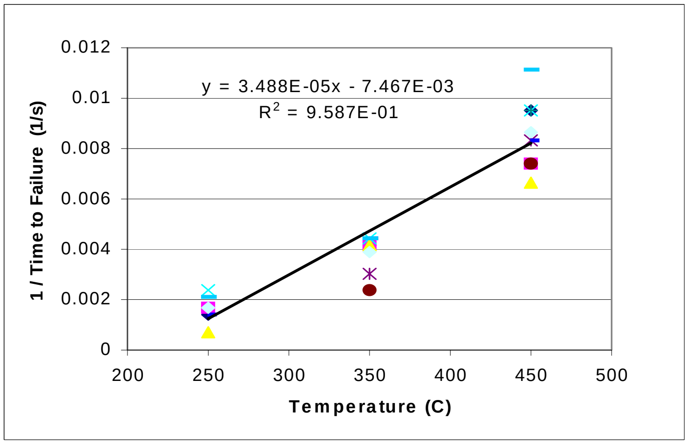

Figure 6.2.4: Time to damage plot for thermoplastic cables showing linear regression curve.

regression were adjusted for values that fell outside the data range where extrapolation is necessary.

**Table A9.7 - Failure Time-Temperature Relationship for Thermoplastic Cables**

| Exposure Temperature | | Time to Failure (minutes) |
|---|---|---|
| **°C** | **°F** | |
| 205 # T < 220 | 400 # T < 425 | 30 |
| 220 # T < 230 | 425 # T < 450 | 25 |
| 240 # T < 245 | 450 # T < 475 | 20 |
| 245 # T < 260 | 475 # T < 500 | 15 |
| 260 # T < 275 | 500 # T < 525 | 10 |
| 275 # T < 290 | 525 # T < 550 | 8 |
| 290 # T < 300 | 550 # T < 575 | 7 |
| 300 # T < 315 | 575 # T < 600 | 6 |
| 315 # T < 330 | 600 # T < 625 | 5 |
| 330 # T < 345 | 625 # T < 650 | 4 |
| 345 # T < 355 | 650 # T < 675 | 3 |
| 355 # T < 370 | 675 # T < 700 | 2 |
| T $ 370 | T $ 700 | 1 |

### Radiant Exposures - Thermoset and Thermoplastic Cables

As noted in Section 6.2.4, the available data for radiant exposure of cables is less complete than that for convective exposures. Most radiant heat tests have been conducted at relatively high heat flux levels, often representative of flashover conditions. This leads to relatively short damage times. The available tests generally reported damage times ranging from as short as a few seconds up to no more than 5-10 minutes. The SDP is also interested in marginal exposure conditions where damage times are expected to be upwards of 30 minutes or more. Given the data limitations, expert judgement has been applied to fill in our gaps in the understanding of radiant heating exposure conditions and the timing of cable damage.

The two tables provided below document the recommended cable damage time/heat flux relationship for thermoset and thermoplastic cables.

**Table A9.8- Estimated Damage Time for Radiant Heating Exposures, Thermoset Cables**

| Exposure Heat Flux | | Damage Time (minutes) |
|---|---|---|
| **$BTU/ft^2s$** | **$kW/m^2$** | |
| <1.0 | <11 | No Damage |
| 1.0 | 11 | 19 |
| 1.2 | 14 | 12 |
| 1.4 | 16 | 6 |
| 1.6 | 18 | 1 |
| 1.75 or greater | 20 or greater | 1 |

| Table A9.9 - Estimated Damage Time for Radiant Heating Exposures, Thermoplastic Cables | | |
|---|---|---|
| **Exposure Heat Flux** | | **Damage Time (minutes)** |
| **BTU/ft²s** | **kW/m²** | |
| <0.5 | <6 | No Damage |
| .5 | 6 | 19 |
| .7 | 8 | 10 |
| 0.9 | 10 | 6 |
| 1.0 | 11 | 4 |
| 1.25 | 14 | 2 |
| 1.4 or greater | 16 or greater | 1 |

### 6.2.6.1 Task 2.6.1: Fire Growth and Damage Time Analysis - FDS1 Scenarios

The damage criteria applied in the plume and hot gas layer analyses (400°F and 625°F for thermoplastic and thermoset cables) are based on testing information as interpreted in the FIVE method. The timing information for failures above the threshold are based the data presented in NUREG/CR-5546.

The radiant heat flux thresholds and timing information are drawn from EPRI NP-1767, and in particular from Figures 3-5, 3-7, 3-8, and 3-15 of that report. Note that the critical heat flux values reported by FMRC/EPRI based on extrapolation of the test data are not appropriate as indicators of thermal damage limits. In fact, the FMRC/EPRI data clearly show failure cases at heat fluxes well below the reported critical values (this is shown clearly in the Figures 3-5, 3-7 and 3-8 in particular). Observations based on these data are as follows:

- As noted in the EPRI report, the onset of thermal degradation is a strong indication that piloted ignition is imminent. Hence, the use of the thermal degradation results as a nominal indication of piloted ignition thresholds appears appropriate.
    - The onset of piloted ignition is also taken as a nominal indication of the immanent onset of thermal damage per NUREG/CR-5546.

- The lowest heat flux exposure level reported in the EPRI report for the thermal degradation tests is 10 $kW/m^2$ (approximately 1.1 $BTU/ft^2s$).

- Figure 3-5 shows the onset of thermal degradation within approximately 10 minutes for a EPR/Hypalon (thermoset) cable exposed at heat fluxes as low as 10 $kW/m^2$ (approximately 0.9 $BTU/ft^2s$). Hence, use of a piloted ignition screening criteria of 11 $kW/m^2$ (1.0 $BTU/ft^2s$) appears a reasonable interpretation of these results.

- Figure 3-7 also shows degradation of a PE/PVC (thermoplastic cable) occurring at the same heat flux levels, but in a shorter time frame (about 5 minutes). It is reasonable to postulate that thermoplastic cables are more susceptible to fire ignition and damage than are thermoset cables. Hence, use of a piloted ignition screening criteria of 6 $kW/m^2$ (0.5 $BTU/ft^2s$) appears a reasonable interpretation of these results.

- For the thermal damage tests, the lowest reported heat flux exposure level for which results are presented is approximately 37 $kW/m^2$ (approximately 3.3 $BTU/ft^2s$).

- At this flux level XPE/Neoprene (thermoset) cables are observed to fail in on the order of as little as 5 minutes
- At this flux level, PE/PVC (thermoplastic) cables were observed to fail within as little as 3 minutes (apparently depending on the size of the test sample)

No results are available for thermal damage times at lower heat flux levels / longer times.

The heat flux damage time estimates have been extrapolated according to these results, and using the lower heat flux results for thermal degradation.

#### 6.2.6.2 Task 2.6.2: Fire Growth and Damage Time Analysis - FDS2 Scenarios

FDS2 fire scenarios involve widespread damage to components and cables in the room of fire origin. In fire PRA, this mode of damage would typically be assessed using a compartment fire model. For SDP Phase 2 analyses, the application of compartment fire models was considered outside the desired scope due to the relatively high level of fire protection expertise required to properly implement and exercise such models. Hence, the fire growth and damage time analysis for FDS2 scenarios has been highly simplified. The assessment considers three potential mechanisms by which widespread fire-induced damage might occur; namely, direct spread of fire to the target location, damage by a hot gas layer, and failure of a degraded raceway fire barrier system.

#### 6.2.6.3 Task 2.6.3: Fire Growth and Damage Time Analysis - FDS3 Scenarios

FDS3 corresponds to what are commonly called room-to-room or inter-compartment fire scenarios in a typical fire PRA. Even in fire PRA, these scenarios are analyzed using very simple probabilistic models. The approach used in the SDP Phase 2 analysis is based on the adaptation of methods documented in the EPRI FIVE methodology. Note also that the screening rules used in Tasks 1.3.2 and 2.2.2 also derive from the same source so that consistency is nominally maintained.

### 6.2.7 Step 2.7: Fire Non-Suppression Probability Analysis

#### 6.2.7.1 Task 2.7.1: Fire Detection Time Analysis

It is important to note that fire detection time plays only one role in the Fire Protection SDP analysis; namely, it is a benchmark time from the point of fire ignition to triggering of the human response to the fire event. In this context, fire detection by any one of several paths is possible. The SDP approach is to credit just one of the available paths - that which is most likely to succeed first. In most cases, this will be detection by a fixed detection system (if available). The other paths are considered should there be no fixed detection system or the fixed detection system is found to be highly degraded (i.e., essentially non-functional).

<u>Detection by a Continuous Fire Watch</u>

A continuous fire watch is given substantial credit for prompt detection unless conditions specific to the fire watch warrant otherwise. It is well established in the literature that humans are highly effective as fire detectors (based primarily on the human sense of smell).

Detection by a Fixed Detection System

The correlation applied in the detection time analysis is a well-established handbook correlation. For further information see NUREG-1805.

Detection by a Roving Fire Watch

A roving fire watch is expected to detect a fire if one is in existence at the time they enter the fire area. The mean time to response is used, which corresponds to one-half the period between patrols.

Detection by General Plant Personnel

Detection by plant personnel has been set to a uniform 15 minutes barring other means of detection. This value was established based on input from a supporting panel of fire protection and fire risk analysis experts. The value applied, while admittedly somewhat arbitrary, is considered a reasonable upper bound estimate of the time to fire detection given a significant and potentially challenging fire in or at the plant, especially given other aspect of the simplified fire modeling approaches used in the SDP (e.g., fires reach peak intensity at time zero).

The manual detection path covers routine activities by plant maintenance or security personnel, observations of the control room staff (e.g., unexplained control indications or instrument reading). The fire event database contains many fires that were detected by such plant personnel. The evidence suggests that these fires were generally first detected either very shortly after ignition (as evidenced by other events or observations) or at the least well before substantial damage had occurred.

### 6.2.7.2 Task 2.7.2: Fixed Fire Suppression System Actuation Analysis

The correlation applied in the actuation time analysis for fixed fire suppression systems is a well-established handbook correlation. For further information see NUREG-1805.

### 6.2.7.3 Task 2.7.3: Plant Personnel and the Manual Fire Brigade Response Time

The approach applied in the analysis of manual fire fighting response, using historical evidence, is a well established and accepted approach in general fire PRA practice. Specific considerations relevant to this particular approach are the following:

- Fire suppression by a hot work fire watches is a unique case. Historical evidence shows that hot work are effective at providing prompt suppression of most fires. This observation has been credited in the fire frequency statistics - fires suppressed promptly by a hot work fire watch have <u>not</u> been included in the base fire frequency. Hence, no additional credit for hot work fire watches is given in this step. (Note that a degraded hot work fire watch finding is reflected by an increase in fire frequency for the same reason.)

- Roving fire watches are not credited for fire suppression in the Phase 2 analysis. Roving fire watches are credited for effecting fire detection (see Task 2.7.1).

- The final line of defense for fire suppression of any fire is the plant fire brigade. The fire brigade response is assessed based on historical evidence from past fires.

Historically, most fires have been suppressed by plant personnel including especially the plant fire brigade. Hence, a large base of historical data exists upon which this analysis is based. In practice, this historical evidence also includes fires suppressed by other members of the plant staff (e.g., security or maintenance personnel who happen upon a fire and effect successful suppression). The approach to analysis is well documented in the literature.

#### 6.2.7.4 Task 2.7.4: Probability of Non-Suppression

$\underline{\text{PNS}}_{\text{Fixed}}$

For cases where the predicted time to fire suppression (fixed suppression system actuation) and to fire damage are close, we assume that the damage will occur. Due to uncertainty in the fire dynamics tools, meaningful credit is not given for the fire suppression system until the delta between suppression and damage time is significant.

Note that in practice, the equation which combines the fixed and manual fire suppression credits ensures that the maximum credit for wet pipe water systems is 0.98 reflecting the general reliability of such systems. For other types of fixed fire suppression, the maximum credit applied is 0.95. These types of systems require an electrical actuation circuit that has a probability of failure in addition to the failure of the mechanical system. (See Estimates of the Operational Reliability of Fire Protection Systems, Bukowski, R. W., et al, International Conference on Fire Research and Engineering, Third Proceedings, 87-98, 1999.)

$\underline{\text{PNS}}_{\text{Manual}}$

See Section 6.2.7.3 above.

$\underline{\text{PNS}}_{\text{Scenario}}$

The roll-up of manual and fixed suppression credits is based on a direct application of event tree - fault tree analysis approaches.

The failure probability values assumed for fixed fire suppression systems (0.02 or 0.05 per demand) is typical of the values assumed in past fire PRAs including the IPEEEs and is discussed above.

#### 6.2.7.5 Task 2.7.5: Finding Screening Check

The screening check is consistent with the previous quantitative screening steps, and the basis remains unchanged. In this step, the new information of probability of non-suppression for individual scenarios is applied. In addition, the designated safe shutdown path is credited as appropriate to each individual fire scenario rather than based on the most conservative result for a given fire ignition source scenario. The information developed in Step 2.6 and 2.7 are consistent with this refinement of the screening CDF calculation.

### 6.2.8 Step 2.8: Analysis of Plant Safe Shutdown Response

In this section, the basis for the human performance tables used in Step 2.8 is presented. The tables were developed taking into account a proposed approach for remote shutdown operations evaluation developed for the Office of Research in August, 2000 and reformatting that approach using the general performance shaping factor (PSF) categories of the SPAR-H method. These tables are based on current understanding of the factors that influence human performance as captured in the above references and in NUREG-1624, Rev. 1 ATHEANA.

The PSF categories adopted from the SPAR-H method are: ergonomics, procedures, training/experience, complexity, and available time. The PSF, fitness for duty, is not considered since it is assumed to be nominal. The PSF, work processes, is assumed to be adequately addressed in the other PSFs, but one aspect, namely communications, is considered as a subset of the PSF, ergonomics.

For each of these PSF categories, a set of task and scenario characteristics has been identified based on the above references. Where it is reasonable to do so, specific performance shaping factors related to the task and scenario characteristics are identified. For each of these combinations of task and scenario characteristics and PSFs, a rating factor characterizes the relative influence on success of the task.

When the time for accomplishing the operator actions is expansive, meaning that the time available is many times greater than the time required to perform the actions, the credit for operator action is increased unless factors are identified that would prevent the actions being completed. The rationale for this is that it would be possible to bring more resources to bear that could partially compensate for the negative factors.

The analysis of CCDP includes treatment of spurious operations resulting from fire-induced cable failures. A table of values for the conditional probability of spurious operation given failure of a cable (PSA) is provided in the table below. The table covers three general cable types (armored, thermoset, and thermoplastic) and various installation configurations. The cited values are ultimately based on data gathered during a joint USNRC/industry test effort. The actual PSA values cited are based primarily on the EPRI Expert Panel Report (TR 1006961), the associated supporting test data analysis report by EPRI (TR 1003326), and independent analysis conducted under USNRC/RES sponsorship (NUREG/CR-6776).

**Table A9.10 - PSA Factors Dependent on Cable Type and Failure Mode**

| State of Cable Knowledge | Thermoset | Thermoplastic | Armored |
|---|---|---|---|
| No available information about cable type or current limiting devices (worst-case value from NEI 00-01 Table 4-4) | .6 (1) | | |
| Cable type known, no other information known (NOI) | .6 (1) | .6 (1) | .15(2) |
| Inter-cable interactions only | .02 (3) | .2 (4) | 0 (5) |
| In conduit, cable type known, NOI | .3 (6) | .6 (7) | |
| In conduit, inter-cable only | .01 (8) | .2 (9) | |
| In conduit, intra-cable | .075 (10) | .3 (11) | |

Notes

1. Worst-case value from NEI 00-01 Table 4-4 and EPRI-1006961 Table 7-2
2. Worst-case value for armored variant of $P_{SACD}$ from NEI 00-01 Table 4-4 and EPRI-1006961 Table 7-2, doubled because presence of CPTs is unknown as with Case # B-15 (.075 * 2 = .15)
3. Case B-3 from NEI 00-01 Table 4-4, doubled because presence of CPTs is unknown
4. Case B-7 from NEI 00-01 Table 4-4, doubled because presence of CPTs is unknown
5. Based on the Hannon to Carpenter memo of March 19, 2003, which stated that inter-cable hot shorts in armored cable were virtually impossible without prior grounding to the cable armoring
6. Half of the value for thermoset cable in a tray (.6), per discussion with D. Funk and S. Nowlen
7. Only one test evaluated thermoplastic cable in conduit. No estimate of spurious actuation probabilities for thermoplastic cable in conduit was made in either the expert panel report (EPRI-1006961) or the circuit failure

characterization report (EPRI-1003326). However, the EPRI characterization report, in describing the results of Test 16, indicated that the number of spurious actuations is lower than for other tests of thermoplastic cable. Therefore, the value is considered to be less than the worst-case thermoplastic value from NEI 00-01 Table 4-4 and EPRI-1006961 Table 7-2 is used, doubled because presence of CPTs is unknown

8. Half of the value for thermoset inter-cable interactions in a tray (.02), per discussion with D. Funk and S. Nowlen
9. Only one test evaluated thermoplastic cable in conduit. No estimate of spurious actuation probabilities for thermoplastic cable in conduit was made in either the expert panel report (EPRI-1006961) or the circuit failure characterization report (EPRI 1003326). However, the EPRI characterization report, in describing the results of Test 16, indicated that the number of spurious actuations is lower than for other tests of thermoplastic cable. Therefore, the value is considered to be less than the thermoplastic value for inter-cable interactions in a tray.
10. Value taken from Case B-11 in NEI 00-01 Table 4-4 and EPRI-1006961 Table 7-2.
11. Only one test evaluated thermoplastic cable in conduit. No estimate of spurious actuation probabilities for thermoplastic cable in conduit was made in either the expert panel report (EPRI-1006961) or the circuit failure characterization report (EPRI-1003326). However, the EPRI characterization report, in describing the results of Test 16, indicated that the number of spurious actuations is lower than for other tests of thermoplastic cable. Therefore the value is less than the value for case B-5 in NEI 00-01 Table 4-4 and EPRI-1006961 Table 7-2.

### 6.2.9 Step 2.9: Final Quantification and Color Assignment

The final quantification of finding risk significance utilizes the most detailed results developed in the Phase 2 analysis for each aspect of the risk equation. The quantification equation itself is based directly on common practice in general fire PRA. The assignment of colors to a finding is based on the relevant USNRC guidance for this and other SDP applications.

# 7.0 REFERENCES

NRC Documents:

Code of Federal Regulations: 10CFR50 Appendix R: The U.S. Code of Federal Regulations, Title 10 - "Energy," Part 50 - "Domestic Licensing of Production and Utilization Facilities," Appendix R - "Fire Protection Program for Nuclear Power Facilities Operating Prior to January 1, 1979."

USNRC: Inspection Manual Chapter 0609, Appendix F, *Fire Protection Significance Determination Process*, USNRC: Feb., 2001.

USNRC: SECY-99-007A, *Recommendations for Reactor Oversight Process Improvements (Follow-up to SECY-99-007)*, USNRC, March 22, 1999.

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NUREG-1805, Iqbal, N., Salley, M.H., *Fire Dynamics Tools (FDT) Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Inspection Program,* Draft for Public Comment, USNRC, June 2003.

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NUREG/CR-5655: Jacobus, M.J., Fuehrer, G.F., *Submergence and High Temperature Steam Testing of Class 1E Electrical Cables*, USNRC, Sandia National Laboratories, May 1991.

NUREG/CR-5384: Nowlen, S.P., *A Summary of the USNRC Fire Protection Research Program at Sandia National Laboratories; 1975-1987*, USNRC, Sandia National Laboratories, December 1989.

NUREG/CR-5546: Nowlen, S.P., *An Investigation of the Effects of Thermal Aging on the Fire Damageability of Electric Cables*, USNRC, Sandia National Laboratories, May 1991.

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