Appendix F - Fire Protection Significance Determination Process (SDP)

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Revision Notes:

- This document is a draft work in progress.
- Highlighted Text identifies gaps that remain in the document and what type of input is needed to resolve the gaps. In all cases, highlighted text is temporary - it will be deleted in the final document.

U. S. Nuclear Regulatory Commission
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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 (ΔCDF) at a nuclear power plant (NPP). In this context, risk significance is based on the ΔCDF acceptance guidelines in Regulatory Guide (RG) 1.174.

A performance issue that leads to an increase in core damage frequency (ΔCDF) 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 1.1 Risk Significance Based on ΔLERF vs ΔCDF

Frequency Range/ry	SDP Based on ΔCDF	SDP Based on ΔLERF
$\geq 10^{-4}$	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:

- Phase 1: Characterization and initial screening of findings
- Phase 2: Initial approximation and basis of risk significance
- 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, safe shutdown (SSD) systems and equipment, or any other aspect of the fire protection program. (Note that findings related to the manual fire brigade are evaluated under a separate SDP process.)

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 inspector 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.

1.2 Applicability

The Fire Protection SDP is designed to provide NRC inspectors 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.

[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 describes 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 inspectors can easily use to obtain a quick 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.

3.0 ABBREVIATIONS AND DEFINITIONS

3.1 Abbreviations

General 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
FDS	Fire Damage State
FPS	Fire Protection System
GDC	General Design Criterion
IMC	Inspection Manual Chapter
IPEEE	Individual Plant Examination of External Events
LER	Licensee Event Report
LERF	Large Early Release Frequency
MCR	Main Control Room
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

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

3.2 Definitions

Alternative 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. (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 areas.

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 compartment of fire origin, and to components or cables protected by a degraded local fire barrier system (e.g., a degraded cable tray fire barrier wrap).
FDS3: Fire damage extends to a fire area adjacent to the compartment 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)

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.

Raceway: An enclosed channel of metal or nonmetallic materials designed expressly for holding wires, cables, or busbars, 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). (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 at any time a screening test indicates that a finding “screens to green,” the finding is assigned a green color rating, and the SDP analysis is complete. The fire protection SDP process contains numerous screening steps in both Phase 1 and Phase 2 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.

4.0 APPROACH AND PROCEDURE FOR SIGNIFICANCE DETERMINATION

4.1 Road Map

The Fire Protection SDP 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:

- Prevention of 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 is based on simplified methods and approaches of a typical fire PRA. 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 of the Fire Protection SDP involves a preliminary screening assessment. The objective of Phase 1 is to identify findings that can be quickly classified as Green so that the finding(s) are 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 a quantitative approach involving several analysis steps of progressively greater refinement and detail. Quantitative screening checks are made each time new or refined analysis detail has been developed. The quantification and screening process is summarized in Table 4.1.1 highlighting the introduction of new or refined information.

Table 4.1.1: Summary of Phase 1 and 2 quantification/screening steps.

Step	Refined or New Information Added	Estimated change in CDF 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 Approach

4.2.1 Phase 1 Qualitative Screening Approach

Phase 1 of the Fire Protection SDP is a preliminary screening check intended for use by the Resident or Regional Office inspector(s) that may allow fire protection findings with a very low risk significance to Screen to Green without detailed analysis. 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 as illustrated in Figure 4.2.1. The finding is first characterized (Step 1.1) based on the fire protection program element that was found to be degraded. The finding is then assigned a degradation rating (Step 1.2) based on the potential impact the degraded condition might have on the performance of the degraded fire protection program element. Phase 1 also involves an initial qualitative screening check (Step 1.3) based on the answers to two questions, and an initial quantitative screening check (Step 1.4) that considers room fire frequency and the duration factor for the finding.

4.2.2 Phase 2 Quantification Approach

Given that a finding did not screen to Green in Phase 1, a Phase 2 analysis is performed. Phase 2 involves a quantitative assessment of the increase in CDF due to a finding. Phase 2 involves nine analysis steps as illustrated in Figure 4.2.2. Each step represents the introduction of new detail and/or the refinement of previous analysis results.

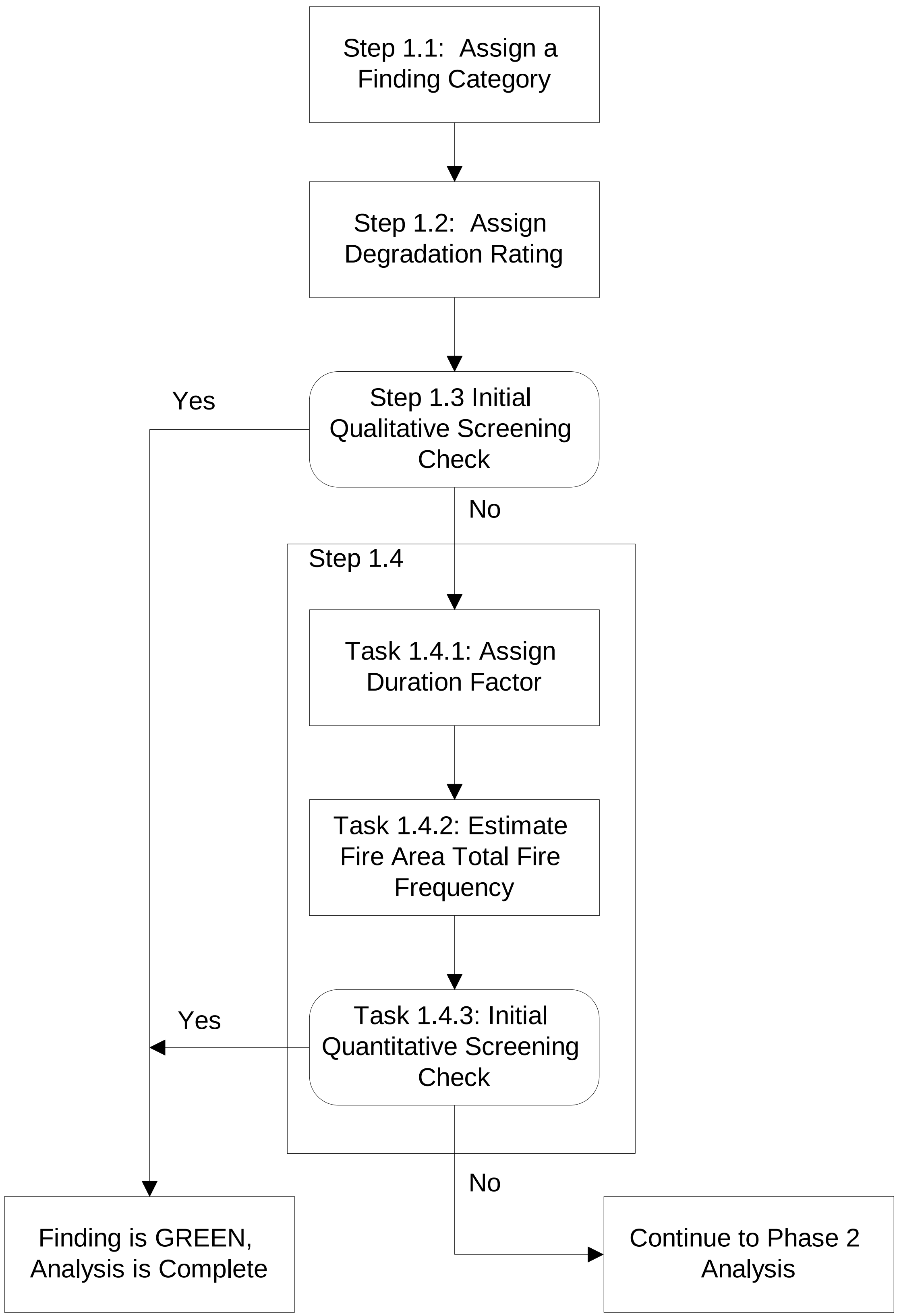
The Phase 2 analysis includes five distinct screening checks. Each time new or refined analysis results are developed, a screening check is made to determine if a sufficient basis has been developed to justify assignment of a preliminary significance ranking of Green. If at any time the quantitative screening criteria are met, the analysis is considered complete, and subsequent steps need not be performed.

The quantification process parallels the approaches used in typical fire PRA practice. For the Phase 2 analysis a simplified version of typical fire PRA approaches are applied. In a fire PRA the fire-induced CDF is quantified as the product of the following three terms:

> Fire Frequency - the likelihood that a fire occurs during a reactor operating year (ry). Note that fire frequency term will also include consideration of fire severity, that is, the likelihood that a fire, if left unchecked, could become severe enough to challenge plant safety.
>
> Fire Damage State Non-Suppression Probability - the likelihood that the fire damages a particular set of plant components/cables; or equivalently, the likelihood that suppression efforts fail to suppress the fire before a pre-defined set of plant cables and/or components is damaged.
>
> Conditional Core Damage Probability (CCDP) - the likelihood that the fire-induced damage to plant components and cables leads to core damage.

The Fire Protection SDP provides a simplified approach that allows the inspector to quantify each of these three factors in the context of a given inspection finding. The Phase 2 quantification process involves nine steps summarized as follows:

Figure 4.1: Phase 1 Flow Chart



Step 2.1 - Independent SSD Path First Screening Assessment: The inspector identifies the designated post-fire SSD path for fires in the fire area under analysis and assigns to it a nominal reliability/failure probability. The SSD path is credited in subsequent quantification calculations based on its independence from potential SDP fire scenarios.

Step 2.2 - Fire Damage State Determination: Based on the finding category assigned in Step 1.1, the inspector determines which FDS scenarios must be analyzed. Step 2.2 includes an explicit screening check for the FDS3 (inter-compartment) scenarios.

Step 2.3 - Fire Scenario Identification and Ignition Source Screening: The inspector will identify one or more fire scenarios to be considered for each FDS retained from Step 2.2. This step involves the identification and characterization of potentially threatening fire ignition sources. A screening analysis is performed to eliminate (screen out) fire ignition sources that cannot lead to fire spread and cannot damage components and cables in the fire area. For unscreened fire ignition sources, the inspector identifies specific fire growth and damage scenarios (ignition source and damage target set combinations) corresponding to each applicable FDS.

Step 2.4 - Fire Frequency For Unscreened Fire Ignition Sources: Refined fire frequency estimates are generated both for the fire area(s) as a whole based only on the retained or unscreened fire ignition sources, and for each retained fire scenario. Fire severity factors may be applied to specific fire scenarios if the ignition source screened out at the expected fire intensity, but was retained at the high confidence fire intensity.

Step 2.5 - Independent SSD Path Second Screening Assessment: In this step, the potential independence of the designated post-fire SSD path identified in Step 2.1 is re-evaluated in the context of each of the retained fire ignition source scenarios (i.e., scenarios retained after Step 2.3).

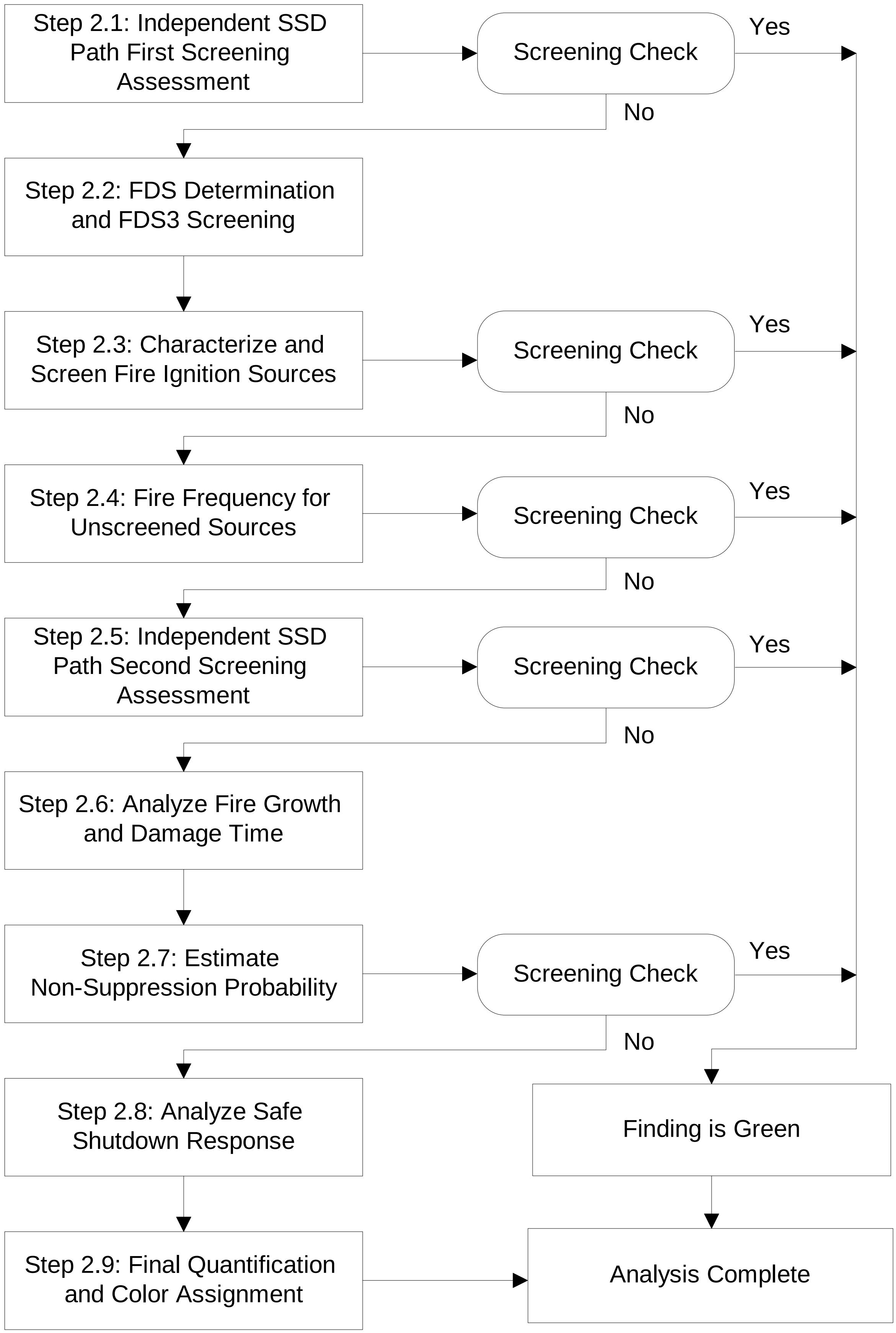
Step 2.6 - Fire Growth and Damage Scenario Time Analysis: The fire growth and damage behavior is analyzed. The output of the analysis is an estimate of the time required to reach the applicable FDS for each retained fire scenario.

Step 2.7 - Fire Non-Suppression Probability Analysis: This step considers each retained fire scenario and estimates the likelihood that fire suppression efforts fail to suppress the fire before the time of fire damage (estimated in Step 2.6).

Step 2.8 - Plant Safe Shutdown Response Analysis: In this step, a more complete analysis of the post-fire SSD response is performed using the USNRC Risk-Informed Inspection Notebooks.

Step 2.9 - Quantification and Preliminary Significance Determination: The results of Steps 2.3 through 2.8 are combined and a final Phase 2 preliminary estimate of the increase in CDF due to the finding is developed. A preliminary significance color is assigned to the finding accordingly.

Figure 4.2: Phase 2 Flow Chart



Note that, in order to optimize the efficiency of the analysis, Phase 2 includes five quantitative 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. The Phase 2 screening checks are summarized as follows:

- Upon completion of Step 2.1, if the designated post-fire SSD path meets the established physical independence criteria, its reliability is credited for all fire scenarios: $CCDP_{2.1}$ = (SSD Path Failure Probability). If the independence criteria are not met, the SSD path is not credited: $CCDP_{2.1}$=1.0. If the SSD path is credited, a screening CDF change is calculated as follows:

$$\Delta CDF_{2.1} \approx DF \times F_{area} \times CCDP_{2.1}$$

- Upon completion of Step 2.3, if all fire ignition sources screen out as non-spreading and non-damaging, the finding Screens to Green (no credible threatening fire scenario).

- Upon completion of Step 2.4, the quantitative screening check is repeated using the refined fire frequencies and fire severity factors where appropriate. The refined screening CDF is calculated as follows:

$$\Delta CDF_{2.4} \approx DF \times \left[\sum F_{Source} \times SF_{Source} \right]_{\substack{AllUnscreened \\ Sources}} \times CCDP_{2.1}$$

- Upon completion of Step 2.5, the designated post-fire SSD path may be credited on a scenario specific basis if the physical independence criteria are satisfied for a given fire ignition source scenario (i.e., based on the worst case plant damage state scenario associated with a given fire ignition source scenario). The refined screening CDF change is calculated as follows:

$$\Delta CDF_{2.5} \approx DF \times \left[\sum F_{Source} \times SF_{Source} \times CCDP_{2.1\text{-Source Limiting}} \right]_{\substack{All\ Unscreened \\ Sources}}$$

- Upon completion of Step 2.7, the inspector uses the newly developed non-suppression probability values in conjunction with the factors considered in the previous screening check to estimate the risk significance of the finding. The inspector can also apply the CCDP in this step based on its independence from individual FDS plant damage state scenarios (i.e, based on each individual plant damage state rather than the worst case for a given fire ignition source scenario). The refined screening CDF change is calculated as follows:

$$\Delta CDF_{2.7} \approx DF \times \left[\sum F_{Source} \times SF_{Source} \times PNS_{Scenario} \times CCDP_{2.1\text{-Scenario}} \right]_{AllScenarios}$$

Given completion of Step 2.8, all quantification steps of the Phase 2 analysis are complete, and the finding is assigned a color accordingly. While the final color may be green, this is not considered a screening step, but rather, reflects the final quantification answer.

4.3 Phase 1: Initial Screening Procedure

Phase 1 of the Fire Protection SDP is a preliminary screening evaluation of a fire protection finding or a set of findings. The Phase 1 screening process is intended to screen out findings that meet the licensing basis requirements, and do not substantially impact the effectiveness of a fire protection DID element. Since this Fire Protection SDP methodology is provided to assess the risk significance of fire protection inspection findings during normal power plant operating conditions, findings related only to fire protection and mitigative capability under cold shutdown conditions are screened out as Green. The Phase 1 screening process is entered when the following items are checked:

- The inspection finding has a clearly stated licensee performance deficiency.

- The statement of licensee performance deficiency should discuss the noncompliance with any applicable licensing basis requirements. The SDP analysis should not proceed if the condition of the fire protection feature was specifically approved in a Safety Evaluation Report (SER) during the fire protection licensing process.

- The finding is considered “more than minor” based on IMC 0612 criteria.

Once the above checklist is satisfied, the Phase 1 screening process proceeds through a three-step screening process described in Section 4.3.1 through 4.3.4.

4.3.1 Step 1.1 - Assign a Finding Category

The inspector assigns a Finding Category based on which element of the plant fire protection program is impacted by the finding. Section 5.1.1 provides examples to illustrate how findings are assigned to one of the following categories:

- Cold shutdown
- Fire prevention and administrative controls
- Fixed fire protection (e.g., detection and suppression)
- Fire confinement (i.e., inter-area fire barriers)
- Localized cable or component fire barriers (e.g., raceway fire barriers)
- Post-fire safe shutdown (SSD)

4.3.2 Step 1.2 - Assign a Degradation Rating

In this step, the inspector assigns a degradation rating reflecting the severity of the observed deficiency. Findings are, in general, rated as reflecting ‘High’, ‘Moderate’, or ‘Low’ degradation of the impacted fire protection program element. For some specific types of findings, only two degradation levels may be defined (e.g., either high or low with no moderate level defined). In other specific cases a modestly more refined degradation rating may be applied (e.g., both ‘Moderate A’ and ‘Moderate B’ ratings may be defined).

The degradation rating impacts both the Phase 1 screening process, and Phase 2 quantification. That is, the degradation rating assigned in Step 1.2 is retained throughout the analysis process.

The exact definition of the degradation rating depends on the impacted fire protection program element. Degradation rating guidance that is specific to various fire protection program elements is provided in Section 5.1. All of the element-specific degradation rating guidance reflects the following generic definitions of low, moderate, and high degradation:

- A LOW degradation reflects a fire protection program element whose performance and reliability will be minimally impacted by the inspection finding. That is, the system, feature, or provision impacted by the finding is expected to display nearly the same level of effectiveness and reliability as it would had the degradation not been present.
    - Note: Findings assigned a LOW degradation rating will, by definition, Screen to Green during the Phase 1 qualitative screening assessment (Step 1.3) and will not be quantitatively assessed.

- A MODERATE degradation implies that a fire protection program element displays significant degradation that will impact performance and/or reliability. However, the element impacted by the finding is still expected to provide some substantial DID benefit despite the noted deficiency. (For some DID elements, moderate degradations may be further subdivided, e.g., Moderate A and Moderate B.)

- A HIGH degradation implies that the performance or reliability of the fire protection program element is severely degraded such that little or no fire protection benefit is anticipated given the deficiency. High degradation implies that no credit will be given to the degraded fire protection program element in quantification of risk significance.

4.3.3 Step 1.3 - Initial Qualitative Screening

In Step 1.3, the finding is screened based on the following two questions:

1. Was the finding assigned a LOW degradation rating?
   □ If Yes - Screen to Green, no further analysis required
   □ If No, continue with Question 2

2. Does the finding only affect ability to reach and maintain cold shutdown conditions?
   □ If Yes - Screen to Green, no further analysis required
   □ If No, continue to Step 1.4

If the answer to both of the above questions is no, then the analysis continues with Step 1.4.

4.3.4 Step 1.4 - Initial Quantitative Screening

In Step 1.4 the inspector performs a preliminary quantitative screening analysis. In Step 1.4 two quantitative factors are considered; namely, total fire frequency for the fire area under analysis, and the finding duration factor. If the product of these two factors is sufficiently small, the finding may be screened to green without further analysis. Step 1.4 involves three analysis tasks described in detail below.

Task 1.4.1: Assign a Duration Factor to the Finding

The inspector assigns a “duration factor” (DF) based on the length of time that the noted performance degradation was, or will be, in existence (i.e., the duration of the degradation). The duration factor is taken from Table 4.3.1. The duration factor determined in Task 1.4.1 is utilized throughout the balance of both the Phase 1 and Phase2 analyses.

Table 4.3.1: Duration Factors

Duration of the Degradation	Duration Factor (DF)
< 3 days	0.01
3 - 30 days	0.1
> 30 days	1.0

Task 1.4.2: Estimate the Fire Frequency for the Fire Area

The inspector estimates the fire frequency for the fire area (or areas) impacted by a deficiency finding using the tables and guidance provided in Section 5.1. For the purposes of Phase 1 screening, fire frequency is estimated based on the area-wide fire frequency, rather than based on the fire frequency for any specific fire hazard within the fire area. It is intended that the fire frequency assigned in this task conservatively bound all fire hazards in the fire area under analysis.

Task 1.4.3: Screening Assessment

The inspector multiplies the fire area fire frequency from Task 1.4.2 by the duration factor from Task 1.4.1 to generate an initial Phase 1 screening change in CDF value ($\Delta CDF_{1.4}$):

$$\Delta CDF_{1.4} = F_{Area} \times DF$$

If the finding impacts multiple fire areas, then the initial Phase 1screening CDF value is based on the sum of the fire frequency for all impacted fire areas as follows:

$$\Delta CDF_{1.4} = (\Sigma F_{Area}) \times DF$$

$\Delta CDF_{1.4}$ is compared to the values in Table 4.3.2. Note that the screening level depends on both the finding category and the assigned degradation rating.

- If $\Delta CDF_{1.4}$ is lower than the corresponding value in Table 4.3.2, the finding Screens to Green and the analysis is complete (no Phase 2 analysis is required).
- If $\Delta CDF_{1.4}$ is greater than or equal to the corresponding value in Table 4.3.2, then the finding does not screen to green, and the analysis continues to Phase 2.

Table 4.3.2: Phase 1 Quantitative Screening Criteria		
Assigned Finding Category (from Step 1.1):	$\Delta CDF_{1.4}$	
	High Degradation	Moderate Degradation
Fire prevention and Administrative Controls	1E-6	1E-4
Fixed Fire Protection Systems		1E-5
Fire Confinement		1E-5
Localized Cable or Component Protection		1E-5
Post-fire SSD		1E-6

4.4 Phase 2: Risk Significance Estimation Procedure

4.4.1 Step 2.1 - Independent SSD Path First Screening Assessment

In Step 2.1, the inspector will identify the designated post-fire SSD path, and will determine if that path can be credited in the initial quantitative screening analysis. A nominal unavailability factor will be assigned to the designated post-fire SSD path, and this value will be carried forward as the Phase 2, Screening Level 1 CCDP value ($CCDP_{2.1}$). Step 2.1 is divided into four analysis tasks as follows:

- Task 2.1.1 - Identify the designated post-fire SSD path
- Task 2.1.2 - Assess unavailability factor for identified SSD path
- Task 2.1.3 - Assess independence of the identified SSD path
- Task 2.1.4 - Screening check

<u>Task 2.1.1 - Identify the designated post-fire SSD path</u>

In Task 2.1.1 the inspector identifies the designated post-fire SSD path for the fire area under analysis. All plant fire areas should have such a SSD path identified as a part of the plant's fire protection program. The identified SSD must meet the following criteria in order to be considered at this stage of the Phase 2 analysis:

- The SSD path must be identified as the designated post-fire SSD path in the plant's fire protection program.
- The SSD path must be supported by a documented post-fire SSD analysis consistent with regulatory requirements.
- Use of the SSD path must be documented and included in the plant operating procedures.

Once the designated post-fire SSD path has been identified, the inspector shall further verify the following characteristics of this SSD path:

- Verify that the licensee has identified and analyzed the SSD SSCs required to support successful operation of the SSD path
- Verify that the licensee has identified and analyzed SSCs that may cause mal-operation of the SSD path (e.g., the required and associated circuits).

- Verify that the licensee has evaluated any manual actions required to support successful operation of the SSD path and has determined that the actions are feasible.
- Verify that all manual actions take place outside the fire area under analysis.
- Verify that the licensee has conducted an acceptable circuit analysis
  - Identify any known unresolved circuit analysis issues that could adversely impact the operability of the designated SSD path.

Additional information that should be gathered includes the following:

- Identify the licensee's compliance strategy for the separation of redundant safe shutdown circuits (i.e., in the context of Appendix R Section III.G.2).
- If the finding category assigned in Step 1.1 is "Fire Confinement" identify any required or associated circuit components or cables that are located in the adjacent fire area(s) separated by the degraded fire barrier element. Also identify any supplemental fire protection (i.e., beyond separation by the degraded barrier element) provided for any such cable or components.

<u>Task 2.1.2 - Assess unavailability factor for identified SSD path</u>

In Task 2.1.2, a screening unavailability factor is assigned to the identified SSD path. The unavailability factor assigned will be either 0.01, 0.1, or 1.0. (Note that a lower number implies that the path is more reliable, that is, the path is less likely to be unavailable.)

The assessment of unavailability at this stage is based on a highly simplified scoping approach. Section 5.2.1.2 provides specific guidance for assigning an unavailability factor to the identified SSD path.

<u>Task 2.1.3 - Assess independence of the identified SSD path</u>

In Task 2.1.3, the inspector shall assess the independence of the identified SSD path. At this stage of the analysis, the inspector has not developed nor screened any specific fire scenarios. Hence, crediting of any SSD path requires that a high level of independence be established. In this context, independence is viewed primarily in the context of spatial orientation and the potential for fire-induced damage to, or fire-induced failure of, the SSD path given a severe and unsuppressed fire.

The first set of independence criteria are based directly on items that should have been verified in Task 2.1.1. Should either of these two criteria not be met, the SSD path is not credited at this stage of analysis:

- Successful operation of the SSD path should not require the execution of any manual actions within the fire area(s) under analysis (verified in Task 2.1.1)

- No known circuit analysis issues (e.g., a known spurious operation issue) for <u>exposed cables</u> should hold the potential to compromise operability of the identified SSD path.
  - Cables within the fire area under analysis <u>are not</u> considered exposed <u>if</u> they are protected by a non-degraded raceway fire barrier with a minimum 3-hour fire endurance rating.
  - Cables within the fire area under analysis <u>are not</u> considered exposed <u>if</u> they are protected by a raceway fire barrier with a minimum one-hour fire endurance

rating, the area is provided with automatic detection and suppression capability, and none of these elements is found to be degraded.

- Cables in and adjoining fire area are not considered exposed if the fire barrier separating adjoining fire area from the fire area under analysis is not degraded.
- If the finding category assigned in Step 1.1 was "Fire Confinement," cables located in the adjacent fire area are considered exposed unless they are protected by a non-degraded localized fire barrier with a minimum 1-hour fire endurance rating.

The second aspect of the independence check depends on the nature of the fire protection that has been provided for the designated SSD path (i.e., in the context of 10CFR50 Appendix R Section III.G.2). Table 4.4.1 provides a matrix of independence criteria for the major options under III.G.2:

If the applicable criteria in Table 4.4.1 are satisfied, then the SSD path will be credited during initial screening in Steps 2.1-2.4. The $CCDP_{2.1}$ value is set to the failure probability of the identified SSD path derived in Step 2.1.2. The analysis continues with Task 2.1.4.

SPECIAL NOTE: Steps 2.5-2.7 include the possibility of crediting the identified SSD path in the context of specific fire scenarios and specific FDS's. Hence, the reliability estimates for the identified SSD path should not be discarded, even if they will not be applied at this stage of the analysis. Rather, the results should be retained for potential use in these later steps.

Table 4.4.1: SSD path independence check criteria

Section III.G.2 compliance strategy for SSD path	**Step 2.1 SSD path independence criteria (all criteria for a given strategy must be met)**
Physical separation into a separate fire area	• The fire area boundary separating the SSD path is not impacted by the finding under analysis
Separation by a 3-hour rated localized fire barrier (e.g., a raceway barrier)	• The fire barrier qualification rating is not in question, and • The fire barrier protecting the redundant train is not impacted by the finding.
Separation by a 1-hour rated localized fire barrier (e.g., a raceway barrier) plus automatic fire detection and suppression coverage for the fire area	• The fire barrier qualification rating is not in question, • The fire barrier protecting the redundant train is not impacted by the finding, • The fire detection system is not impacted by the finding, and • The fire suppression system is not impacted by the finding.
Spatial separation or other means of protection (e.g., exemptions, reliance on remote shutdown)	• SSD Path will not be credited pending further refinement of the SDP fire scenarios

Task 2.1.4 - Screening check

Given that a SSD path meeting the independence criteria in Task 2.1.3 has been identified, and a unavailability factor has been assigned, an additional screening check is performed to assess whether or not the finding can be screened to green. The screening check is similar to that performed in Step 1.4, with the addition of the newly defined $CCDP_{2.1}$ value.

- Note: If the identified SSD path was assigned a failure probability of 1.0, then Task 2.1.4 will provide no added screening benefit over Step 1.4 and should be skipped.

The inspector multiplies the fire area fire frequency from Task 1.4.2 by the duration factor from Task 1.4.1 and by the $CCDP_{2.1}$ from Task 2.1.3 to generate the Phase 2 screening Level 1 change in CDF value ($\Delta CDF_{2.1}$):

$$\Delta CDF_{2.1} = F_{Area} \ X \ DF \ X \ CCDP_{2.1}$$

If the finding impacts multiple fire areas, then the initial Phase 1screening CDF value is based on the sum of the fire frequency for all impacted fire areas as follows:

$$\Delta CDF_{2.1} = (\Sigma F_{Area}) \ X \ DF \ X \ CCDP_{2.1}$$

$\Delta CDF_{2.1}$ is compared to the values in Table 4.4.2. Note that the screening level depends on both the finding category and the assigned degradation rating.

- If $\Delta CDF_{2.1}$ is lower than the corresponding value in Table 4.4.2, the finding Screens to Green and the analysis is complete.

- If $\Delta CDF_{2.1}$ is greater than or equal to the corresponding value in Table 4.4.2, then the finding does not screen to green, and the analysis continues to Step 2.2.

Table 4.4.2: Phase 2 Screening Level 1 Quantitative Screening Criteria

Assigned Finding Category (from Step 1.1):	$\Delta CDF_{2.1}$	
	High Degradation	Moderate Degradation
Fire prevention and Administrative Controls	1E-6	1E-4
Fixed Fire Protection Systems		1E-5
Fire Confinement		1E-5
Localized Cable or Component Protection		1E-5
Post-fire SSD		1E-6

4.4.2 Step 2.2 - Fire Damage State Determination

In Step 2.2, the inspector determines which FDS's must be considered in order to estimate the risk significance of a given finding. This step involves two analysis tasks:

- Task 2.2.1: Initial FDS Assignment

- Task 2.2.2: FDS3 Screening Assessment.

Task 2.2.1 - Initial FDS Assignment

In Task 2.2.1, the inspector completes an initial assessment of which FDS scenarios must be carried forward in the analysis. Using Table 4.4.3, identify which FDS may need to be considered based on the finding category assigned in Step 1.1. All identified FDS scenarios will be considered in subsequent analyses with the possible exception of the FDS3 scenarios (hence, this assessment is preliminary). Task 2.2.2 will consider the potential screening of FDS3 scenarios.

Table 4.4.3: FDS/Finding Category Matrix

Finding Type or Category:	FDS1	FDS2	FDS3
Fire prevention and administrative controls:	Yes	Yes	Yes
Fixed fire protection systems:	Yes	Yes	Yes
Fire confinement:	No	No	Yes
Localized cable or component protection:			
Given a High degradation:	Yes[1]	Yes	Yes
Given a Moderate degradation:	No	Yes	Yes
Post-fire SSD:	Yes	Yes	Yes

Note 1: For a highly degraded local barrier, the protected components/cables are treated as fully exposed and may be assumed damaged in FDS1 scenarios depending on their proximity to the fire ignition source.

Task 2.2.2 - Screening Assessment for FDS3 Scenarios

In Task 2.2.2, the inspector will conduct a screening analysis to determine whether or not to retain the FDS3 scenarios as potentially viable risk contributors.

> SPECIAL NOTE: If the finding category assigned Step 1.1 is “Fire Confinement,” then FDS3 scenarios will not be screened out in this task. As a result Task 2.2.2 is skipped and the analysis continues with Step 2.3. For all other finding categories the FDS3 screening assessment, Task 2.2.2, is conducted.

Specific screening guidance is provided in Section 5.2.2. If the FDS3 scenarios are successfully screened out (per the guidance), then the subsequent analysis will not further consider any FDS3 scenarios. If the FDS3 scenarios do not screen out, then they will continue to be considered in the subsequent analysis steps.

4.4.3 Step 2.3 - Fire Ignition Source Scenario Identification, Characterization, and Screening

In Step 2.3, the inspector identifies, characterizes, and screens fire ignition source scenarios related to the finding being analyzed. Each fire ignition source scenario identified will either contribute one or more fire scenarios to the risk quantification, or will be screened out in Step 2.3. Fire ignition sources will be screened out if they meet the following two criteria:

(1) they cannot cause fire to spread to secondary combustibles, AND

(2) they cannot cause damage to one or more components/cables in the fire area are screened out.

Fire ignition sources that are screened out are not analyzed further and are excluded from the refined fire area fire frequency. Specific guidance supporting this task if provided in Section 5.2.3.

Step 2.3 involves five analysis tasks:

- Task 2.3.1: Identify and count fire ignition sources of potential interest and group sources that will be treated using a representative case examples.

- Task 2.3.2: Characterize each fire ignition source (fire severity and nominal location).

- Task 2.3.3: Identify the nearest fire ignition or damage target to each fire ignition source.

- Task 2.3.4: Conduct a fire ignition source screening check to identify those fire ignition sources that cannot lead to either fire spread to secondary combustibles or fire-induced damage to any cables or other components. The screening check considers both the expected and high confidence fire intensity values.

- Task 2.3.5: Screen finding to Green if ALL fire ignition sources are screened out in Task 2.3.4.

<u>Task 2.3.1: Identify and Count Fire Ignition Sources</u>

In Task 2.3.1, the inspector begins the process of defining fire scenarios by identifying fire ignition sources within the fire area(s) being evaluated.

For most findings, the inspector identifies and catalogs each unique fire ignition source type in each fire area being evaluated.

For certain types of findings only specific fire ignition sources are of interest so the fire ignition source identification task is sharply limited in scope. For findings of the following types, consult Section 5.2.3 for specific guidance on which fire ignition sources to consider:

- Findings related to hot work (e.g., a degraded hot work fire watch, or lack of adequate fire prevention/mitigation provisions during hot work), or
- Violations of the combustible controls program.

For these two cases, a specific count of fire ignition sources is not conducted.

Also note that in the specific case of findings categorized as fire confinement in Step 1.1 (findings of degradation to an inter-area fire barrier element), the inspector must identify and count the fire ignition sources located on BOTH sides of the degraded fire barrier. That is, the scope of Task 2.3.1 and subsequent steps expands to encompass two or more fire areas; and in particular, those fire areas that are separated by the degraded fire barrier element(s).

For all other cases, cataloging of the fire ignition sources includes a count of the number of fire ignition sources of each type present. (The counting results will be used to generate fire frequencies in later steps.) Note that the ignition source count is conducted only for the fire area(s) under analysis, not for the plant as a whole.

Fire ignition sources are binned by type or general classification. That is, the inspector assigns each fire ignition source to one of several fire ignition source type bins. These bins have been pre-defined and are used in generating refined fire frequency estimates in later steps. Hence, all fire ignition sources must be assigned to one, and only one, of the identified fire ignition source type bins.

Section 5.2.3.1 provides guidance and worksheets to support this task. In particular, tables are provided identifying the fire ignition source type bins to be used by inspectors. Specific guidance is also provided on how to count sources for each of these type bins (e.g., how to count electrical panels). A worksheet for recording the results of this task is also provided.

<u>Task 2.3.2: Characterize Fire Ignition Sources</u>

In Task 2.3.2 fire severity characteristics and a nominal location are assigned to each unique fire ignition source identified in Task 2.3.1. Guidance in support of this task is provided in Section 5.2.3.2. Fire ignition sources are classified into to general types - ‘simple’ and ‘non-simple’:

- Simple fire ignition sources are assigned fire characteristics and locations on a fully generic basis using predefined guidance. Most fixed fire ignition sources are of the simple type.

- Non-simple fire ignition sources are either unique or require the application of case-specific information.

Section 5.2.3.2 provides explicit guidance for the characterization of both simple and non-simple fire ignition sources.

Note that the simple fire ignition sources are characterized using five discrete fire intensity levels or heat release rate (HRR) levels; namely, 70 kW, 200 kW, 600 kW, 2 MW, and 10 MW. To address the uncertainty in fire source severity, each fire ignition source is associated with two HRR values:

- The lower HRR value reflects the anticipated or expected fire severity, and will be associated with a fire severity factor of 1.0.
- The higher HRR value reflects a high confidence limit fire severity and will be associated with a 0.1 fire severity factor.

Severity factors, as appropriate to a given fire ignition source are applied during quantification.

> EXCEPTION: Self-ignited cable fires and cable fires ignited during hot work will be assumed to have only one fire intensity; namely, 70 kW. Once ignited, the cable fire will be assumed to spread and grow in accordance with the cable tray fire spread rules provided in Section 5.2.4 below. No severity factor is applied to these fires.

The inspector also assigns a nominal location, or locations, to each unique fire ignition source:

- For most stand-alone fire ignition sources, the location assigned is obvious and corresponds to the location of the individual ignition source.

- For certain types of fire ignition sources, the inspector may choose to group individual fire ignition sources of the same type for the purposes of analysis. In such cases, one or more locations will be assigned to represent the group. Note that grouping of fire ignition sources is most commonly applied in the analysis of electrical panel fires. Specific guidance on when grouping of ignition sources is appropriate is provided in Section 5.2.3.2.

- For certain fire ignition sources, multiple locations may apply, and the inspector must choose a location. This applies to non-fixed sources such as transient fuel fires, hot work fires, oil spill fires, and self-ignited cable fires.

<u>Task 2.3.3: Identify Nearest and Most Vulnerable Ignition or Damage Targets</u>

In Task 2.3.3 those ignition or damage targets that might first become involved in a particular fire scenario are identified by type and relative location. Fire ignition sources that can neither spread nor cause component or cable damage are screened out of the analysis and will not be analyzed further. Identifying the relevant ignition and damage targets for each fire ignition source (or set of sources) is a significant factor in this screening assessment. Specific guidance in support of this task is provided in Section 5.2.3.3.

The fire ignition source screening task considers fire spread and damage that may occur given the following three fire phenomena:

- flame zone and plume behaviors that take place directly above the fire ignition source,
- direct radiant heating of targets (line of sight), and
- hot gas layer effects.

Hence, for each unique fire ignition source scenario, the inspector will identify the following ignition and/or damage targets:

- Secondary combustible materials directly above the fire ignition source that might be ignited by the flame zone and/or plume;
- Secondary combustible materials within a direct line of sight of the fire ignition source that might be ignited by direct radiant heating;
- Thermal damage targets (components or cables) directly above the fire ignition source that might be damaged by the flame zone or plume effects;
- Thermal damage targets (components or cables) within a direct line of sight of the fire ignition source that may be damaged direct radiant heating; and
- The most fragile thermal damage target in the general fire area (for hot gas layer exposures considerations).

For each identified target, a threshold ignition and/or damage criteria will be established using the guidance in Section 5.2.3. A worksheet for recording the results of this task is included.

<u>Task 2.3.4: Fire Ignition Source Screening</u>

In Task 2.3.4 the fire spread/damage potential of each fire ignition source is assessed using zone of influence charts. Supporting guidance is provided in Section 5.2.3.4. Fire ignition sources will be screened out if they meet the following criteria:

- the fire ignition source cannot cause ignition of secondary combustible fuels, AND

- the fire ignition source cannot cause damage consistent with any of the fire damage state scenarios of interest.

Fire ignition sources that screen out (i.e., that meet the above two conditions) will not be analyzed further and will be eliminated from the fire frequency calculation.

Task 2.3.5: Finding Screening Check

The Task 2.3.5 screening step considers whether or not one or more potentially challenging fire scenarios has been identified. If no such fire ignition source scenarios have been identified, then the finding Screens to Green and the analysis is complete. The screening criteria for this step are as follows:

- If all identified fire ignition sources screen out in Task 2.3.4, then no potentially challenging fire scenarios were developed. In this case, the Phase 2 analysis is complete and the finding should be assigned a Green preliminary significance determination rating. Subsequent analysis tasks and steps need not be completed.

- If one or more of the fire ignition sources is retained, even if only at the higher severity value, then the analysis continues to Step 2.4.

4.4.4 Step 2.4 - Fire Frequency For Unscreened Fire Sources

In Step 2.4 the inspector refines the fire area fire frequency by estimating the fire frequency (F_{Source}) for each unscreened fire ignition source scenario. This step includes fire frequency adjustments to reflect findings against fire prevention and other administrative controls programs, compensatory measures. Note that the partitioning of certain fire ignition sources (e.g., transients) to specific locations is deferred to later steps. Step 2.3 also includes a screening check to determine if the finding can Screen to Green given the newly estimated fire area fire frequencies. Guidance and worksheets to support this step are provided in Section 5.2.4.

Step 2.4 involves four analysis tasks:

- Task 2.4.1: Estimate nominal fire frequencies for each unscreened fire ignition source scenario and apply severity factors as appropriate to each fire ignition source scenario.

- Task 2.4.2: Increase the nominal fire frequencies for specific fire ignition sources if the finding being evaluated is one whose risk significance is appropriately represented by an increase in fire frequency.

- Task 2.4.3: Reduce the nominal fire frequencies for specific fire sources if there are compensatory measures in place for the fire area under evaluation that will act to reduce the likelihood of fire occurrence.

- Task 2.4.4: Perform a screening check given the updated fire frequency estimates.

Task 2.4.1: Nominal Fire Frequency Estimation

In Task 2.4.1, the inspector establishes the nominal fire frequency for each unscreened fire ignition source scenario. Specific guidance and worksheets to support this task is provided in Section 5.2.4.1. The nominal fire frequency will stand as the final fire frequency for most fire ignition sources. However, the frequency of transients and/or hot work fires may be adjusted depending on the nature of the finding being analyzed (see Tasks 2.4.2 and 2.4.3).

The fire frequency estimation method is a component-based approach. That is, the fire frequency is assigned on a per-source basis for each member of each type of fire ignition source present in the fire area. The analysis utilizes the counting results obtained in Task 2.3.1.
Also considered is the fire severity factor associated with each fire ignition source based on the screening results from Task 2.3.4. Screening results and severity factors are applied as follows:

- Fire ignition sources that screened out for both the expected (lower) and high confidence (higher) fire severity/HRR levels are excluded.
- A fire severity factor of either 1.0 or 0.1 is assigned to each fire ignition source scenario, either individual source or grouped set based on the screening results from Step 2.3 based on the following criteria:

    - If a fire ignition source (or set of grouped fire ignition sources) was retained for both its expected and high confidence fire severity/HRR levels, then the severity factor applied is 1.0 (i.e., no severity factor reduction).

    - If a fire ignition source (or set of grouped fire ignition sources) was retained <u>only</u> at its high-confidence fire severity/HRR level, then a severity factor of 0.1 is applied to all scenarios associated with that fire ignition source.

The counting results and severity factor results entered into the fire frequency worksheet and are used to generate an updated estimate of the nominal frequency of potentially challenging fires associated with each unique fire ignition source scenario.

The fire frequency is then summed over all identified fire ignition source scenarios to generate an updated estimate of the fire area fire frequency. This refined value reflects the frequency of potentially challenging fires in the fire compartment. (If the electronic spreadsheet is used, this calculation is updated automatically.)

<u>Task 2.4.2: Findings Quantified Based on Increase in Fire Frequency</u>

In Task 2.4.2, the inspector will address those specific inspection findings that will be reflected in the SDP process as leading to an increase in the fire frequency. The fire frequency increase is only applicable to certain types of fire ignition sources; namely, hot work fires and transients. If an increase the fire frequency is needed, the appropriate multiplication factor is recorded in the fire frequency worksheet started in Task 2.4.1.

The necessity to conduct Tasks 2.4.2 is driven entirely by the nature of the finding being evaluated:

- If the finding category assigned in Step 1.1 is anything other than “Fire Prevention and Administrative Controls” then no increases in the nominal fire frequencies developed in

Task 2.4.1 are necessary. Task 2.4.2 is skipped, and the analysis should continue with Task 2.4.3.

Within the general category of Fire Prevention and Administrative Controls findings, only certain types of finding will result in an increase in fire frequency. In particular, if the inspection finding being evaluated is associated with any of the following fire protection DID elements, then Task 2.4.2 is applicable and is completed:

- combustible controls programs,
- hot work permitting programs,
- hot work fire watches or
- roving, continuous, or periodic fire watches that perform a combustible control function (i.e., a fire watch of any type whose stated purpose/function/objective includes the identification and/or removal of inappropriate or excess combustible materials in or from a fire area being monitored).

If the finding is not against one (or more) of the fire protection DID elements listed above, then no adjustment of the fire frequency is needed, and this task is skipped.

If the finding is against one (or more) for the fire protection DID elements listed above, refer to the specific guidance provided in Section 5.2.4.2 and determine the appropriate fire frequency multiplication factor to be applied on a fire ignition source scenario specific basis.

By default, all fire frequency adjustment factors for Task 2.4.2 are set to 1.0 (no adjustment). If one of more fire frequency adjustment factors is identified, the values are entered into the Task 2.4 worksheet/spreadsheet (replacing the default value of 1.0). Fire frequency estimates are updated accordingly (automatically in the case of the electronic spreadsheet).

<u>Task 2.4.3: Credit for Compensatory Measures that Reduce Fire Frequency</u>

In Task 2.4.3 the inspector will account for compensatory measures that act to reduce fire frequency. In most such cases, compensatory measures are credited with reducing the frequency of transient fuel fires in particular.

- If there are NO compensatory measures active for the fire area under evaluation, then Task 2.3.3 is skipped. The analysis continues with Task 2.4.4.

Given that one or more compensatory measures is/are in place, the necessity to complete Task 2.4.3 depends on the nature of those compensatory measures. If any of the following compensatory measures are in place for the fire area under analysis, then the inspector should consult Section 5.2.4.3 and assign a fire frequency multiplication factor to the appropriate fire ignition source scenarios:

- fire watches that perform a combustible control function,
- temporary restrictions on, or enhancements to, combustible control limits, or
- temporary suspension of any hot-work activities in a fire area.

If none of the above listed compensatory measures are active for the fire area under analysis, no adjustment of the fire frequency is needed and this task is skipped. The analysis continues with Task 2.3.4.

By default, all fire frequency adjustment factors for Task 2.4.3 are set to 1.0 (no adjustment). If one of more scenario-specific fire frequency adjustment factors is identified, the values are entered into the Task 2.4 worksheet/spreadsheet (replacing the default value). Fire frequency estimates are updated accordingly (automatically in the case of the electronic spreadsheet).

Task 2.4.4: Finding Screening Check

In Task 2.4.4, the inspector will determine if a finding can be screened to Green given the newly calculated fire frequency reflecting only the unscreened fire sources. Given completion of Tasks 2.4.1-3, the inspector has refined the fire scenario and fire compartment fire frequencies to reflect the following factors:

- elimination of fire ignition sources screened out in Step 2.3,
- severity factors to reflect the fire intensity screening results from Step 2.3,
- increases in fire frequency resulting from certain findings, and
- decreases in fire frequency resulting from certain compensatory measures.

This screening step is based on the refined fire frequency estimate for the fire area as a whole; that is, the sum of the revised fire frequency for unscreened fire scenarios. Mathematically, the refined fire area fire frequency is expressed by the following equation:

$$F_{Area\,2.4} = \sum \left[F_{Source} \times SF_{Source} \times AF_{Source,2.4.2} \times AF_{Source,2.4.3} \right]_{\substack{AllUnscreenedFire \\ IgnitionSources}}$$

NOTE: At this point, fire frequencies and severity factors have been refined to the full extent of the fire protection SDP Phase 2 analysis. The fire frequency, severity factor, and adjustment factor values derived in this step will be used throughout the balance of the Phase 2 analysis.

The screening approach is again similar to that applied in Step 2.1, except that the refined fire area fire frequency is used in lieu of the total fire area fire frequency from Step 1.4 that has been used in previous screening checks. The screening check is based on the following updated change in CDF value:

$$\Delta CDF_{2.4} = DF \times F_{Area,2.4} \times CCDP_{2.1}$$

This value is compared against the values in Table 4.4.4 to determine whether or not the finding Screens to Green without further analysis.

Table 4.4.4: Phase 2, Task 2.4.4 Quantitative Screening Levels

Finding Type or Category:	Screening Value	
	Moderate Degradation Finding	High Degradation Finding
Fire prevention and Administrative Controls	1E-5	
Fixed Fire Protection Systems	1E-5	
Fire Confinement	1E-5(1)	1E-6
Localized Cable or Component Protection	1E-5(1)	
Post-fire SSD	1E-6	

Note 1: This entry applies to both 'Moderate A' and 'Moderate B' findings against a fire barrier.

- If the value of $\Delta CDF_{2.4}$ is lower than the corresponding value in Table 4.4.4, then the finding Screens to Green, and the analysis is complete.
- If the value of $\Delta CDF_{2.4}$ exceeds the corresponding value in Table 4.4.4 then the analysis continues to Step 2.5.

4.4.5 Step 2.5 - Definition of Specific Fire Scenarios and Independent SSD Path Second Screening Assessment

In Step 2.5 the inspector continues the process of defining specific fire scenarios by considering post-fire safe shutdown at a scenario-specific level. In particular, the designated post-fire SSD path originally identified in Step 2.1 is re-assessed for potential applicability on a scenario-specific basis.

Step 2.5 involves four analysis tasks as follows:

- Task 2.5.1: Identify specific fire growth scenarios corresponding to each unscreened fire ignition source and each applicable FDS.
- Task 2.5.2: Identify specific fire damage scenarios corresponding to each unscreened fire ignition source and each applicable FDS.
- Task 2.5.3: Assess the independence of the post-fire SSD path identified in Step 2.1 in the specific context of each fire scenario from Task 2.5.1.
- Task 2.5.4: Screening check including consideration of scenario-specific SSD credit.

4.4.5.1 Task 2.5.1: Identify Specific Fire Growth and Damage Scenarios

In Task 2.5.1 the inspector will identify one or more fire growth and damage scenarios for each unscreened fire ignition source scenario. The fire growth and damage scenarios will also reflect each applicable FDS being carried forward in the analysis process (i.e. as identified in Step 2.2).

Recall that in Step 2.3, the inspector has defined a specific set of fire ignition source scenarios, each involving either an individual fire ignition source, or a set of grouped fire ignition sources. The identification of fire growth and damage scenarios involves two elements: identification of likely fire spread paths, and identification of corresponding fire damage target sets.

The damage target sets identify those components and cables that will be assumed to fail given each FDS of interest. For each identified damage target, a failure criteria and threshold is also assigned. The target sets are chosen to suit specific fire ignition source scenarios and each FDS of interest:

- For FDS1 scenarios, the inspector will identify unprotected components and cables in the immediate vicinity of the fire ignition source (e.g., directly above or next to the fire ignition source). FDS1 scenarios will include damage to:
  - any unprotected components or cables that are subject to heating either by the fire plume or direct radiant heating,
  - components and cables near the fire source that are protected by a highly degraded fire barrier that are subject to plume or direct radiant heating.

- For FDS2 scenarios, the inspector will identify components and cables throughout the fire area that might be damaged by a fire initiated in a given fire ignition source. FDS2 fire scenarios will include damage to:
  - all cables and components that would be damaged in the corresponding FDS1 fire scenario for the same fire ignition source (unprotected components and cables near the fire ignition source),
  - components and cables near the fire source that are protected by a moderately degraded fire barrier,
  - components and cables that are not near the fire source that are protected by a highly degraded fire barrier, and
  - components and cables protected by a fire barrier with a fire endurance rating of less than one hour.

- For FDS3 scenarios, the inspector will identify targets both within the primary fire area and in any adjoining fire areas that may be effected given fire spread to an adjacent fire area. The FDS 3 fire scenarios include damage to:
  - components and cables that would be damaged in the corresponding FDS1 and FDS2 fire scenarios for the same fire ignition source, and
  - components and cables located in the adjacent fire area.

Specific guidance in support of this task is provided in Section 5.2.5.1.

4.4.5.2 Task 2.5.2: Identify Specific Plant Damage State Scenarios

Task 2.5.2 involves the ‘translation’ of fire-induced component and cable damage corresponding to a specific fire growth and damage scenario (i.e., loss of a fire damage target set) into a specific plant damage state. The plant damage state scenario characterizes the functional impacts of component and cable failure on the plant systems.

In most cases, the loss of a system component or cable will be assumed to render that system unavailable. However, in some cases it may be appropriate to determine whether or not system function is partially degraded, or involves unique failure modes. The potential for manual operation of the system or function is also relevant if the licensee's post-fire SSD procedures includes operator actions associated with such systems.

Specific guidance for making damage state choices is provided in Section 5.2.5.2.

4.4.5.3 Task 2.5.3: Assess Fire Scenario-Specific SSD Path Independence

In Task 2.5.3 the inspector re-evaluates the potential for crediting the designated post-fire SSD path (originally identified in Step 2.1) on a scenario specific basis. The SSD path unavailability factor assigned in Step 2.1 is then applied on a scenario specific basis.

> SPECIAL NOTE: If the designated SSD path met the independence criteria of Step 2.1, then it has already been credited for <u>all</u> fire scenarios and there is no additional screening benefit to be gained in this Step. In this case, Tasks 2.5.3 and 2.5.4 are skipped. The original SSD path failure probability is carried forward to Steps 2.6 and 2.7 as a screening CCDP for all individual scenarios.

The inspector will examine the plant damage state scenario(s) associated with each unique fire scenario defined in Tasks 2.5.1 and 2.5.2 and determine whether or not the designated post-fire SSD path identified in Step 2.1 is physically independent of that plant damage state. The results are recorded on the Step 2.5 worksheet for each unique fire scenario.

The SSD success path can be credited on a scenario specific basis if all of the following criteria are met given a specific combination of a fire ignition source scenario, fire growth and damage scenario, and plant damage state scenario:

In order to credit the designated SSD path, the following features should have been verified in Step 2.1:

- The credited SSD success path must be identified and analyzed in the licensee's post-fire SSD analysis, must be supported by procedures covering plant response to fires in the designated fire area, and must not be potentially compromised by a known circuit analysis issue.

In addition to these general criteria the following additional criterial are applied on a scenario-specific basis given the postulated plant damage state for each fire scenario:

- Cables or components needed to ensure successful operation of the SSD success path must not be damaged given the postulated fire growth and damage scenario associated with a given fire scenario.

- The operability of the SSD path must not be compromised given the postulated plant damage state associated with a given fire scenario.

- All operator actions required to support successful operation of the SSD success path must be feasible given the fire scenario being postulated.
    - Operator actions within the impacted fire area will not be considered feasible.

- Operator actions in an adjacent fire area will not be considered feasible in the specific context of an FDS3 fire scenario that involves that same adjacent fire area.

The above criteria are review for each unique fire scenario being carried forward in the analysis. Given that the SSD success path meets all three of the above criteria, it will be credited on a fire scenario specific basis in subsequent steps using the same overall system unavailability factor (failure probability) as was determined in Step 2.1 ($CCDP_{2.1}$).

4.4.5.4 Task 2.5.4: Screening Check

In Task 2.5.4, the inspector performs a quantitative screening check that will include a bounding value of the scenario specific SSD credit for each fire ignition source.

The SSD path credit is applied on a bounding basis for each fire ignition source. The inspector first determines if the SSD path can be credited for all fire scenarios arising from a given fire ignition source scenario. That is, since each fire ignition source can lead to multiple fire scenarios each potentially involving a unique plant damage state, credit for the SSD path in this Task will be based only on the worst-case conditions for each fire ignition source. (See Section 5.2.5.4 for further explanation.)

- For each fire ignition source identify the worst-case plant damage state:
  - In descending order of damage, consider the FDS3, then the FDS2, and then the FDS1 scenarios as applicable to a given fire ignition source.

- If the designated SSD path was deemed independent of the worst-case FDS scenario for a given fire ignition source, then it is credited for all fire scenarios involving that fire ignition source.

If the inspector determines that the SSD path <u>cannot</u> be credited for any of the identified fire ignition sources given its worst-case damage state, then Step 2.5.4 is complete, the finding will not yet Screen to Green, and the analysis continues with Step 2.6. However, if the SSD path can be credited for at least one fire ignition source, then Task 2.5.4 continues and the screening check is performed.

A revised screening CDF is calculated as follows:

$$\Delta CDF_{2.5} \approx DF \times \left[\sum F_{Source} \times SF_{Source} \times AF_{Sourc2.4.2} \times AF_{Source2.4.3} \times CCDP_{2.1\text{-}SourceLimiting} \right]_{\substack{All\ Unscreened \\ Sources}}$$

A screening check is then made based on the values and criteria provided in Table 4.4.4 (see Step 2.4).

4.4.6 Step 2.6 - Fire Growth and Damage Scenario Time Analysis

In Step 2.6 the inspector analyzes fire behavior for unscreened fire scenarios in order to estimate the time to reach a particular FDS. Specific guidance supporting Step 2.6 is provided in Section 5.2.6. Step 2.6 involves up to three analysis tasks as follows:

- Task 2.6.1: Perform a fire damage state time analysis for unscreened fire ignition source scenarios relevant to FDS1

- Task 2.6.2: Perform a fire damage state time analysis for unscreened fire ignition source scenarios relevant to FDS2

- Task 2.6.3: Perform a fire damage state time analysis for unscreened FDS3 fire scenarios

Note that the inspector will skip certain of these tasks if a particular FDS is not relevant to the finding being analyzed. For example, if the FDS3 scenarios were screened out in Step 2.2, then Task 2.6.4 is not performed.

Also note that each analysis task will require the collection and documentation of information needed to complete the fire growth and damage analysis. Worksheets are provided to support the documentation of this information (see Section 5.2.6).

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

In Task 2.6.1 the inspector analyzes fire scenarios associated with FDS1. Specific guidance on fire growth and damage modeling for FDS1 scenarios is provided in Section 5.2.6.1. Recall that FDS1 involves fire damage to unprotected components and cables in the immediate vicinity of the fire ignition source. For these scenarios, the inspector will estimate the time required to reach this state of localized damage.

> SPECIAL NOTE: If the inspection finding does not require the evaluation of any FDS1 scenarios (as determined in Step 2.2), or if no credible potentially risk-important FDS1 fire scenarios were identified in Step 2.5, then this task is skipped.

For FDS1, two fire damage mechanisms are considered; namely, fire plume effects (including direct flame impingement), and direct radiant heating. Included in the timing analysis is consideration of fire spread to secondary combustibles if such fire spread is required to create the damaging exposure conditions.

- The inspector first predicts the exposure conditions for the damage target(s) using closed-form fire modeling correlations.
  - Target exposure conditions may involve a plume temperature and/or a radiant heat flux depending on the location of the target relative to the fire.
  - Given the estimated exposure temperature and/or heat flux, a table is consulted to estimate the time to damage.

- For some scenarios, the spread of fire to secondary combustibles (typically cables) near the fire source is required to create damaging exposure conditions at the location of the target.
  - In such cases, the damage time will include the time required for critical fire spread.

The modeling tools required are provided in the form of computer spreadsheets, closed form correlations, and/or worksheets that will lead the inspector through the analysis.

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

Task 2.6.2 involves the analysis of fire growth and damage for FDS2 scenarios. Specific guidance in support of this task is provided in Section 5.2.6.2.

SPECIAL NOTE: If the finding does not require the analysis of any FDS2 scenarios, or if no credible FDS2 scenarios were identified in Step 2.5, then Task 2.6.2 is skipped.

Recall that FDS2 involves widespread damage to targets located within the fire area including damage to components protected by a degraded fire barrier system. FDS2 requires that all of the damage targets fail. In effect, the FDS2 scenarios involve FDS1 level damage plus additional damage in a wider portion of the fire area.

- The analysis of FDS2 scenarios involves elements similar to those for FDS1; namely, plume and direct radiant heating exposures combined with localized fire spread.
  - If a specific fire ignition source has been analyzed for an FDS1 scenario, the resulting time to damage results for targets near the fire source carry forward to the FDS2 scenario as well.
  - If a specific fire ignition source has not been analyzed for an FDS1 scenario, it may be necessary to predict time to damage for targets near the fire source using the FDS1 fire modeling tools (provided in Task 2.6.1).

- One unique aspect of the FDS2 scenarios is hot gas layer effects.
  - The hot gas layer temperature is estimated using a correlation described in Section 5.2.6.2.
  - If the hot gas layer exceeds the damage threshold, a time to damage table is consulted.
  - If spread of the fire to secondary combustibles (typically cables) is critical to creating a damaging hot gas layer, the time required to spread the fire to the critical level is estimated.

- A second unique aspect of some FDS2 scenarios will be the potential for damage due directly to the spread of fire beyond the immediate vicinity of the fire ignition source.
  - In such cases the inspector will construct a fire spread pattern and assess the time required to spread the fire to the critical target location(s).

- The third unique aspect of FDS2 scenarios is the potential failure of components that are protected by a moderately degraded fire barrier system.
  - For such findings, the performance time of the fire barrier system is reduced to reflect the noted deficiency.
  - Time to damage is based on (1) establishing a potentially damaging exposure condition (temperature and/or heat flux) and (2) the degraded fire barrier performance time.

<u>Task 2.6.3: Fire Growth and Damage Time Analysis - FDS3 Scenarios</u>

Task 2.6.3 involves damage time analysis for the unscreened FDS3 fire scenarios.

SPECIAL NOTE: If the FDS3 scenarios were screened our in Step 2.2, or if no credible FDS3 scenarios were identified in Step 2.5, then Task 2.6.3 is skipped, and the analysis continues with Step 2.7.

Recall that FDS3 involves inter-compartment fire spread which occurs when an inter-compartment fire barrier element (e.g., penetration seal, door, damper) is challenged and fails. Specific guidance for the conduct of Task 2.6.3 is provided in Section 5.2.6.3.

In many ways, the FDS3 scenarios are the simplest to evaluate. These scenarios build upon the fire endurance rating of the fire barrier. If the barrier element itself is the finding (i.e., the barrier is degraded), then degradation of the barrier element will be reflected as a reduced performance time.

The fundamental objective of Task 2.6.3 is to assess the likelihood of fire spread between two (or more) fire areas. The scope of the analysis depends in part on the nature of the finding:

- If the inspection finding is not associated with a degraded inter-compartment fire barrier element, then the focus is placed on fires within the fire area under analysis that may spread to any adjacent fire area.

- If the inspection finding is associated with a degraded inter-compartment fire barrier, then the focus is placed on fires involving the two fire areas that are separated by the degraded barrier element; however, the inspector must consider both fires within the fire area under analysis that may spread to the adjacent fire area, and fires in the adjacent fire area that might spread into the fire area under analysis.

The inspector also considers the potential that fire spread through a degraded barrier will actually threaten additional fire PRA damage targets. That is, the proximity of the damage targets in the adjacent space to the failed or degraded fire barrier element is assessed, and damage timing may be delayed further if the damage targets are remote from the breached fire barrier.

4.4.7 Step 2.7 - Non-Suppression Probability Analysis

In Step 2.7 the inspector quantifies the factor 'PNS_i', the Probability of Non-Suppression, for each fire growth and damage scenario of interest. Step 2.7 involves four analysis tasks as follows:

- Task 2.7.1: Estimate the time to fire detection.
- Task 2.7.2: Evaluate the performance time and overall effectiveness for fixed fire suppression systems
- Task 2.7.3: Estimate the fire suppression time for plant personnel including the manual fire brigade.
- Task 2.7.4: Estimate the probability of non-suppression for each analyzed fire scenario.
- Task 2.7.5: Finding screening check

Task 2.7.1: Fire Detection

In Task 2.7.1 the inspector estimates the time to fire detection. This time is important because it triggers other human performance actions such as manual control actions and activation of the manual fire brigade. Section 5.2.7.1 provides specific guidance for this task.

The fire detection analysis considers the possibility of detection by any one of the following mechanisms:

- Prompt detection by a posted and continuos fire watch,
- Detection by a roving fire watch,
- Detection by fixed fire detection systems, and
- Detection by general plant personnel.

Only one of the above means of detection need to succeed in order for the fire to be detected. Hence, the first and/or most likely mechanism of detection is generally credited. A fire detection time is assigned accordingly.

Specific guidance in support of the fire detection analysis is provided in Section 5.2.7.1 below.

Task 2.7.2: Fixed Fire Suppression System Analysis

In Task 2.7.2 the inspector assesses the performance and actuation timing of fixed fire suppression systems. In this step, findings against a fixed fire suppression system are also assessed. Detailed guidance on this task is provided in Section 5.2.7.2.

> SPECIAL NOTE: If the fire area under analysis is not equipped with a fixed fire suppression system this step is skipped and the analysis continues with Task 2.7.3.

> SPECIAL NOTE: If the fire area is equipped with a fixed fire suppression system, but the system has been found to be HIGHLY DEGRADED, then the system is not credited in the Phase 2 analysis, and Task 2.7.2 is skipped.

The inspector will consider both automatically actuated and manually actuated fixed fire suppression systems in this Task. Two factors are key to the fixed suppression assessment:

- Effectiveness: If the fixed suppression system actuates, will it control a fire involving the postulated fire ignition source?
- Timing: When will the system discharge the fire suppressant?

If the suppression system is deemed effective, then its actuation will be assumed to disrupt the fire scenario and prevent further fire damage thereby ending the fire scenario.

If the finding being evaluated involves a moderate degradation to the fixed fire suppression system, then the inspector will adjust the credit given to the system. The adjustment may impact either the effectiveness of the system, or the timing of suppressant discharge. Specific guidance is provided in Section 5.2.7.2.

Note that in quantification, the probability that the fire suppression system will fail on demand is included. Should the fixed suppression system fail, fire suppression must be achieved by the manual fire brigade. Hence, even given a fixed fire detection system, an analysis of fire brigade response is also needed (see Task 2.7.3).

Task 2.7.3: Plant Personnel and the Manual Fire Brigade

In Task 2.7.3 the timing associated with manual fire suppression evaluated. In all fire scenarios, the ultimate means of fire suppression is the fire brigade. Hence, manual fire fighting response is generally analyzed for all fire scenarios.

The manual fire fighting response is based on the application of historical evidence from past fire events. Based on this historical evidence, fire duration curves have been pre-calculated for a number of cases. Cases are based on either the fire ignition source type (e.g., pump fires), or in some cases on the specific fire location (e.g., the main control room). In Task 2.7.3, the inspector will select the most representative case from the pre-analyzed set. The analysis of the selected fire duration curve is conducted in Task 2.7.4.

The pre-calculated duration curves are provided in Section 5.2.7.3.

Task 2.7.4: Probability of Non-Suppression

In Task 2.7.4, the inspector combines information taken from Step 2.6 with the results of the completed tasks in Step 2.7 to estimate the likelihood that fire suppression efforts fail to suppress the fire before the FDS is reached - the probability of non-suppression or PNS. PNS is assessed on a scenario-specific basis.

The method applied to quantify PNS depends on whether or not a fixed fire suppression is being credited:

- For cases where fixed fire suppression systems are not being credited, PNS is based entirely on the response of the manual fire brigade compared to the predicted damage time.

- For fire areas protected by fixed suppression (either automatic or manually actuated), two suppression paths are considered: success of the fixed suppression system; and failure of the fixed suppression system to actuate on demand with fall-back to the manual fire brigade.

Fixed Suppression System: $PNS_{fixed\text{-}scenario}$

If the fire area is protected by fixed fire suppression, the inspector will estimate PNS_{fixed} for each surviving scenario ($PNS_{fixed\text{-}scenario}$) for which the fire suppression system is deemed effective. A look-up table is consulted and assigns $PNS_{fixed\text{-}scenario}$ based on the difference between the predicted time to suppression system actuation (from Task 2.7.2) and the predicted time to fire damage (from Step 2.6). The table and further instructions are provided in Section 5.2.7.4. Note that the assessment is conducted for each unscreened fire scenario based on the scenario-specific fire damage and fire suppression times.

Manual Fire Suppression: $PNS_{manual\text{-}scenario}$

The value of PNS_{manual} for a given scenario ($PNS_{manual\text{-}scenario}$) is dependent on three factors: the predicted time to fire damage (Step 2.6), the predicted time to fire detection (Task 2.7.1), and the selected fire duration curve (Task 2.7.3).

Both the fire damage and the fire detection/suppression processes begin at time zero. The total fire response time is the time required to detect the fire plus the time required to suppress the fire. The fire damage time is compared to this total fire response time, not just to the manual fire fighting response time. Phrased another way, the time available to manually suppress the fire is reduced in comparison to the predicted fire damage time because the manual fire fighting response cannot begin until fire detection has occurred.

The process to be completed (for each surviving scenario) is as follows:

- The fire detection time determined in Task 2.7.1 is subtracted from the fire damage time determined in Step 2.6:
  - Example: The fire damage time in Step 2.6 was determined to be 12 minutes. In Task 2.7.1, the fire detection time was determined to be 3 minutes based on the presence of a fixed detection system. The difference between these two values is 9 minutes - this

represents the time from the point of fire detection available to suppress the fire before the fire damage state is reached.

- If the above time value is negative (i.e., time to detection is greater than the time to damage), then $PNS_{manual\text{-}scenario} = 0$
- If the above time value is positive (i.e., time to detection is less that time to damage), then $PNS_{manual\text{-}scenario}$ is read directly from the selected fire duration curve based on this time.

This process is illustrated in Section 5.2.7.4. Note that the assessment is repeated for each unscreened fire scenario.

<u>Composite Suppression Factor:</u> $PNS_{scenario}$

If the fire area is not covered by fixed fire suppression, then:

$$PNS_{scenario} = PNS_{manual\text{-}scenario}$$

If the fire area is covered by wet-pipe sprinklers, a general reliability of 0.98 is assumed for the fixed suppression system. In this case, the PNS is quantified as follows:

$$PNS_{scenario} = (\ 0.98 \times PNS_{fixed\text{-}scenario}\ ) + (\ 0.02 \times PNS_{manual\text{-}scenario}\ )$$

If the fire area is covered by a dry-pipe sprinklers or deluge system, or by a gaseous suppression system, a general reliability of 0.95 is assumed for the fixed suppression system. In this case, the PNS is quantified as follows:

$$PNS_{scenario} = (\ 0.95 \times PNS_{fixed\text{-}scenario}\ ) + (\ 0.05 \times PNS_{manual\text{-}scenario}\ )$$

<u>Task 2.7.5: Finding Screening Check</u>

In Task 2.7.5 a screening check is made to determine if a finding will Screen to Green given the new information. This screening check adds consideration of the non-suppression probability for each fire scenario to the factors considered in previous screening checks. In this step, the designated post-fire SSD path identified in Step 2.1 is applied on a scenario-specific basis consistent with the detailed scenario results from Step 2.5.

The estimated risk contribution, or screening CDF, for each fire scenario is based on the product of the following factors:

$$\Delta CDF_{2.7} \approx DF \times \left[\sum F_{Source} \times SF_{Source} \times AF_{Source2.4.2} \times AF_{Source2.4.3} \times PNS_{Scenario} \times CCDP_{2.1\text{-}Scenario} \right]_{AllScenarios}$$

If $CDF_{2.7}$ is less than or equal to 1E-6, then the finding Screens to Green, and the analysis is complete. If $CDF_{2.7}$ is greater than 1E-6, then the analysis continues to Step 2.8.

4.4.8 Step 2.8 - Plant Safe Shutdown Response Analysis

Step 2.8 analyzes the plant SSD response and quantifies the factor '$CCDP_i$' for each fire growth and damage scenario of interest. This value is passed forward to Step 2.9.

In previous steps the Phase 2 analysis has developed one or more fire scenarios that lead to the failure of some set of plant components and/or cables. Step 2.8 considers how these component and cable failures and failures of required human recovery actions might impact plant safe shutdown. The likelihood that operators fail to achieve SSD is the final factor in the risk quantification equation. This factor is estimated using the plant-specific USNRC Risk-Informed Inspection Notebook (or more simply, the 'plant notebook'), modified as necessary to include operator actions.

The plant notebooks are based on accident sequences developed in the context of internal events PRA analysis, with a separate worksheet for a number of initiating events. To use the notebooks, the inspector must determine which initiating event is caused by the fire, and which systems and functions may be credited for a given fire scenario. In addition, the role of the operators in effecting safe shutdown must be taken into account. In addition to the operator actions already accounted for in the notebooks, there may be some actions that are specifically required in response to a fire. To address these issues, Step 2.8 involves five supporting tasks:

- Task 2.8.1: Identify which plant accident initiating event(s) worksheet(s) in the plant notebook will be used to assess the fire scenario CCDP. In particular, identify those initiating events that result from following plant procedures (e.g., SBO), and those that might result from failing to perform manual actions (e.g., spurious opening of relief valves).

- Task 2.8.2: Identify those systems and functions that can be credited as available to support plant SSD response for each fire damage state scenario and initiating event of interest.

- Task 2.8.3: Identify manual actions included in the SSD procedures followed in response to a fire. The manual actions of concern include those introduced as compensatory measures for degraded elements of the SSD program, those required for manual control of systems, and also those procedural directions to abandon the control room in favor of using the remote shutdown panel.

- Task 2.8.4: Assess the failure probability of manual actions identified in Task 2.8.2 using the Tables in Section 5.2.8.4.

- Task 2.8.5: Assess the CCDP using the plant notebooks by 1) incorporating failure of those systems and functions that will not be credited for the given fire scenario for each initiating event identified, and 2) incorporating human error probabilities for manual actions as discussed in Section 5.2.8.5.

<u>Task 2.8.1: Select Plant Accident Initiating Event Worksheets</u>

The plant notebooks provide accident sequence worksheets for a range of plant accident initiating events. The inspector must select one or more of these worksheets to represent the fire-induced SSD challenge.

- If it cannot be assured that cables associated with the offsite power distribution will not be affected by the fire, use the loss of offsite power worksheet.

- If offsite power is not lost, and it cannot be assured that the power conversion system is available, use the loss of power conversion system (loss of feedwater) initiating event worksheet.

- If neither offsite power nor the power conversion system is lost, use the general transient worksheet.

- If a manual action is specifically designed to prevent a spurious actuation of equipment that would result in an initiating event, such as a spurious actuation of a safety/relief valve, the worksheet for that initiating event should be selected as well as that for the case where the manual action is successful.

- If a small LOCA is possible (e.g., RCP seal failure, safety/relief valve opening) us the SBLOCA worksheet.

Task 2.8.2: Identify Credited System and Functions

In the fire SDP context it is not generally appropriate to credit (i.e., assume the availability of) the full complement of plant systems and functions included in these models. The following two factors are key to determining whether or not systems and functions should be credited in a fire scenario analysis:

- The accident sequence models in the plant notebooks typically credit systems and functions not credited in the licensee's post-fire SSD analysis. In the fire protection SDP context, it is appropriate to credit all available systems and functions whether or not they are credited in the post-fire SSD analysis. However, the inspector must ensure that the credited systems and functions actually will be available given the postulated fire scenario. That is, systems and functions should be assumed to fail unless it can be determined, with reasonable confidence, that they will in fact survive the fire scenario.

- The question of system or function loss or survival hinges on the actual location of components and cables related to that system or function (e.g., the related power and control cables in particular). Fire is a spatial phenomenon - it will cause damage to components and cables within a limited spatial region of the plant, often only a limited portion of any given fire area. Hence, the inspector's ability to credit systems and functions hinges on the licensee's state of knowledge regarding cable and component routing within the plant. This knowledge state varies substantially. Inspectors are not expected to expend significant time verifying equipment or cable routing. The inspectors can, however, utilize routing information provided by the licensee. In the absence of such routing information, unverified systems and functions are assumed to be unavailable (i.e., they are assumed to fail).

- Circuit problems may result in spurious actuation of SSCs, leading to failure of required functions, or creation of a LOCA through a spuriously open PORV, for example.

Task 2.8.3: Identify Ex-control Room Manual Actions

One of the characteristics of the safe shutdown practices at nuclear plants is the use of ex-control room manual actions. There are three types of manual actions to be considered:

- Manual actions taken as precautionary measures to allow for potentially degraded elements of the safe shutdown program. These include such actions as the removal of power from specific pieces of equipment, and are often invoked as a result of a concern about circuit failure modes leading to spurious actuation of plant equipment. Of concern here are those whose failure could result in a loss of a function required for safe shutdown, or those that could lead to a challenging initiating event, e.g., a spuriously open PORV.

- Manual actions to perform safe shutdown functions.

- Specific procedures related to the abandonment of the main control room in order to operate the plant from the remote shutdown panel. The set of steps involved in safe shutdown may, for the purposes of the SDP, be regarded as a single manual action.

Task 2.8.4: Assess the Failure Probability of Manual Actions

The probability of failure of a manual action is estimated using the Tables in Section 5.2.8.4. One table is provided to assess compensatory manual actions, and a second for remote shutdown operations. For operator actions already incorporated in the worksheets and that are performed in the control room, use the human error probabilities used in the notebooks, even though it is recognized that there may be additional negative performance shaping factors on human performance given a fire.

Task 2.8.5: Assess the CCDP

In Task 2.8.5, the inspector assesses the CCDP applicable to each fire scenario. Section 5.2.8.5 provides additional guidance on how to modify the evaluation of the notebook worksheet to account for the manual actions. The plant notebooks are used, in conjunction with the evaluations of human error probabilities identified and evaluated in Tasks 2.8.3 and 2.8.4 respectively. Typically, only one worksheet will be used, corresponding to the initiating event whose characteristics most closely resemble the impact of the fire on the plant, as identified in Task 2.8.1 above. The SSCs for which credit can be taken in evaluating the worksheets are identified in Task 2.8.2.

The CCDP is obtained by:

- setting the initiating event frequency measure to 0 (this is a conditional core damage probability),

- reducing the credit for each function by failing every SSC for which success is not guaranteed. So, for example, if only one of two trains is protected, the credit is reduced from 3 to 2,

- incorporating the impact of the human error contribution.

    - When normally automatic functions are required to be operated manually, the human failure contribution is taken into account by comparing the credit for the manual action, obtained from the corresponding table in Section 5.2.8, with that for the hardware, and using the more conservative of the two
    - For some compensatory manual actions that are included in procedures it may be necessary to use two worksheets, one corresponding to the case where the manual action is successful, the other to the case where it is unsuccessful. The results from

these two worksheets are weighted by the probability of success and failure respectively.

- For remote shutdown operations, the human error probability obtained from Table 5.2.XX2 is compared to the result of evaluating the worksheet appropriate to the initiating event resulting from the procedural directions with credit only for those SSCs called for in the procedure, and the more conservative value is used. A detailed analysis of individual human actions should not be attempted in Phase 2.

Special Cases:

A Findings Against the Post-Fire SSD Program

Findings against a licensee's post-fire SSD program would be manifested by an increase in the likelihood that operators fail to achieve SSD given a fire. Such findings may have implications for fires in several locations. The phase 2 should only be applied when the finding can be identified with a specific fire area. For findings with plant-wide consequences a Phase 3 assessment should be performed.

B Findings Related to Circuit Issues

In a similar manner to the SSD findings discussed above, circuit issues may have implications for several fire areas, since the cable associated with the circuit may run through several locations. Again, for anything other than the case where the effect is localized, a Phase 3 analysis should be performed. When there is a known issue associated with an area in which an unrelated finding is being assessed, the CCDP evaluation should account for the impact, which could be either the creation of an initiating event, or the failure of a system to perform its function.

4.4.9 Step 2.9 - Quantification and Preliminary Significance Determination

The analysis of fire scenarios is complete with the completion of Step 2.8. Step 2.9 involves the final quantification of the FDS scenarios of interest, and a preliminary determination of a finding's significance using in the following equation:

$$CDF_{2.9} = DF\sum_{i=1}^{n} F_i SF_i AF_{i,2.4.2} AF_{i,2.4.3} PNS_i CCDP_i$$

Where:

n	=	number of fire scenarios evaluated for a given finding (covering all relevant FDS's)
DF	=	Duration factor from Step 1.4
F_i	=	Fire frequency for fire ignition source 'i' from Task 2.4.1
$AF_{i,2.4.2}$	=	Ignition source specific frequency adjustment factor from Task 2.4.2
$AF_{i,2.4.3}$	=	Ignition source specific frequency adjustment factor from Task 2.4.3
SF_i	=	Severity factor for scenario 'i', if applicable from Task 2.4.4
PNS_i	=	Probability of non-suppression for scenario 'i' from Step 2.7
$CCDP_i$	=	Conditional core damage probability for scenario 'i' from Step 2.8

Based on the change in CDF estimated, the finding is assigned a significance color per Table 1.1.

5.0 SUPPORTING GUIDANCE, TABLES, AND WORKSHEETS

5.1 Phase 1 Analysis Supporting Information

This section provides guidance in support of the Fire Protection SDP Phase 1 analysis. The organization of the chapter follows the Phase 1 four-step analysis structure as set forth in Section 4.2.1 and 4.3 above.

5.1.1 Step 1.1: Assignment of a Finding Category

Examples of specific findings applicable to each finding category are illustrated in Table 5.1.1.

Table 5.1.1: Examples of finding category.

Finding Category:	**Elements of the fire protection program covered by each category:**
Cold shutdown	• findings related to the ability to achieve and maintain cold shutdown only
Fire prevention and administrative controls	• the plant combustible material controls program • other administrative controls such as work permit programs • hot work fire watches • roving or periodic fire watches • training programs • compliance documentation
Fixed fire protection systems	• fixed fire detection systems • fixed fire suppression systems (automatic or manual) • fire watches posted as a compensatory measure for a fixed fire protection system outage or degradation
Fire confinement	• inter-area fire barrier elements (seals, doors, dampers, etc.) • water curtains • fire and/or smoke dampers • fire doors
Localized cable or component protection	• raceway or component fire barriers (e.g., cable wraps) • radiant heat shields • spatial separation (e.g., per App. R Section III.G.2)

Table 5.1.1: Examples of finding category.	
Finding Category:	**Elements of the fire protection program covered by each category:**
Post-fire SSD	• post-fire SSD component list (e.g., completeness) • post-fire SSD analysis (e.g., completeness) • post-fire plant response procedures • alternate shutdown (e.g., manual actions) • remote shutdown and control room abandonment • circuit failure modes and effects (e.g., spurious operation issues)

5.1.2 Step 1.2: Assignment of a Degradation Rating

This section provides guidance on the assignment of a degradation rating to various findings. Degradation rating guidance is provide for each of the finding categories defined in Step 1.1.

5.1.2.1 Fire Prevention and Administrative Controls Programs

This section provides guidance on assignment of a degradation rating to findings against the plant fire prevention program and other administrative controls (e.g., hot work permitting, transient combustible control programs, fire watches, etc.).

Findings against hot work permitting or fire watch provisions:

Degradations for fire watches for hot work can be high, moderate, and low. The following provides a general description of the applied degradation levels:

- A high degradation implies that both early detection and early suppression (both by the fire watch) are not available.

- Moderate degradation implies loss of early suppression capability.

- Low degradations are warranted for inspection violations that will not have any significant effect on the likelihood that a fire might occur, or that a fire which does occur might not be promptly suppressed.

Examples of a high and medium degradations are as follows:

- High degradations
  - Failures to implement a continuous fire watch in positions to observe all areas of vulnerability to a fire from the hot work operation.
  - Failure to implement a fire watch at the site

- Moderate degradations
  - Watchers that are inadequately equipped with fire extinguishers or other required equipment. Inadequately equipped includes:

        - not having a portable fire extinguisher on the watch when one is required by the hot work permit
        - having a discharged or inadequately charged extinguisher
        - having the wrong type of extinguisher for the fire hazards involved or conditions at the site (dry chemical in an area of high wind currents)
    - Fire watch failing to maintain anyone of the following safe conditions[2] during hot work operations
        - Location is free of combustibles or that combustibles that can not be moved are shielded against ignition
        - Hot work equipment to be used shall be in satisfactory operating condition and in good repair.
        - Where combustible materials, such as paper clippings, wood shavings, or textile fibers are on the floor, the floor shall be swept clean for a radius of 35 ft.
        - Combustible floors wet down, covered with damp sand or fire-resistant sheets for a 35 ft. radius.
    - Fire watch failing to maintain fire watch for at least ½ hour after completion of hot work at all required observation points

- Low degradations
    - Fire watcher not having specific familiarity with the facility at the location of the hot work, the hazards of the work and procedures for sounding an alarm at that point as determined from an interview after completion of a watch.
    - Improper fire watcher training consisting of records showing a lack of required basic courses, refresher courses, and practice drills.
    - Cases where a portable extinguisher of the proper type is nearby (within 30 feet - unobstructed distance) even though watchers are inadequately equipped with fire extinguishers or other required equipment. This includes cases where a the proper portable extinguisher is nearby even though:
        - Not having a portable fire extinguisher on the watch when one is required by the hot work permit
        - having a discharged or inadequately charged extinguisher
        - having the wrong type of extinguisher for the fire hazards involved or conditions at the site (dry chemical in an area of high wind currents)
    - Violations of the hot work permitting program, but all normally required fire prevention measures (e.g., a properly equipped and trained fire watch) are in place.
    - Violations associated with hot work record keeping.

Note that moderate degradations, by their nature, are additive. That is, if more than one moderate degradation exists, the values should be added together but the total for moderate degradations should not exceed the value of a high degradation. Also, if a high degradation is assigned, no moderate degradations should also be assigned.

Note that fire watches compensating for temporary loss of detection/suppression and/or barriers primarily impact early fire detection/suppression time for ignition sources other than hot work and are treated in their respective places in this document.

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[2]Safe conditions were obtained from list of conditions in subsection 3-3.2 in NFPA 51B, "Standard for Fire Prevention During Welding, Cutting, and Other Hot Work," 1999.

Findings against the combustible controls program:

Another finding which potentially can affect frequency is violation of transient combustible control limits, specifically those combustibles which could result in the ignition of a fire from existing sources of heat or electrical energy. Transient combustibles of significance from a fire frequency standpoint are considered to be low flashpoint liquids (below 200 °F) and self igniting combustibles (oily rags). In addition to combustibles, evidence of tobacco smoking or the existence of unauthorized heaters or heat sources can also be considered as adversely affecting compartment fire frequency.

Degradations ratings for findings against the combustible controls program are either high or low (no moderate level is defined). Examples of high and low degradations are as follows:

High degradations:

- A measurable quantity of a low flashpoint (200°F) combustible liquid beyond the quantity allowed by the plant's combustible loading controls, unattended, and not in an approved container.
- Unattended storage of self heating materials such as oily rags not in an approved container.
- Evidence of smoking in a non-smoking area.
- An unapproved heater or heat source in the area.

Low degradations:

- Low flashpoint combustible liquids in quantities above those allowed by plant regulations but in approved containers.

5.1.1.2 Fixed Fire Detection & Suppression Degradation

Fire Detection

- Low Degradation:
    - If an area has a degraded detection system, but there is a redundant undegraded detection system in the area.
    - Less than 10% of smoke or heat detectors are degraded (inoperable, misplaced or missing), and operable detection is available near combustibles of concern. (Not applicable for areas with the potential for unconfined combustible or flammable liquid fire.)
    - Less than 25% detectors (heat or smoke) degraded (inoperable, misplaced or missing) in continuously occupied areas.
- Moderate Degradation: A degradation level between Low and High.
- High Degradation: System will fail to function
    - power off

- detectors incompatible with system
- annunciators disabled, inaudible, or inoperable

Water Based Suppression

- Low Degradation:
  - Less than 10% of heads are non functional and
  - there is an operable head is within 10 feet of combustibles of concern, and
  - system is nominally code compliant.

- Moderate Degradation:
  - Less than 25% of the heads are non functional or
  - the closest operable head is between 10 and 20 feet of combustibles of concern.

- High Degradation:
  - Non functional system, or
  - 25% or more of heads out of service, or
  - nearest head greater than 20 feet from combustibles of concern.

Gaseous Based Suppression

Note: depending on the type of degradation, for example, a hole that goes to the control room, a low degradation may be problematic. Meaning, the system may be effective at extinguishing but the system may cause control room evacuation.

- Low Degradation:
  - Hole in wall or floor less than area of one five inch diameter penetration seal (Not to control room or remote shutdown area)
  - Hole in ceiling up to 100 square inches (Not to control room or remote shutdown area),
  - Time delay in system operation of exceeds design by 60 seconds or less,
  - Discharge heads are obstructed,
  - Discharge time exceeds allowable by less that 25%,
  - Lack of test data,
  - Test data shows concentration for 15 minutes (where 20 minutes are required for licensing basis)
  - Achievable concentration is Halon 6% (where 7% is committed), or CO_2 50% (where 60% is committed).

- Moderate Degradation: A degradation level between Low and High
  - Design concentration adequate but cannot be maintained for sufficient time to ensure fire extinguishment

- High Degradation: System will fail to function
  - Power off
  - Inadequate agent to achieve required concentration for deep seated fires: Halon less than 5%; CO_2 less than 40%.

5.1.2.3 Fire Barrier Degradation

For fire barriers four levels of degradation have been defined. In particular, the moderate degradation level has been split into two sub-levels; namely, 'Moderate A' and 'Moderate B'. Moderate B will reflect a more severe level of degradation than Moderate A, although consistent with the generic definition of a moderate degradation, both rankings will imply that some substantial credit will be given despite the observed degradation. This distinction allows for additional discrimination in assessing performance degradations against a fire barrier or barrier element. The degradation ratings for fire barriers are defined in Table 5.1.2.

Table 5.1.2: Generic definition degradation levels for application to fire barriers and barrier elements

Low =	Minor defect observed that will have no effect on fire endurance, no performance reduction applied
Moderate A =	Fire barrier performance is reduced to approximately 65% of nominal fire endurance rating
Moderate B =	Fire barrier performance is reduced to approximately 35% of nominal fire endurance rating
High =	Fire barrier or penetration integrity is severely challenged - No credit for barrier

The guidance for assigning one of the above degradation levels depends on the type of fire barrier being considered. Table 5.1.3 provides examples to illustrate how an observed degradation is correlated to a degradation rating for each of several fire barrier types. The inspector should select the fire barrier type that most closely matches the barrier being considered and continue the evaluation.

Table 5.1.3: Guidance for ranking an observed fire barrier degradation finding based on the type of barrier system against which the degradation has been noted.

Barrier Type	Characteristics associated with each degradation Level			
	Low	Moderate A	Moderate B	High
Elastomers: low density foams / high density (e.g., silicone foam)	• Less than 10% of req'd seal depth missing • Barriers/components not in preventative maintenance program • Seal materials not listed in program • Greater than 12 inches of material • Poor quality foam cell structure (falls within Dow Corning's #6 category) over <25% of the surface area • Through cracks smaller than 1/8" in seal material that are less than 50% of the seal depth • 1/8" thru barrier gaps or cracks	• 10 to 25% of seal req'd depth is missing • Poor quality foam cell structure (falls within Dow Corning's #6 category) of approximately >25% of the surface area • No tested or evaluated configuration between 9 and 11 inches depth.	• Greater than 3/8" cracks in seal material extend to opposite face • No tested or evaluated configuration between 6 and 9 inches	• No tested or evaluated seal configuration and less than 6 inches of foam • > 50% required barrier depth removed or never installed • Through crack or equivalent diameter greater 1"
Sacrificial and non-sacrificial board or blanket (e.g., mineral wool or ceramic fiber)	• < 10% depth of barrier material removed or never installed • Through crack or equivalent diameter less than 1/8" • Compression of material	• 10% to 25% design depth of barrier material removed or never installed over 6 in area • Through crack or equivalent diameter greater ½" • Large metallic cross section support or large cross section cables entering wrap without 2-6" of wrap	• 25% to 50% design barrier material depth over area of 6 sq. in. Material removed or never installed • Through crack or equivalent diameter of greater than 2 sq in. • Large metallic cross section support or large cross section cables entering wrap with less than 2" of wrap	• No tested or evaluated barrier configuration • > 50% required barrier depth removed or never installed • Through crack or equivalent diameter greater 1".

Table 5.1.3: Guidance for ranking an observed fire barrier degradation finding based on the type of barrier system against which the degradation has been noted.

Barrier Type	Characteristics associated with each degradation Level			
	Low	Moderate A	Moderate B	High
Unique / Boot seals	• Severe tears, loose bands, open bands, outer boot missing • Missing boot both sides	• Support missing	• 2-3" of seal	• No ceramic fiber
Concrete and cement-based grout or penetration seal materials	• Surface cracks < 1/16" with no noticeable depth penetration • Through cracks smaller than 1/8" in barrier that are not more than 50% of the required barrier thickness • 1/16" thru barrier gaps or cracks	• Greater than 30% of required concrete depth missing	• Large surface area deformations (over 50% of surface) which would cause higher heat absorptions • <4.5 inches thick	• Cracks determined to interfere with structural integrity • <2 inches thick
Doors	• Improper non-combustible door labeling material. • Several small open exposed holes in doors, door gap issues not exceeding 25% of manufacturer's recommended specifications or up to 3/8" gap. • Multiple holes in door on one side of a door surface with less than 1/8" inch opening. • Door frames with greater than 1/8" thru gap	• Small screw holes in doors <3/8" on both sides • Improperly installed fire door hardware (other than latch) • Bent or warped fire door with gaps less than 1 inch • Fire door to frame or floor clearance gaps up to 1 inch.	• Multiple holes in door surface with greater than 1 inch opening • Door latch not functional, • Latch engagement <1/2 inch.	• Door propped open or broken latch.
Dampers	• Damper not in maintenance inspection program. • Damper frames with greater than 3/8" thru gap. • Damper can close completely	• Damper will close greater than 95%, Temperature of fusible link excessively high or fusible link improperly installed.	• Damper will close >90%, • No damper at fire barrier in steel duct work • Damper is not rated to close against anticipated ventilation	• Damper sealing less than or equal to 90%, will not close • Broken latch (where latch required for closure) • No damper installed

Table 5.1.3: Guidance for ranking an observed fire barrier degradation finding based on the type of barrier system against which the degradation has been noted.

Barrier Type	Characteristics associated with each degradation Level			
	Low	Moderate A	Moderate B	High
Unsealed conduits	• Conduits smaller than 1 inch with 3 feet on each side of barrier	• Conduits > 4 Inch with greater than 5 feet on each side of barrier or >2 Inch with greater than 3 feet on each side of barrier	• Conduits > 4 Inch with less than 5 feet on each side of barrier or >2 Inch with less than 3 feet on each side of barrier	

Water Curtain

Low Degradation - Less than 10% of heads obstructed or fouled, and no adjacent heads fouled.

Moderate - Not applicable.

High Degradation - Greater than 10% of heads obstructed or fouled or two adjacent heads fouled or obstructed. System inoperable.

Radiant Energy Shields

Note: If the radiant energy shield is a 'Rated' barrier (Darmatt, Interram) use the appropriate barrier type from elsewhere in this table.

- Low Degradation
  - barrier completely obstructs line of sight between the target of interest and
  - potential fire sources that could affect redundant targets, and it is non-combustible.

- Moderate Degradation
  - barrier provides partial line of sight obstruction between target of interest and potential fire sources that could affect redundant targets, or
  - it is combustible, but of rated material (Thermo-Lag).

- High Degradation
  - barrier does not provide line of sight obstruction between target of interest and potential fire sources that could affect redundant targets, or
  - it is combustible and not made of a rated material.

5.1.2.4 Safe Shutdown Findings

For findings related to the licensee's post-fire SSD program, three levels of degradation have been defined as follows:

Quantification Rank	Description
High	"Precludes safe shutdown" • No way for operator to diagnose (bad procedure, no indicator/instrumentation) • No way for operator to operate SSD system (manual actions not feasable) • Place plant in unrecoverable condition • Lack of alternate shutdown procedure • Reaching into energized equipment

Moderate	"Recoverable not precluded, but requires successful completion of challenging actions" • Incomplete instructions for complex tasks • Manual actions in first 30-60 minutes of time sequence outside control room (other than Alt SSD Panel) • Inadequate staffing • Inadequate staff training • Tools not staged or where intended by procedure • Actions in environmentally hazardous areas • Operators using normal procedure when fire procedure has special requirements • Climbing ladders • Poor labeling • Significant modification
Low	"Action readily apparent, easily performed" • Typographical procedure errors • Plenty of time (by analysis) • Poor procedures, but common actions • Straightforward actions, pulling fuse block, installing staged jumper with clear directions

5.1.3 Step 1.3: Initial Qualitative Screening Check

No specific guidance in support of Step 1.3 is currently provided.

5.1.4 Step 1.4: Initial Quantitative Screening Check

This section provides guidance in support of Step 1.4, and specifically, in support of Task 1.4.2. The objective of Task 1.4.2 is to estimate the fire area fire frequency for use in the Task 1.4.3, the initial quantitative screening check.

Table 5.1.4 provides a listing of nominal fire event frequencies for use in the initial Phase 1 Quantitative screening assessment. Note that the frequency estimates generated in Phase 1 are intended to conservatively bound the fire area fire frequency.

Table 5.1.4: Generic fire area fire frequencies for use in Phase 1 quantitative screening.

Room Identifier	Generic Fire Frequency
Main Control Room	3E-3
Cable Spreading Room - Cables Only	6E-4
Cable Spreading Room - Cables plus Other Electrical Equipment	2E-3
Cable Vault or Tunnel Area - Cables Only	6E-4
Cable Vault or Tunnel Area - Cables plus Other Electrical Equipment	2E-3
Switchgear Room	1E-2

Turbine Building - Main Deck (per unit)	3E-2
Reactor Building (BWR)	3E-2
Auxiliary Building (PWR)	1E-2
Pump Room	7E-3
Battery Room	2E-3
EDG Building	2E-2
Intake Structure	1E-2
Radwaste Area	5E-3
Transformer Yard	1E-2
Containment - PWR	1E-3
Containment - BWR	3E-3

5.2 Phase 2 Analysis Supporting Information

REVISION NOTE: It is anticipated that worksheets will be provided to support the inspector in implementation of the Phase 2 analysis. These worksheets have not been fully developed as of this revision (Rev. 2.3a). Completion of the required worksheets is one objective of the planned pre-implementation table-top exercises. This will include the completion of electronic versions of the calculation worksheets as well.

5.2.1 Step 2.1: Independent SSD Path First Screening Assessment

This step involves the identification and assessment of the Post-Fire SSD path for the fire areas that will be examined during an inspection. Note that Tasks 2.1.1 and 2.1.2 can be completed based entirely on plant documentation (e.g., documents that may be requested during the "bagman" trip); hence, these tasks can be completed during pre-inspection planning activities before entry into the plant site for the actual inspection. While not required, this approach is strongly recommended as it will increase the efficiency of the on-site inspection process.

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

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

The regulatory requirements for fire protection established by the USNRC 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 inspector 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, a document that should be obtained and reviewed during the pre-inspection preparation activities. Hence, this Task can, and should, be completed prior to the initial entry onto the plant site for the actual inspection. The inspector will be picking specific fire areas to be considered during the inspection. For each chosen area, the designated post-fire SSD path should be identified.

Once identified the inspector should also identify the corresponding Appendix R Section III.G.2 compliance strategy. This section requires the separation and protection of the SSD capability. If an exemption exists to III.G.2 for the area of interest, the exemption should also be carefully reviewed.

The inspector should also obtain and review the corresponding procedures for execution of post-fire SSD. Particular note should be taken of any operator or human actions that are credited in the SSD process. 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.

As a final step, the functions and systems that are required to support the SSD path should be identified. The inspector 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

The total unavailability numbers to be used in the screening CCDP evaluation are shown in Table 5.2.1. Note that these numbers are consistent with those values identified in the worksheets used to calculate the CCDP values in the more detailed analysis which follows in Step 2.8.

Certain additional caveats exist on the determination of the screening CCDP. Those caveats are:

- No credit is given for a train of equipment requiring the performance of ex-control room manual actions.
- No credit is given for manual actions impacted by fire effects such as smoke or high temperatures, or by discharge of carbon-dioxide fixed suppression systems
- Only manual actions which are specifically identified in the respective plant specific worksheet can be credited (provided they pass the above set of caveats). The total credit for the screening CCDP may be 0.1 or 0.01, but no less, as referenced above.

Table 5.2.1: Total unavailability values for SSD path based screening CCDP (Step 2.1)	
Type of Remaining Mitigation Capability	**Screening Unavailability Factor**
1 Automatic Steam-Driven (ASD) Train: A collection of associated equipment that includes a single turbine-driven component to provide 100% of a specified safety function. The probability of such a train being unavailable due to failure, test, or maintenance is assumed to be approximately 0.1 when credited as "Remaining Mitigation Capability."	0.1
1 Train: A collection of associated equipment (e.g., pumps, valves, breakers, etc.) that together can provide 100% of a specified safety function. The probability of this equipment being unavailable due to failure, test, or maintenance is approximately 1E-2 when credited as "Remaining Mitigation Capability."	0.01
Operator Action Credit: Major actions performed by operators during accident scenarios (e.g., primary heat removal using bleed and feed, etc.). These actions are credited using three categories of human error probabilities (HEPs). These categories are Operator Action = 0.1 which represents a failure probability between 5E-2 and 0.5, Operator Action =0.01 which represents a failure probability between 5E-3 and 5E-2. Credit is based upon the following criteria being satisfied: (1) sufficient time is available; (2) environmental conditions allow access, where needed; (3) procedures describing the appropriate operator actions exist; (4) training is conducted on the existing procedures under similar conditions; and (5) any equipment needed to perform these actions is available and ready for use.	0.1 or 0.01

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

No specific guidance in support of this task is currently provided.

5.2.1.4 Task 2.1.4: Finding Screening Check

No specific guidance in support of this task is currently provided.

5.2.2 Step 2.2: FDS Determination and FDS3 Screening

5.2.2.1 Task 2.2.1: Initial FDS Assignment

No specific guidance in support of this task is currently provided.

5.2.2.2 Task 2.2.2: Screening Assessment for FDS3 Scenarios

In general, inter-area fire barriers (fire barriers that separate fire areas) are expected to display high reliability. The analysis of room to room fire scenarios (FDS3) is a challenging task in fire PRA. Hence, screening criteria will be applied to determine the need to retain FDS3 fire scenarios as potential viable risk scenarios in the Phase 2 analysis.

The screening criteria are expressed in terms of the fire protection features for the "exposing" and "exposed" fire areas. The "exposing" fire area is the area in which the fire is assumed to be started. The "exposed" area is the adjacent space that might be impacted should fire spread from the exposing area, through an inter-area fire barrier, and into the exposed area.

For a moderately degraded fire barrier do not consider fire damage from room to room when the below criteria are met. Also, for low degradation, where the finding is not the fire barrier, the FDS3 damage state may not have to be evaluated. These are loosely based on EPRI's FIVE methodology, page 5-8. Highly degraded barriers are considered as if the barrier is not effective and can not be screened.

The following screening criteria may not require area walkdown:

- If the boundary of the fire area is considered to have a 2-hour or greater fire endurance rating, the FDS3 scenarios need not be evaluated.
  - This criteria will also apply to moderate degradations of an inter-compartment fire barrier element so long as the degraded performance is expected to provide at least two hours fire endurance. In this specific case, screening of the FDS3 scenarios means that no scenarios have been retained, and the finding screens to green without further analysis.

- If there is a non-degraded gaseous room-flooding fire suppression system in the exposing compartment, the FDS3 scenarios need not be evaluated unless:
  - If the finding involves a degradation of the inter-area fire barrier in the form of an unsealed opening, this gaseous suppression system may not be effective, and the FDS3 scenarios would be retained.

- If there is a non-degraded or moderately degraded full area water-based fire suppression system in the exposing compartment, the FDS3 scenarios need not be evaluated.
  - (Full area water systems will likely be effective at keeping a fire from going from area to area, even if moderately degraded.)

- If the exposed areas adjacent to the exposing fire area contain no safe shutdown components or plant trip initiators, the FDS3 scenarios need not be evaluated.
  - This criteria can be applied on a pair-by-pair basis to screen out compartment pairs and limit the scope of the FDS3 analysis. That is, FDS3 scenarios nominally might involve the exposing area in combination with any of the adjacent areas as the exposed area. If any of these adjacent compartments meet this criteria, then FDS3 scenarios involving that area as the exposed are need not be evaluated.

The following screening criteria require area walk-down:

- If the exposing area is covered by a partial-coverage automatic, water-based fire suppression system, and the system provides effective coverage for all of the fixed or *in situ* fire ignition sources in the area, the FDS3 need note be evaluated.

- Boundaries that consist of degraded non-combustible 1-hour fire rated barrier or barrier less than 3 hours that has been evaluated to match the loading in the room with no significant accumulation of combustible in the area of the barrier, such that the barrier would could not be impacted by direct flame impingement only hot gases - no FDS3 need be evaluated. (It is expected that a moderately degraded barrier (even 20 minute barrier) would be able to withstand a hot environment (~700F) for an extended period of time, and therefore would screen. Layer of kaowool over silicone foam would screen. Undegraded half inch marinite over foam would screen.)

5.2.3 Step 2.3: Characterize and Screen Fire Ignition Sources

5.2.3.1 Task 2.3.1: Identify and Count Fire Ignition Sources

Cases Where Igntion Source Identification is Limited to Specific Sources:

For most findings, the inspector will be asked to identify all potential fire ignition source scenarios within the fire area(s) under analysis. However, for certain types of specific findings, the search for fire ignition sources is sharply limited. These cases are as follows:

- If the finding is against the administrative controls program and is associated with hot work permitting or fire watch elements of the program, then only the potential for hot work fires is considered. No consideration of fires initiated by the fixed or *in situ* fire ignition sources is necessary, because the risk contribution arising from such fires does not change given a finding against the hot work control programs. Note that fires initiated by hot work may well involve the ignition of, or spread to, an *in situ* or transient combustible material (e.g., cables, trash, or stored materials), but the fire ignition source is the hot work activity itself.

- If the finding is against the administrative controls program and is associated with the combustible material control elements of that program, then only fires initiated in or by transient combustible materials need to be considered. Once again, no consideration of fires initiated by the fixed or *in situ* fire ignition sources is necessary, because the risk contribution arising from such fires does not change given a finding against the combustible material control programs. Note that fires initiated in a transient material may well spread to *in situ* combustible materials (e.g., cables or an adjacent electrical panel) but the fire ignition source is the transient combustible material.

- If a finding is related to the degradation of specific portions of a water-based fire suppression system, it may be appropriate to limit the fire ignition source search to those sources whose coverage is impacted by the specific degradation.

- No other specific cases of a similar nature have been identified. However, should the inspector encounter a fire protection program degradation finding that is very specific to fires involving one or more specific fire ignition sources, then the SDP Phase 2 analysis can be focused on only those specific sources. It is recommended that the inspector seek additional guidance and support in making such a decision. Careful and complete documentation of the decision will also be required.

Cases Where Fire Ignition Source Identification is Not Limited:

For all other types of findings, fire ignition source will generally include any electrical or mechanical components and other potential fuel sources located in a particular fire area. Fire ignition source scenarios to be included are electrical equipment fires, potential sources of oil leakage (e.g., lubricated pumps and motors), potential sources of flammable gas leaks, fires that may result from the failure of major plant components (e.g., the turbine generator set or a diesel generator), and fires associated with maintenance activities such as welding and cutting.

Table 5.2.2: Fire ignition source counting worksheet.			
Fire Ignition Source Type Bin	**Count**	**Fire Ignition Source Type Bin**	**Count**
Turbine Generator Set		Reactor Coolant Pumps (PWR)	
Boiler Heating Units		Reactor Feed Pumps (BWR)	
Yard Transformers		Main Feedwater Pumps	
Indoor Dry Transformers		Other Pumps	
Indoor Oil-Filled Transformers		Diesel Generators	
Bus Bars		Other Motor Generator Sets	
Switchgear Cabinets		Gas Turbine Generators	
General Electrical Cabinets		H2 Recombiner (BWR)	
General Control Cabinets		Hydrogen Storage Tank	
Control Room Service Cabinets		Misc. Hydrogen Fires	
Battery Racks		Air Compressors (< 100 HP)	
Electric Motors (<100 HP)		Air Compressors (>= 100 HP)	
Electric Motors (>= 100 HP)		Ventilation Subsystems	
Dryers		Hot Work Activities (welding or cutting)	
Non-Qualified Cable Runs		General Transient Fuel and Ignition Sources	

Note that one fire ignition source scenario that is applicable to all areas of the plant is transient fuel fires (e.g., trash, refuse, temporary storage materials, etc.).

The inspector should identify all potential fire ignition sources in the room, and assign each identified fire ignition source to one of the type bins identified in Worksheet/Table 5.2.2. (Note: In Step 2.4, the inspector will be asked to enter a total number of unscreened sources of each fire ignition source type in the fire area(s) under analysis. It may be convenient to complete the counting task (Task 2.4.3) in conjunction with the source identification task.)

- Example 1: Given the binning approach, it is not necessary to separately catalog each individual electrical cabinet in a room. Instead, the inspector catalogues electrical panels by type in accordance with the fire ignition source bins (e.g., switchgear vs. general electrical panels vs. control/relay panels), and generates a count of the number of each type of panel present. Panels are counted based on the number of distinct vertical sections present.

- Example 2: A fire area is found to contain the following fire ignition sources: two large motors (>100 HP), two switchgear banks each containing 12 well defined vertical panel sections (counted as a total of 24 switchgear panels), one dry type 4 kV transformer, and a moderate load of electrical cables. This area therefore contains four unique fire ignition source types: electric motors >= 100 HP (2), switchgear cabinets (24), indoor dry transformer (1), and cables (moderate load).

Counting Fire Ignition Sources:

The counting of fire ignition sources applies only to cases where the identification of fire ignition sources was not limited. That is, if the only fire sources of interest are transients and/or hot work fires, then no counting of other ignition sources is required.

Recall that fire ignition source scenarios may involve either an individual fire ignition source (e.g., a pump, motor, electrical panel, transient fuel source), or may involve a grouped set of similar fire ignition sources (e.g., a bank of like electrical panels). Counting guidance is also provided in Section 5.2.4. In general the inspector will:

- Count the number of individual unscreened fire ignition sources of each fire ignition source type.

- Identify groups of like fire ignition sources that will be treated as a set for fire scenario development purposes, and count the number of individual members comprising the set. A grouped set of fire ignition sources will be treated, in effect, like a single fire ignition source. However, the fire frequency for the set is based on the total number of members (e.g., a grouped set of sources with 10 members will have 10 times the fire frequency of an individual source of the same type).

5.2.3.2 Task 2.3.2: Characterize Fire Source Severity and Location

The objective of Task 2.3.2 is to characterize each of the fire ignition sources in the fire area. Characterization involves assigning fire intensity values and a location to each source.

In some cases, the characterization of a fire ignition source requires the consideration of case-specific factors that are not amenable to pre-definition in a generic context. These 'Non-Simple' Fire Ignition Sources include the following:

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

All other fire ignition sources are considered 'Simple' Fire Ignition Sources. Characterization of the simple and non-simple cases are discussed in the following two subsections.

Cases Involving 'Simple' Fire Ignition Sources

The fire intensity values for the 'simple' fire ignition sources are based on the ignition source type bin assigned by the inspector. Table 5.2.3 maps each of the identified fire ignition source type bins to a corresponding fire characterization type category. Table 5.2.4 assigns expected and high confidence fire intensity values to each fire characterization type category for the simple cases.

- Example 1: Among the identified fire ignition sources is a 150 HP electric motor. The motor is binned as type "electric motors >= 100 HP." The corresponding fire characterization type is "large electrical fire." As such, it is assigned an expected fire intensity of 200 kW, and a high confidence fire intensity of 600 kW.

- Example 2: Among the identified fire ignition sources is a battery charger. The charger is binned as a "General Electrical Cabinet" and the corresponding fire characterization type is "small electrical fire." As such, it is assigned an expected fire intensity of 70 kW and a high confidence fire intensity of 200 kW.

Recall that in Step 2.2, Fire Ignition Source Scenario Identification and Characterization, each fire ignition source was assigned two potential fire intensity values. In Step 2.4, some fire ignition sources may have screened out in whole (i.e., given either intensity value) or in part (i.e., given the lower value but not the higher intensity value). The treatment of severity factor is based on the damage potential of the fire ignition source considering these results as follows:

- Nominally, if the lower, or anticipated, fire intensity leads to fire spread and/or damage, this value will be assumed to characterize all fires involving that fire ignition source; i.e., a 1.0 severity factor is applied.

- If only the higher, or 95% confidence limit, fire intensity value leads to fire damage, then this higher value will be assumed to represent the most severe 10% of fires involving that fire ignition source; that is, a 0.1 severity factor will be applied. That is, the 95% confidence limit will be assumed representative of a bin of fire events representing the top 10% of fires (a bin twice as wide as the associated confidence limit).

In some cases, it may be appropriate to consider the risk contribution from both the lower and higher fire intensity values. In particular, if the lower intensity fire is found to have a long fire damage time, then the higher intensity fire may actually be more risk significant. Section 5.5 includes a test to determine if this case is applicable.

Table 5.2.3: Mapping of specific fire ignition source bins to general fire scenario characterization type bins.	
Fire Ignition Source Type Bin	**Fire Scenario Characterization Bin**
Turbine Generator Set	Exciter Fires - Small Electrical Fire
	Oil leaks and spills - Oil Fire
	Hydrogen leaks - Hydrogen Fires
Boiler Heating Units	Engines and Heaters
Yard Transformers	Very Large Fire Sources
Indoor Dry Transformers	Small Electrical Fire
Indoor Oil-Filled Transformers	Indoor Oil-Filled Transformer
Bus Bars	Non-Thermal - Energetic Faults
Switchgear Cabinets	Thermal - Small Electrical Fire
	Non-Thermal - Energetic Faults
General Electrical Cabinets	Small Electrical Fire
General Control Cabinets	Large Electrical Fire
Control Room Service Cabinets	Large Electrical Fire
Battery Banks/Racks	Small Electrical Fire
Electric Motors (<100 HP)	Small Electrical Fire
Electric Motors (>= 100 HP)	Large Electrical Fire
Dryers	Small Electrical Fire
Non-Qualified Cable Runs	Self-Ignited Cable Fire
Reactor Coolant Pumps (PWR)	Motor Fires - Large Electrical Fire
	Oil leaks and spills - Oil Fire
Reactor Feed Pumps (BWR)	Motor Fires - Large Electrical Fire
	Oil leaks and spills - Oil Fire
Main Feedwater Pumps	Motor Fires - Large Electrical Fire
	Oil leaks and spills - Oil Fire
Other Pumps (< 100 HP)	Motor Fires - Small Electrical Fire
	Oil leaks and spills - Oil Fire

Table 5.2.3: Mapping of specific fire ignition source bins to general fire scenario characterization type bins.

Fire Ignition Source Type Bin	Fire Scenario Characterization Bin
Other Pumps (>= 100 HP)	Motor Fires - Large Electrical Fire
	Oil leaks and spills - Oil Fire
Diesel Generators	Engines and Heaters
Other Motor Generator Sets	Engines and Heaters
Gas Turbine Generators	Engines and Heaters
H2 Recombiner (BWR)	Hydrogen fires
Hydrogen Storage Tank	Hydrogen fires
Misc. Hydrogen Fires	Hydrogen fires
Air Compressors (< 100 HP)	Small Electrical Fire
Air Compressors (>= 100 HP)	Large Electrical Fire
Ventilation Subsystems	Small Electrical Fire
Hot Work	Solid and Transient Combustibles
General Transients	Solid and Transient Combustibles

Table 5.2.4: Mapping of general fire scenario characterization type bins to fire intensity characteristics.

Fire Size Bins	Generic Fire Type Bins With Simple Predefined Fire Characteristics					
	Small Electrical Fire	Large Electrical Fire	Indoor oil-filled transformers	Very Large Fire Sources	Engines and Heaters	Solid and Transient Combustibles
70 kW	50th percentile fire				50th percentile fire	50th percentile fire
200 kW	95th percentile fire	50th percentile fire			95th percentile fire	95th percentile fire
650 kW		95th percentile fire	50th percentile fire	50th percentile fire		
(2 MW) TBD			95th percentile fire			
(10 MW) TBD				95th percentile fire		

Self-Ignited Cable Fires

Self-ignited cable fires are generally considered only for thermoplastic or non-qualified cables. That is, cables rated as low flame spread per the IEEE-383 standard will not be assumed subject to self-ignited cable fires so long as proper current limiting provisions are provided.

A self ignited cable fire will begin burning in one specific tray (choice is up to inspector and may be driven by target locations if well known). The fire will be treated as a small electrical fire, although using only the 70kW expected fire intensity. The corresponding high confidence fire intensity (200 kW) will not be considered. Subsequent spread of the fire will be assumed using the rules-based approach to cable fires. The initially ignited cable tray will be treated as the exposure source for subsequent trays.

Oil spill fires

In the specific case of oil spill fires (e.g., from pumps, motors, or the turbine generator set), and for certain findings solid transient fuel fires, the fire characterization task requires additional knowledge and will not fit neatly into the pre-defined fire bins:

> Example 3: For those fire ignitions sources that hold the potential for oil spill fires (e.g., pumps, oil-filled transformers, and the main turbine generator set) the inspector must determine the quantity of oil that might be spilled in the event of an oil release. The inspector must also determine local characteristics that might influence the size of the oil pool formed (e.g., the existence of a berm or curb that would limit oil flow). The fire source is then characterized based on assumptions regarding the release of the contained oil. In general, the expected fire will involve release of 10% of the contained oil, and the high confidence fire will involve 100% of the contained oil. These assumptions may be modified to suit a specific application based on inspector judgement. Additional guidance is provided in Section 5.2.3.

Hydrogen fires

DESCRIPTION PENDING

Energetic electrical arcing faults leading to fires

DESCRIPTION PENDING

Adjusting transient fire source characteristics

If a finding against the administrative controls program involves the identification of inappropriate material types or quantities within a fire area, then the inspector is expected to adjust the characteristics of the transient fire ignition source to reflect the as-found condition. The nominal fire characteristics provided in Table 5.2.4 are based on nominal transient fuel packages (as described in Section 4.4.2.3). For larger or more volatile fuel sources, and if the finding involves significant quantities of flammable or combustible liquids, then some additional consideration is needed.

> Example: If the finding is against the administrative controls program, combustible materials control element, then some careful consideration of the characteristics of postulated

transient fires may be needed. If, for example, the inspector has found inappropriate types or amount of combustible material, then the characteristics of the transient combustible material fire should be adjusted to reflect the as-found condition. The generic fire characteristics are based on the types of transient combustible materials that one should routinely expect to encounter in normal plant operations. In general the nominal characteristics assigned reflect burning of a single bag of trash, a single trash can with a normal load of trash, a small amount of wood scrap (i.e., a single pallet), a small plastic bucket in combination with and a small quantity of cleaning solvent, and other similar fuel packages.

ADDITIONAL GUIDANCE PENDING

Hot work fires

GUIDANCE PENDING

Grouping of Fire Ignition Sources:

In some applications it is both more efficient and appropriate to group fire ignition sources for the purpose of analysis. The most common example is in the treatment of electrical panel fires. 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 member of a group may be represented by one (or more) fire ignition source scenario(s) that conservatively bound(s) the conditions of the group.

In such cases, a group of fire ignition source 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:

In the case of most fixed fire ignition sources, the location to be assigned is based on the physical location of the source:

- For fixed fire ignition sources, the assigned location 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.

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). The tables in Section 5.2.3 provide specific guidance on where to assume that a particular fire source is located. Note that in some cases, it is appropriate to assume more than one location for a given fire ignition source scenario.

In general the location chosen should conservatively bound the potential for fire spread and damage for the entire set of ignition sources intended to be represented by the case example. This often means choosing the specific ignition source or location that is nearest to secondary combustibles, or is nearest to a thermal damage target. For radiant heat exposure, nearest means line of site. For plume exposure nearest means, first, most directly above the source, and second, nearest in vertical distance. Indeed, in the screening of a set of fire ignition sources, the radiant heating stand-off distance might be measured from one location, and distance to the nearest overhead secondary combustible from another location. If the source still screens out, then the analysis has conservatively bounded any potential fire effects for the full ignition source set. If the set does not screen, the consideration of additional sub-scenarios to represent the ignition sources may be appropriate.

Note that for a hot gas layer exposure, the location of the fire in the room makes no difference. With regard to the current task, the physical location of the fire is only important in the context of radiant or plume heating. (Location can also impact fire detection or suppression system actuation - see Step 2.7.)

> Example 1: Transient combustible fuels could appear in almost any fire area, and in most any location within a given fire area. For these cases, the fire source will be assigned as a “room-wide” fire source. Fire locations will be assigned based on the proximity to secondary combustibles and/or damage targets.

SPECIAL NOTE: In the case of transients, the exact location of the fire (e.g., directly under a cable pinch point) may prove critical to the fire spread and damage potential. In this step, only the potential for a transient fire to spread or cause damage given placement in some location within the room will be considered. A partitioning factor may be applied to such cases during the detailed analysis of specific fire scenarios in Steps 2.6 and 2.7 below.

Example 2: 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 3: The physical situation is similar to Example 2, 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. A unique fire location is assigned to represent each of these three scenarios.

5.2.3.3 Task 2.3.3: Identify Nearest Ignition and Damage Targets

Note that the same target may be considered as both an ignition and damage target. For example, a cable tray directly above a fire ignition source is a likely target for both ignition and damage. Indeed, in many cases the ignition and damage targets will be electrical cables. However, other combustible materials or damage targets should also be considered if present.

Note also that the ignition and/or damage of any one target by any means of fire exposure is sufficient to prevent screening of a fire ignition source. Hence, the inspector need not exhaustively explore all potential targets or exposure modes given that one ignited or damaged target and exposure mode is identified. Given fire behavior in typical nuclear power plant fire scenarios, it is generally most fruitful to first explore possible plume exposures (the most likely damage/ignition mode for most scenarios), followed by direct radiant heating exposures, followed finally by hot gas layer exposures, although the order of consideration is not critical.

The identification of nearest ignition and damage targets will most often involve the identification of cables as both damage and ignition targets. Often the same cable will represent both targets.

For cables, the ignition and damage criteria will be assumed to be the same. Heat flux and temperature criteria for damage and/or ignition are identified in Table 5.2.5.

Table 5.2.5: Screening criteria for the assessment of the ignition and damage potential of electrical cables.

Cable Type	Radiant Heating Criteria	Temperature Criteria
Thermo-plastic	6 kW/m^2 (0.5 BTU/ft^2s)	205°C (400°F)
Thermo-set	11 kW/m^2 (1.0 BTU/ft^2s)	330°C (625°F)

Additional rules for application in the target identification task are as follows:

- Cables in conduit will be considered potential damage targets, but not ignition targets. Cables in conduit will not contribute to fire growth and spread. The conduit will be given NO credit for delaying the onset of thermal damage.

- Cables coated by a fire-retardant coating will be considered as both thermal damage and fire spread targets. For the purposes of the Phase 2 analysis, no credit will be given to the coating for delaying or preventing the onset of damage and/or ignition.

- In identifying damage targets, do not include components within or directly associated with the fire ignition source itself. The fire ignition source will inherently be assumed to be damaged given any fire involving itself as the source so further evaluation of the components as damage targets is unnecessary.
  - Example: for an electrical panel fire, all equipment and components within the panel will be assumed to fail. Per the counting guidance, a panel will be defined as a distinct vertical section in this context.
  - Example: Given a self-ignited cable fire, all cables in the initiating raceway will be assumed to fail immediately on fire ignition (time zero).

- If a scenario should arise involving solid state control components as a thermal damage target, the failure criteria to be applied in screening are: 0.25 BTU/ft^2s and 200°F. The criteria for ignition of the components will assume properties similar to thermo-plastic cables: 0.5 BTU/ft^2s and 400°F.

- Pipes and water tanks constructed of ferrous metal will be considered invulnerable to fire damage.

- For major components such as motors, valves, etc., the fire vulnerability will be assumed to be limited by the vulnerability of the required power, control, and or instrument cables supporting the component.

- Passive components (e.g., flow check valves) will be considered invulnerable to fire.

Mixed Cable Insulation/Jacket Type Configurations

There are cables that are formulated with a thermoset insulation and a thermoplastic jacket, and potentially, *vise-versa*. Armored cables that may have a bare metal armor exposed, or may have either a thermo-set or thermoplastic covering over the metallic armor. For such cases, some special consideration is needed.

In the SDP process, the analysis does not distinguish between ignition and damage behaviors. Ignition of a cable is taken as an indication of imminent failure. In the assessment of whether to treat a cable as a thermoset or thermoplastic, the weakest link will dominate. For example, a cable with a thermoset insulation and a thermoplastic jacket will be treated using the failure criteria of a thermoplastic cable to reflect the reduced resistance to ignition of the jacket material. A cable with a thermoplastic insulation and a thermoset jacket will also be treated as a thermoplastic due to the likelihood of melting of the insulation material.

Table 5.2.6 provides a decision matrix for the selection of which failure/ignition property set to apply to a given cable.

Table 5.2.6: Cable properties selection decision matrix		
Cable Construction / Configuration		Ignition/Damage Parameter Set to be Used
Insulation Type	Jacket/Covering Type	
TS	TS	TS
TS	TP	TP
TP	TS	TP
TP	TP	TP
Armored - TS	TS, or No Cover	TS
Armored - TS	TP Cover	TP
Armored - TP	TS, TP, or No Cover	TP
TS = Thermoset TP = Thermoplastic		

5.2.3.4 Task 2.3.4: Screen Fire Ignition Sources

The fire source screening process considers both the potential for fire spread to secondary combustible and the potential for fire damage given a fire ignition source scenario. Screening of a fire ignition source scenario may result due to one of two conditions. First, a fire ignition source scenario may screen out if it is in a location that is sufficiently removed from secondary combustible materials and potential damage targets such that fire spread and/or damage cannot occur. Second, a fire ignition source scenario may screen out if it has insufficient fire intensity to cause fire spread and/or damage.

The fire effects include three modes of fire-induced damage: exposure to direct line of sight radiant heating, exposure to the heating effects of the fire plume, and hot gas layer heating effects. The first two modes, radiant and plume effects, are based on zone of influence charts. The hot gas layer mode is based on a correlation to estimate hot gas layer temperature.

Recall that in Task 2.3.3 potential ignition and damage targets were identified for each unique fire ignition source. The fire ignition source screening analysis is based on the application of graphical ‘zone of influence’ charts (also called the ‘ball and column’ charts) and on consideration of hot gas layer effects for a given fire source. If one or more of the identified ignition or damage targets lies within a fire ignition source’s zone of influence, or if the hot gas layer can reach temperatures sufficient to damage or ignite a target, then the ignition source is retained. The zone of influence charts corresponding to each fire intensity used in the SDP analysis are provided in Section 5.2.3.

A hot gas layer temperature analysis is also performed to ensure that the fire ignition source, in and of itself, cannot lead to component damage. In general, 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 for this analysis (see Section 5.2.3.4)

Recall that in Step 2.2 each fire ignition source was assigned two fire severity values. The fire ignition source screening analysis first considers each source based on the fire characteristics associated with the higher fire intensity (the 95% confidence limit fire intensity). If the fire ignition source screens out assuming the higher intensity fire values, then the lower intensity fire can be screened out without analysis. However, if the higher intensity fire does not screen out, the screening analysis should be repeated using the values characterizing the lower intensity fire for that source (the anticipated or nominal fire intensity). Results for both fire intensity values are to be recorded.

- If a fire ignition source does not screen out for either of its fire intensity conditions, then both the higher and lower intensity characteristics are retained for consideration in subsequent analysis steps.

- In some cases, the fire ignition source may screen out given the lower intensity fire characteristics, but will not screen out given the higher intensity fire characteristics. In this case, the fire ignition source is retained (it is screened in), but only at the higher fire intensity. That is, the inspector need only consider these fire ignition source scenarios given the higher intensity fire characteristics in subsequent analysis steps.

It is also possible that the screening analysis will result in the elimination of potential fire source locations rather than elimination of the fire source in its entirety. For example, transient fuel fires will likely be retained only in specific locations, typically locations directly below or adjacent to an ignition or damage target. Similarly, it may be possible to eliminate some panels as non-threatening while others may be retained for further analysis based on their proximity to secondary combustibles and/or damage targets. In such cases, the results of the location analysis should also be recorded. In later steps (Steps 2.6 and 2.7) the fire frequency will be adjusted to reflect a location partitioning factor.

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 CD ROM is used to calculate centerline temperature of a buoyant fire plume:

- Plume_Temperature_Calculations.xls

Inputs required for use of this correlation are also described in detail in the NUREG, and are summarized as follows:

- heat release rate of the fire (kW)
- distance from the fire location to the ceiling (ft)
- surface area of the combustible fuel (ft^2)
- convective fraction (use 0.6)

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 CD ROM that may be applied are:

- Fire with Natural Ventilation: Temperature_NV.xls (Click on Thermally Thin)
- Fire with Forced Ventilation: Temperature_FV1.xls (Click on Thermally Thin)

Note that in both cases the “thermally thin” correlation is used. This case represents the long time limiting conditions for fire development, and yeilds a single temperature in the hot gas layer representing a sustained fire condition. This case is appropriate to the SDP Phase 2 analysis.

The required inputs for use of the above correlations are described in detail in Section 2.11 of NUREG-1805. They are summarized as follows:

- The user must obtain the following values before attempting a calculation using either the natural or forced ventilation spreadsheets:
  - Compartment width (ft)
  - Compartment length (ft)
  - Compartment height (ft)
  - Interior lining material thickness (in.)
  - Select type of lining material from table
  - Fire heat release rate, HRR (kW)

- When using the natural ventilation spreadsheet, the user must also obtain the following values:
  - Vent width (ft)
  - Vent height (ft)
  - Top of vent from floor (ft)

- When using the forced ventilation spreadsheet, the user must also obtain the following values:
  - Forced ventilation rate (cfm)

Radiant heating correlation

The correlation for estimating fire radiant heating effects is described in detail in Chapter 5 of NUREG-1805:

- Wind Free Condition (i.e., indoor fires):
  - Heat_Flux_Calculations_Wind_Free.xls (Click on Point Source) or (Click on Solid Flame 1) or (Click on Solid Flame 2)

- Presence of Wind (i.e., outdoor fires with wind)
  - Heat_Flux_Calculations_Wind.xls (Click on Solid Flame 1) or (Click on Solid Flame 2)

Inputs for Calculating Incident Radiative Heat Flux from a Fire to a Target are described in Section 5.6 of NUREG-1805 and are summarized as follows:

- The user must obtain the following information before using the spreadsheet.
  - fuel type (material)
  - fuel spill area or dike area (ft^2)
  - distance between fire and target (ft)
  - vertical distance of target from ground level (ft)
  - wind speed (ft/min) for wind calculation only

Zone of influence charts - development and application

The zone of influence chart is based on consideration of the fire plume and radiant heating effects.

The fire plume is represented by a cylinder that extends above the fire source. The diameter of the cylinder is based on the diameter of the fire ignition source itself. The height of the cylinder is calculated based either on the ignition temperature threshold for secondary combustible materials in the vicinity of the fire, or based on the damage temperature threshold for components and cables that may be located above the fire source, whichever results in the most conservative (i.e., tallest) cylinder.

The ball and column zone of influence chart is shown generically in Figure 5.2.1. The values of the variables H, R, and W are dependent on the fire source intensity and target failure/ignition criteria. Tables 5.2.7a, 5.2.7b and 5.2.7c provide values for these variables that can be used for each of the five fire intensity values specified in the fire characterization task, and for both thermo-set and thermo-plastic cables.

The parameters of the zone of influence chart are also 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. See Table 5.2.7a.
- For a fire located directly next to a wall, the nominal fire intensity/HRR is multiplied by two in the plume temperature calculation. See Table 5.2.7b.
- For a fire located directly next to a corner, the nominal fire intensity/HRR is multiplied by four in the plume temperature calculation. See Table 5.2.7c.

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.

> SPECIAL NOTE: 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. The ball and column charts are based on the same correlations as are used in the FDS1 fire growth and damage time analysis (see Task 2.6.1). It is recommended that the inspector seek additional support in such cases.

The screening of fire ignition sources is based on a direct visual check for damage or ignition targets within the zone of influence for a given fire source. If no such targets are within the zone of influence, the fire ignition source screens out.

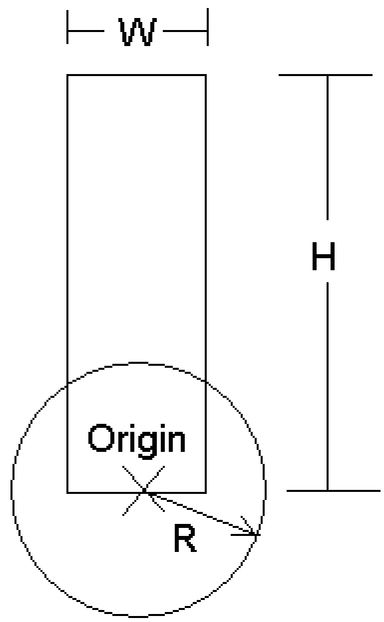


Figure 5.2.1: Generic Ball and Column zone of influence chart.

Table 5.2.7a: Pre-calculated values for use in the Ball and Column zone of influence chart for fires in an *open location away from walls*.				
Nominal Fire HRR	Thermo-plastic Cables		Thermo-set Cables	
	H	R	H	R
70 kW	TBD			TBD
200 kW				
650 kW				
2 MW				
10 MW	TBD			TBD

Table 5.2.7b: Pre-calculated values for use in the Ball and Column zone of influence chart for fires *adjacent to a wall*.				
Nominal Fire HRR	Thermo-plastic Cables		Thermo-set Cables	
	H	R	H	R
70 kW	TBD			TBD
200 kW				
650 kW				
2 MW				
10 MW	TBD			TBD

Table 5.2.7c: Pre-calculated values for use in the Ball and Column zone of influence chart for fires *adjacent to a corner*.				
Nominal Fire HRR	Thermo-plastic Cables		Thermo-set Cables	
	H	R	H	R
70 kW	TBD			TBD
200 kW				
650 kW				
2 MW				
10 MW	TBD			TBD

The origin of the zone of influence chart is taken as the physical center of the fire ignition source itself in most cases. For example, with an electrical panel, the fire origin is at the center of the panel and at the half-height location - the sides of the panel do not effect the zone of influence. Exceptions are as follows:

- For oil or liquid fuel spill fires, the origin is on the floor at the center of the spill.

- For a hydrogen or other gas fire, the origin is at the point of release.

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

The process of estimating the nominal fire frequency involves application of a worksheet. It is strongly recommended that this worksheet be exercised in its electronic format due to the potential for error in executing a hand calculation of the individual fire frequency values.

The inspector is asked to count fire ignition sources in the fire area. General Counting guidance is provided in Table 5.2.8. Specific counting guidance related to fire ignition sources requiring application of more qualitative counting bases is provided in the text immediately 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. The frequency of cable fires is assumed to depend on IEEE-383 qualification, quantity of cables present and whether or not welding may occur in the area. It must be noted that it is assumed that cables inside conduits do not contribute to the frequency of fire. For quantity of cables the following three levels are defined:

- "Low" may be used for areas that have a few cable trays that are generally less than half empty. For example, this level may be used for a compartment 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.

Table 5.2.8: Fire Ignition Source Counting Guidance.	
Fire Ignition Source Type Bin	**Counting Notes and Guidelines**
Turbine Generator Set	Count as a unit - will contribute three types of fires; namely, exciter, oil and hydrogen.
Boiler Heating Units	Generally found in the turbine bulding - count the number of water heating sources. Pumps and motors are counted separately.
Yard Transformers	This covers all large oil-filled transformers located outside including the unit main and auxiliary transformers
Indoor Dry Transformers	Do not include very small dry transformers such as individual lighting transformers or control power transformers within an MCC. Note that battery chargers and inverters are counted separately.
Indoor Oil-Filled Transformers	Associated with power distribution equipment
Bus Bars	Count number of distinct busses, and estimate total linear feet
Switchgear Cabinets	Count distinct vertical sections (not individual cubicles)
General Electrical Cabinets	Count distinct vertical sections. This bin includes MCCs, breaker panels, battery chargers, inverters, and other similar cabinets.
General Control Cabinets	Count distinct vertical sections. This bin includes signal conditioning cabinets, control relay cabinets, open relay racks, solid state equipment cabinets, remote shutdown panels, fire protection panels and other similar.
Control Room Service Cabinets	Count distinct vertical sections. Include those panels directly associated with the functions of the Main Control Room even if the fire area being analyzed is a separate fire area (e.g., a relay room or auxiliary electrical equipment room).
Battery Racks	Count by number of distinct horizontal racks present

Table 5.2.8: Fire Ignition Source Counting Guidance.

Fire Ignition Source Type Bin	Counting Notes and Guidelines
Electric Motors (<100 HP)	Exclude motors associated with pumps, ventilation subsystems, or compressors (counted in other bins). Include motor operated valves.
Electric Motors (>= 100 HP)	
Dryers	Count units if present
Non-Qualified Cable Runs	Estimate based on a High, Moderate, or Low cable load
Reactor Coolant Pumps (PWR)	Present in Containment
Reactor Feed Pumps (BWR)	Present in Containment
Main Feedwater Pumps	Count individual pump/motor units as a set.
Other Pumps	Include all pumps not explicitly covered by other bins (e.g., fire pumps, service water, component cooling water, etc.). Pump and motor are counted as a unit.
Diesel Generators	Count motor and generator set as a unit.
Other Motor Generator Sets	Often found associated with the reactor protection system (for example).
Gas Turbine Generators	Count each as a single unit if present
H2 Recombiner (BWR)	Count each as a single unit if present

Table 5.2.8: Fire Ignition Source Counting Guidance.

Fire Ignition Source Type Bin	Counting Notes and Guidelines
Hydrogen Storage Tank	Count as a single unit if any tanks are present in the fire area
Misc. Hydrogen Fires	Count a single unit if normally charged hydrogen piping is present.
Air Compressors (< 100 HP)	Count compressor and motor as a unit
Air Compressors (>= 100 HP)	Count compressor and motor as a unit
Ventilation Subsystems	Count individual subsystem elements (e.g., fan unit, cooling unit, heating unit, etc.). Do not count passive or non-powered elements (e.g., duct work, a fresh air intate structure, dampers, etc.).
Hot Work Activities (welding or cutting)	Do not attempt to count potential ignition sources. Note if hot work is ever performed in the fire area during normal plant operations
General Transient Fuel and Ignition Sources	Note, but do not count, transient combustible fuels sources. Determine plant combustible control limits. Area is classified as High, Moderate, or Low.

- "Medium" shall be used for areas that have several cable trays that are generally more than half full. For example, this level may be used for a compartment 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" shall be 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.

Transient fuel loading assessment

Examples of transient combustible fire ignition sources include wood planks, plastic wrapping materials, cleaning fluids, pipe cutting fluids, lubricating oil, general refuse, etc. Other examples include temporary fans and heaters, temporary lighting, extension cords, etc. (Note that welding fires are treated separately.)

To model transient fires (i.e., fires involving a transient combustible or transient ignition sources or both) several influencing factors should be taken into account. During the review of IPEEEs submitted to the U.S. NRC [4] it was noted that not all plant areas could be treated alike. For example, some plant areas are normally closed for casual access by plant personnel. The likelihood of a fire involving transient combustibles in such areas is expected to be small compared to areas with high foot traffic. Also, from a review of fire frequency and fire event data [5, 7], it was concluded that welding may have a significant impact on transient fire frequency. Therefore, an attempt was made to model the influence of various factors on the frequency of fires attributable to transient combustibles or transient ignition sources.

The range of possible conditions influencing the frequency has been divided into four levels:

- "Low" may be used for an area that is either normally closed for any type of traffic or is not visited often and no equipment or items are permitted to be stored in the area. For example, 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. Same can be assigned to a cable spreading room that has nothing but cables in cable trays and access to the room is strictly controlled.

- "Medium" may be used for areas that either have occasional foot traffic, or items may be stored in the area or ignition sources may be brought into the area. For example, a compartment 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. Items may be stored in the room, to avoid storing it in the corridor, once or twice a year in preparation to conduct repair work on equipment nearby. Also, some repair work, which may take place once in a few years, may be permitted in the room while the plant is in power.

- "High" may be used for areas that either have heavy traffic, or items are typically stored in the area or ignition sources are often brought into the area. For example, those parts of a power plant with characteristics similar to an office can be regarded as "high" transient combustible level area. 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 may be used in the area once every few weeks. Health physics access control area is one such area.

- "Very High" may be assigned to those areas that have a heavy traffic and either highly combustible or flammable materials are stored in the area or transient ignition sources are frequently brought into the area. For example, a main corridor with flammable fluids cabinet, a staging area where items are repaired or constructed before they are taken to other parts of the plant for installation, or a truck loading and unloading bay can be regarded as "very high" transient combustible level areas.

It is recommended that all plant areas to be assigned a transient combustible fire frequency unless the licensee can unequivocally prove that no transient combustibles or ignition sources would be present during power operations. Only those areas of the plant that are practically impossible to enter may be exempt from this rule.

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

Hot Work Fire Frequency

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. The following criteria will be applied:

- If the finding involves the conduct of hot work in an area where hot work is not normally allowed or anticipated, then the hot work fire frequency is introduced into the fire area fire frequency whereas it might nominally have been excluded.

- If the finding involves a violation of the hot work fire watch provisions, then:
  - For high degradation findings against hot work fire watches, the fire watch credit assumed in the nominal fire frequency is removed. As a result, the nominal fire frequency for hot work fires is multiplied by 10.
  - For moderately degraded findings against the fire watch, the nominal fire frequency for hot work fires is multiplied by 3.

Findings against the combustible controls program

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. Recall that findings against the combustible controls program are ranked either as high or low (no moderate degradation levels are defined).

- For a high degradation of the combustible controls program, the nominal transient fire frequency is multiplied by 10.

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

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 compartment under consideration. The inspector should ensure during the exposure time of the finding that 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. Some criteria that the inspector may use to credit measures which may reduce fire frequency are:

- For transient combustible fire frequency: Combustible control system exists with frequent surveillance patrols (at least once per shift) and a review of surveillance reports show no discovery of improperly stored combustibles.
- For hot work fire frequency: Area has not been used for hot work as verified through a review of hot work permits issued.

If neither of the above listed compensatory measures are active for the fire area under analysis, no decrease of the fire frequency is needed and this task is skipped.

The fire frequency contributions for transients and/or hot work fires can be eliminated from a fire area if justified over the exposure time of the finding when it can be proven that the contribution to frequency is eliminated. In these cases, the inspector must be able to confidently indicate that either or both of these activities did not occur during the exposure time. In the case of eliminating frequency contributions from hot work, the inspector can review hot work permits associated with these activities, and confirm that no hot work occurred. In the case of eliminating frequency contributions from transient fires, frequent patrols (one per shift) must have documented no surveillance reports of improperly stored materials.

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: Independent SSD Path Second Screening Determination

At this stage of the analysis, it is necessary that the inspector more clearly define each of the fire scenarios that will be analyzed in the subsequent analysis steps. 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.

With the completion of Task 2.3, the inspector has already identified and screened fire ignition source scenarios (the first element of a fire scenario). In Step 2.5, the inspector will further define the next two elements of the specific fire scenarios; namely, fire growth and damage scenarios, and the corresponding plant damage state scenarios. (The fire suppression scenario is addressed in Step 2.7 and 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 is applied on a somewhat more scenario-specific basis.

5.2.5.1 Task 2.5.1: Identify Fire Growth and Damage Scenarios

General treatment of localized fire barriers and raceway fire wraps

The following considerations will apply in assessing the damage potential for components or cables protected by a localized fire barrier wrap (e.g, a raceway fire barrier) or fire retardant coating:

- Components and cables will be considered fully exposed unless they are protected by a fire barrier with a specific fire endurance rating established in accordance with accepted standard testing protocols. Non-rated barrier systems are not credited.

- Components and cables protected by a non-degraded fire barrier with a minimum fire endurance rating of two hours will be assumed to invulnerable to fire damage unless the inspector identifies a high-hazard fire source (e.g., a large oil spill or oil-filled transformer) that can result in a direct flame impingement exposure to the fire barrier (see Section 5.2.4 for further discussion).

- Components and cables protected by a fire barrier system with a minimum 1-hour fire protection rating installed as a part of the licensee's Appendix R III.G.2 separation criteria compliance strategy will be considered as fire damage targets (i.e., are subject to fire-induced failure) <u>only</u> if some aspect of the III.G.2 fire protection strategy is found to be degraded. The degradation may be associated with any aspect of the licensees compliance strategy including the fire barrier itself, the automatic fire suppression system, the automatic fire detection system, or post-fire safe shutdown.

- Components and cables protected by a fire barrier system with less than 1-hour fire endurance rating are considered damage targets, but the fire barrier system will be credited for providing protection commensurate with the demonstrated fire endurance rating.

- Cables protected by a fire retardant coating are treated as exposed fire ignition and damage targets unless the coating has a specific demonstrated fire endurance rating. If the coating has such a rating, it is treated as a fire barrier consistent with the cases cited immediately above.

- Cables in conduits are considered exposed fire damage targets, but will not contribute to fire spread. A conduit is not a fire barrier.

Special consideration for direct flame impingement on a raceway fire barrier

The discussion immediately above describes how cables and components protected by a local fire barrier wrap are treated for general fire scenarios. Beyond the conditions of a general fire scenario, the inspector should also be aware of potential performance issues under severe fire exposure conditions. In particular, if a high hazard fire source can create a direct flame impingement exposure condition, a raceway fire barrier may not provide protection against fire damage.

The commonly applied fire barrier qualification standard (e.g., ASTM E119 and associated subsidiary documents) involves the exposure of a fire barrier system to relatively harsh temperature conditions. However, the standard test does not involve direct flame impingement which can create a far more severe exposure condition. Hence, the performance of a fire barrier system is not assured should the fire exposure conditions involve direct flame impingement from a high hazard fire source.

> Example 1: The inspector encounters redundant safe shutdown cables routed below the main turbine generator set that are protected by one hour raceway fire barriers. In the event of a severe fire involving a spill of oil from the lube oil system, the raceways may be exposed to direct flame impingement conditions.
>
> Example 2: The inspector encounters redundant safe shutdown cables routed directly above an oil-filled transformer. The cables are protected by a three-hour fire wrap. In the event of a catastrophic transformer fire, the cable raceways might experience direct flame impingement.

If the inspector encounters a situation where raceway fire barriers are being applied in an area with high hazard fire ignition sources such that direct flame impingement on the barriers is possible, a Phase 3 analysis may be warranted. The inspector should seek additional guidance in the analysis of such configurations.

General Rules for Developing Fire Scenarios

First, you must have an ignition source - something which can start a fire - and a package of fuel which can be ignited. Lacking either of these, there is no credible scenario. Often both the ignition source and the initial fuel package are inherent elements of an electrical component. In other cases (e.g., transients, a spill of oil) if there is a fuel package available, the inspector will assume that a fire ignition source may be introduced such that the fire will be ignited. The fire event frequency statistics inherently reflect the probability that such fires do occur in actual plant experience. Hence, the inspector does not explicitly focus on identifying a specific source to actually ignite a fire. Rather, the inspector focuses on identification of fire ignition sources as a consolidated ignition/initial fuel package. The likelihood that ignition actually occurs is based on the event data. consistent with operating consistent with the fire frequency estimates provided for various fuel packages. However, should the inspector find that no fire ignition sources exist in the fire area, then no fire scenarios can be developed excepting transient fires.

- IEEE-383 rated low flame spread cables are not an ignition source so long as protective devices (fuses or circuit breakers) are properly sized (no self-ignited cable fire will be postulated).

- For small combustible liquid fires (less than one gallon) damage is postulated only if the target is in the plume or suffers direct flame impingement.

- Fires inside solid metal cabinets will remain within the cabinet, unless the cabinet is vented (i.e., has ventilation grills or openings), cable penetrations into the cabinet are not sealed (e.g., in the top of the panel), and/or combustibles are in direct contact with the cabinet (exception - arcing faults).

- High energy electrical faults (arcing faults at 440VAC and higher) can propagate damage outside solid metal cabinets. In such cases, the panel will be assumed breached by the initial fault.

- For ventilated cabinets, the zone of influence chart is applied to determine the damage/ignition zone. In such cases, the origin of the fire is placed at the center of the panel (vertical and horizontal center).

- For a combustible liquid fire, the fire origin for the zone of influence chart will be placed at the surface, and the width of the zone of influence will cover the entire surface of the pool.

- For ordinary combustibles (paper, wood, anti-contamination clothing, rags, plastic) the fire origin is placed at the top of the stack of material.

- Exposed oil-soaked rags and paper can be considered a source of spontaneous combustion.

- Transient combustibles for fire scenarios can be assumed to be the maximum amount for which a permit is not required, or the actual amounts identified during the inspection, whichever is greater.

- Oil in closed bearing housings does not contribute to a fire

- Lubricating oil in a “wicking” configuration (oil-soaked insulation, oily rags) will ignite at temperatures as low as 500°F

Specific Considerations for Development of Scenarios for Spreading Fires:

The inspector will identify the likely fire spread paths associated with each unscreened fire ignition source scenario. In Step 2.3, the inspector identified the nearest secondary combustible material to a given fire ignition source. Given that the fire ignition source survived screening, it is likely that this material will be ignited during the fire. Three exceptions might lead to this:

- presence of in the fire area of a thermally fragile damage target (e.g., a solid state circuit board) that is damaged but not ignited,
- a case involving no direct path for fire spread, but a source of sufficient intensity to create a damaging hot gas layer, or

- a case involving cables within a conduit that are damaged by the fire but do not contribute to fire spread, and where no other fire spread paths were identified.

Assuming that the ignition of at least one secondary combustible material was determined to be credible, it is now necessary to postulate the further spread of the fire assuming that the fire remains unsuppressed. In this step the inspector is seeking direct paths for fire spread. That is, the fire will not be assumed, a-priori, to ultimately engulf all combustible materials in the fire area unless credible paths and mechanisms for fire spread can be identified. The assessment in this particular step is rule-based as discussed in Section 5.2.5. In some cases, the fire ignition source screening tools applied in Step 2.3 may be re-applied to support this task (the zone of influence charts, and the hot gas layer temperature estimating tool).

SPECIAL NOTE: The fire spread path will most often involve spread of the fire into and among cable trays. Rules for cable tray fire spread behavior are immediately provided below.

The inspector will also identify specific fire damage scenarios (i.e., fire damage target sets) corresponding to each FDS of interest. The identification of fire damage scenarios requires the identification of specific component and cable damage targets that will be assumed to be failed as a result of the corresponding fire growth scenarios.

The fire damage target sets may be unique to each fire ignition source scenario, or may be common to two or more fire ignition source scenarios. In some cases, the same fire damage target set may apply to all fire ignition source scenarios in the fire area. The ability to refine fire damage sets to specific fire scenarios is often driven by the level of cable and component routing information available.

- Example 1: Assume that cable routing information available to the inspector is of sufficient detail to distinguish the location of a specific target cable within a specific set of cable trays in the fire area. In this case, the inspector can likely tailor the fire damage target set to individual fire ignition sources based on the proximity of the specific target cables.

- Example 1b: The availability of detailed cable routing information may be used as a basis for defining multiple damage target sets for a given fire ignition source scenario. In such cases, the target sets should be cumulative - adding new targets as the fire damage spreads within the fire area. The first damage target set might involve only the first target cable. A second set may involve the same first cable plus a second cable, and so forth. (In practice, the inspector will often find that the final risk quantification will be dominated by one of the identified fire damage target sets. This will be one potential outcome of Step 2.8.) In such a case, the inspector applies judgement in assessing when a fire has progressed from FDS1 to FDS2.

- Example 2: Assume that cable routing information is sufficient to identify that one or more cables associated with a potential target system are located within the fire area, but their specific routing within the fire area is not known. In this case, the target set for all unscreened fire ignition source may be assumed to include these cables. The location of the target cable will be assumed to be in the tray (or conduit) nearest each fire ignition source barring other information suggesting this assumption is excessively conservative (e.g., assuming that a power cable is in a nearby tray containing only instrument cables).

SPECIAL NOTE: The inspector is not expected to gather additional cable or component routing information beyond that provided by the licensee. The inspector is expected to utilize the cable and component routing information provided by the licensee.

SPECIAL NOTE: Even given a spreading fire, with the application of specific cable and component routing information, the inspector may be unable to identify a potentially risk-important set of fire damage targets for a given fire ignition source. This can result in the screening of specific FDS scenarios associated with a given source, or in the screening of a fire ignition source in its entirety.

- Example 3: If cable routing information demonstrates that none of the cables directly above a fire ignition source are potentially risk important, then that fire ignition source may be incapable of producing a potentially risk important FDS1 fire scenario. The potential for FDS2 and FDS3 scenarios should still be considered (consistent with the results of Step 2.3).

- Example 3b: Continuing example 3, the inspector also finds that there is no direct path for fire spread beyond the cables directly above the fire ignition source, and (using the hot gas layer temperature tool) that burning of the fire ignition source in combination with those cables that are overhead is still insufficient to create a damaging hot gas layer exposure. Therefore, the inspector determines that no FDS2 scenarios are credible for this ignition source.

Should the inspector be unable to define any credible and potentially risk-important fire growth and damage scenarios for a given fire ignition source, then that fire ignition source may be screened out from further consideration (i.e., in the same context that other fire ignition sources may have been screened out in Step 2.3). If the newly screened out fire ignition source(s) was a significant contributor to the area fire frequency, the inspector should repeat the screening check in Step 2.4 (Task 2.4.4) eliminating the fire source(s).

<u>Rules for Development of Cable Tray Fire Scenario:</u>

- Fires in horizontal cable trays spread along the tray at the rate of ten feet per hour.

- Thermoplastic cables and ordinary combustibles (e.g., paper, wood) exposed to temperatures of 450°F can be considered to be ignited

- Thermoset cables exposed to temperatures of 700°F can be considered to be ignited.

- Assuming that the first cable tray in a stack of horizontal cable trays is within the zone of influence of a given fire ignition source, the spread of fire within the stack will be assumed to spread as follows:
  - Exposure source to first tray: 5 minutes
  - First tray to second tray: 4 minutes after ignition of first tray
  - Second tray to third tray: 3 minutes after ignition of second first tray
  - Third tray to fourth tray: 2 minutes after ignition of third tray
  - Fourth tray to fifth tray: 1 minute after ignition of fourth tray
  - Balance of trays in stack: 1 minutes after ignition of fifth tray

  This assessment assumes that the trays are separated in accordance with RG 1.75 separation criteria for cables of a single division.

- For trays separated in accordance with RG1.75 criteria for redundant divisions, involvement of the redundant division will require at least four burning trays below in the first division. Ignition of the separated tray will occur 5 minutes after ignition of the fourth tray in the first division.

Spread to adjacent trays:

- If there is a second stack of cable trays next to the first stack, spread to the first (lowest) tray in the second stack will be assumed to ocurr concurrent with spread of fire to the third tray in the original stack (i.e., 7 minutes after ignition of the first tray in the first stack).
- Subsequent spread of fire in the second stack will mimic the continued growth of fire in the first stack (e.g., the second tray in the second stack will ignite within 2 minutes of the first tray in the second stack - at the same time as the fourth tray in the first stack.)
- Fire spread will occur at the same rate to stacks on either or both sides of the original tray stack.

Specific Considerations in the Development of Scenarios for Non-Spreading Fires:

In the case of non-spreading fires, the inspector determines that there is no basis for defining a fire spread path beyond the fire ignition source itself (i.e., there are no exposed combustible materials within the fire ignition sources zone of influence). In this case, the inspector should still identify a damage target set if possible. Such sources will have been retained in Step 2.3 only if they were capable of causing damage to at least one identified fire damage target. In this step, the inspector will identify the full range of fire damage targets that might be damaged.

- Hot Gas Layer Scenarios: If fires involving a specific fire ignition source are of sufficient intensity to cause hot gas layer damage to cables and/or components in the area, then all vulnerable cables and/or components will comprise the fire damage target set. Such target sets will be considered in the context of FDS2 fire scenarios. Therefore, components and cables protected by a non-degraded fire barrier system of at least one-hour fire endurance duration will not be considered vulnerable. All unprotected cable and components will be considered vulnerable. Damage to cables and components protected by a degraded barrier system will be considered vulnerable consistent with the assigned degradation rating (e.g., based on the time of protection).

- Scenarios involving damage to cables in conduit: As noted in Step 2.3, cable in conduit are considered potential damage targets, but do not contribute to fire spread or intensity. Hence, if a specific fire ignition source has the potential to damage cables in conduit, then these cables become the fire damage target set. No fire spread path is assumed. Fire damage may involve FDS1 and/or FDS2 scenarios, depending on whether any of the target conduits are wrapped with fire barrier materials that were found degraded. The zone of influence charts used in Step 2.3 can be used to identified potential damage targets within reach of the non-spreading fire.

- Scenarios involving thermally fragile damage targets: In the case of non-spreading fires that can damage thermally fragile fire damage targets, the treatment parallels the treatment of hot gas layer scenarios.

SPECIAL NOTE: Given a non-spreading fire, and the application of specific cable and component routing information, the inspector may be unable to identify a potentially risk-important set of fire damage targets. For example, the nearest damage target may prove to be unimportant, and other potentially important damage targets may not lie within the fire ignition source's zone of influence. In such cases, the non-spreading fire ignition source may be screened out from further consideration (i.e., in the same context that other fire ignition sources may have been screened out in Step 2.3). If the newly screened out fire ignition source was a significant contributor to the area fire frequency, the inspector should repeat the screening check in Step 2.4 (Task 2.4.4) eliminating the fire source.

Special Considerations for FDS3 Scenarios

GUIDANCE PENDING

5.2.5.2 Task 2.5.2: Identify Plant Damage State Scenarios

Specific plant damage states will be determined in part by the mode of circuit faulting assumed given loss of a component or cable. Cables in particular hold the potential to cause unique failure modes in comparison to the types of failures that are postulated in, for example, an internal events PRA analysis. The incorporation of such failure modes requires unique treatment of the corresponding plant response models, an activity that will be taken up more fully in Step 2.8.

Example 1: Loss of motive/power cables to a major system component, such as a motor driven pump, will be assumed to renders that system inoperable and unrecoverable.

Example 2: Loss of motive power to some system components, such as a motor operated valve, may leave the system nominally operational, but may render the normal control functions inoperable (e.g., the operators may be able to shut down the system, but would be otherwise unable to control or change its operating configuration using the normal controls).

- Note: In such cases, manual operation the component might still be possible. However, for SDP Phase 2 analyses, such manual actions would only be considered if included in the plant fire response procedures.

Example 3: Failure of a control cable may lead to spurious actuation of a system if that system is impacted by a known circuit analysis issue.

Example 4: Loss of a instrument or indication signal may leave a system nominally operable, but might complicate operator actions related to that system.

In Task 2.5.2 the inspector must make judgements as to how various plant systems are impacted by a scenario-specific fire growth and damage scenario (i.e., by loss of the fire damage target set). Each fire growth and damage scenario will lead to one or more plant damage state scenarios.

Example 5: Loss of a specific control cable might lead either to a loss of function or spurious operation fault mode for the impacted system. This can lead to the identification of two distinct plant damage state scenarios arising from one fire growth and damage scenario.

The implication of the plant damage state assessment is that systems and functions that are not assumed lost due to fire will credited in the assessment of plant post-fire SSD efforts in Step 2.8 whether or not they are designated Appendix R safe shutdown systems or not.

SPECIAL NOTE: In assessing which systems/functions might be lost given a fire in a specific fire area, systems are assumed to be lost unless it can be verified (e.g., using information provided by the licensee) that the system will survive.

> Example 6: The licensee has not included off-site power on the Appendix R post-fire Safe Shutdown equipment lists. Cable and component routing information is not sufficient to determine with reasonable confidence whether or not any cables that might cause failure of off-site power are located within the fire area under analysis. In this case, the plant damage state scenario will include the assumption that the all fires involving unscreened fire ignition sources in the fire area induce a loss of off-site power.

> Example 6b: The licensee has not included off-site power on the Appendix R post-fire Safe Shutdown equipment lists. However, the licensee has traced the components and cables associated with off-site power, and provides information that verifies that off-site power will not be compromised by fires in the fire area under analysis. In this case, the plant damage state scenario can assume the survival of off-site power.

The inspector may apply judgement in establishing a reasonable confidence that a particular system or function will survive given fires in the fire area.

> Example 7: It may be reasonable to assume the survival of off-site power given a fire in the service water intake structure unless the physical plant layout presents the potential that cable or equipment supporting the off-site power systems were routed through or housed within that location.

> Example 7b: It would be reasonable to assume off-site power would be lost given any fire in the switch yard or any fire involving the unit main or unit auxiliary transformers.

Additional guidance in the form of rule sets for translating component losses into system functional impacts is provided in Section 5.2.4.2.

5.2.5.3 Task 2.5.3: 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 fire might survive given an FDS1 scenario, but might fail given an FDS2 or FDS3 scenario.

5.2.5.4 Task 2.5.4: 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 (Task 2.5.1), and therefore to one or more plant damage state scenarios (Task 2.5.2). In Task 2.5.3, 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 inspector 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 inspector 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 2.5.4; hence, the SSD path is not credited for this fire ignition source.

SPECIAL NOTE: The results from Task 2.5.3 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.

SPECIAL 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 2.5.3 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.

Plume heating

For fire plume exposures, the inspector estimates the plume temperature at the target location. 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 60% of the heat is released convectively (convective fraction = 0.6).

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 Table 5.2.9 or 5.2.10.

Table 5.2.9: Failure Time-Temperature relationship for thermoset cables.

Exposure Temperature		Time to Failure (minutes)
°C	°F	
330	625	28
350	660	13
370	700	9
390	735	7
410	770	5
430	805	4
450	840	3
470	880	2
490 (or greater)	915 (or greater)	1

Table 5.2.10: Failure Time-Temperature relationship for thermoplastic cables.

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

<u>Radiant heating</u>

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 staff fire modeling tool set, and the damage time is assessed base on the intensity of the exposure. The inspector 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 40% of heat released by fire is radiant energy (radiant fraction = 0.4).

Once the exposure heat flux has been estimated, Tables 5.2.11 and 5.2.12 provide estimates of the time to cable failure versus exposure heat flux.

Table 5.2.11: Estimated damage time for radiant heating exposures, Thermo-Set Cables

Exposure Heat Flux		Damage Time (minutes)
BTU/ft^{2}s	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 5.2.12: Estimated damage time for radiant heating exposures, Thermo-Plastic Cables

Exposure Heat Flux		Damage Time (minutes)
BTU/ft^{2}s	kW/m^2	
<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

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

The analysis of time to damage for FDS2 fire scenarios will be dominated by one of the following four factors:

- the time required for fire to grow to a sufficient size and intensity so as to create a damaging hot gas layer exposure condition,

- the time required for the fire to spread to a critical location damaging exposed fire damage targets,

- the time required to cause damage to components or cables protected by a moderately degraded fire barrier system, or a non-degraded fire barrier system with a fire endurance rating of less than two hours.

<u>Fire growth creates a damaging hot gas layer</u>

In some scenarios, fire damage will occur due to a hot gas layer exposure, but only after the fire spreads beyond to fire ignition source. That is, the fire ignition source itself may not be of sufficient intensity to create a damaging hot gas layer, but if the fire spreads to secondary combustible, then a damaging hot gas layer could be created.

In such situations the secondary combustible is likely to be cables. Common examples include a hot work fire that ignites a cable tray, a self-ignited cable tray fire, a transient fire that ignites one or more cable trays, or an electrical equipment fire that ignites one or more cable trays.

- The inspector applies a modified version of the hot gas layer correlation. In this modified version (provided in the electronic worksheets), the correlation is inverted. That is, rather than estimating the hot gas layer temperature for a given fire, the correlation estimates the fire intensity required to create a damaging hot gas layer. The inspector inputs the appropriate damage criteria along with other aspects of the room environment (size, ventilation, etc.), and the correlation returns and estimate of the fire intensity needed.

- The inspector then estimates the extent of fire spread required to create such a fire. In the typical case of fire spread to cables, this means estimating the number square feet of burning cables that are required, in combination with the original fire ignition source, to create a fire of the required intensity.

- Using the fire spread rules provide in Section 5.2.5.1, the time required to achieve the required extent of fire spread is estimated.

- If the available fuel load will not support the required fire intensity, then this damage mechanism is found to be incredible, and is screened from further consideration.

- If a sufficient fire can be created, the fire damage time is then taken as the estimated fire spread time. No additional time delay to target damage is assumed given the pre-heating of the target during the fire growth and spread period.

Fire spreads to the location of an exposed fire damage target

In some scenarios, the mechanism for fire damage may be the spread of fire from a fire ignition source to the location of a critical target. In this case, it is likely that fire spread through one or more cable trays will be the concern. A typical case might involve a fire ignition source that ignites cables directly overhead, and the subsequent spreads of fire through the tray(s) to the location of a cable “pinch point” where the routing of a target cable converges with the fire spread path.

In such cases, the fire damage time is determined by the time required to spread fire to the target cable location. Once fire spreads to the target, no additional failure time delay is assumed (due to pre-heating of the cable during the period of fire spread).

The rules provided in Section 5.2.5.1 for the analysis of cable tray fires are applied to estimate the required fire spread time.

Fire causes failure of a localized or raceway fire barrier

In this case, the inspector is postulating that a prolonged fire might cause the failure of a localized fire barrier protecting cables or components. This damage mechanism would be relevant to the following example cases:

- A moderately degraded fire barrier that is given some credit for fire protection: For a moderately degraded barrier, the fire endurance rating is reduced to reflect the degradation. The fire barrier system would typically be protecting required or associated circuit cables where the Appendix R Section III.G.2 protection strategy involved a three-hour fire barrier wrap, or a one-hour wrap plus detection and suppression.

- A non-degraded raceway fire barrier system protecting important safe shutdown system with a rating of less than two hours: In this case, the barrier may be associated with an exemption or exception to the separation requirements of Appendix R Section III.G.2, or that analysis may involve a finding against other aspects of the III.G.2 requirements(e.g., the fire detection and/or suppression systems).

In this case, the inspector will assume that given a damaging fire exposure condition the cables will fail in a time equal to the fire endurance time of the fire barrier system *as reduced by the noted degradation* plus one-half the time to damage normally associated with the fire exposure conditions using the appropriate table in Section 5.2.6.1.

> Example 1: A particular cable tray containing thermoplastic cables is wrapped with a fire barrier system that has a nominal 1 hour fire endurance rating. The barrier system is degraded, and the degradation rating was ‘Moderate B’. Given the degradation, the 1 hour fire barrier fire endurance rating is reduced to 21 minutes (35% of the nominal performance rating). The inspector has determined that the fire plume for a given fire ignition source creates a potentially damaging fire exposure condition with an exposure temperature of 245°C (475°F). The damage time at this exposure temperature taken from Table 5.2.10 (Section 2.6.1) is 15 minutes. Hence the net damage time for the protected cables is (21+15/2) = 28 minutes. (Note that time to damage is rounded down to the nearest minute.)

> Example 2: A particular cable tray containing thermoplastic cables is wrapped with a fire barrier system that has a 20 minute fire endurance rating. The barrier system is not degraded, but failure of the protected cables could impact post-fire safe shutdown. The inspector has determined that the fire plume for a given fire ignition source creates a potentially damaging fire exposure condition with an exposure temperature of 245°C (475°F). The damage time at this exposure temperature taken from Table 5.2.10 (Section 2.6.1) is 15 minutes. Hence the net damage time for the protected cables is (20+15/2) = 27 minutes. (Note that time to damage is rounded down to the nearest minute.)

> Example 3: The licensee separation compliance strategy utilized a one-hour fire barrier wrap plus automatic detection and suppression. The fire suppression system was found to be highly degraded, and will not be credited in the analysis. The fire barrier is not degraded and will be given full credit in the analysis. One identified FDS2 scenario involves failure of the cables within the wrapped raceway. The inspector determines that a fire involving a particular fire ignition source can create a damaging plume exposure condition. The minimum time to fire damage for this FDS2 scenario is one hour.

5.2.6.3 Task 2.6.4: Fire Growth and Damage Time Analysis - FDS3 Scenarios

The time to damage for FDS3 fire scenarios is determined by two factors:

- the time required for a fire to spread to the location of the degraded fire barrier element or to a non-degraded fire barrier element that might fail,

- the time to failure of the challenged fire barrier element.

5.2.7 Step 2.7: Fire Non-Suppression Probability Analysis

In the suppression time/probability analysis, all possible modes of fire detection and suppression are considered. All areas of the plant will be covered by the manual fire brigade, but many plant areas will have additional fire detection and suppression capability in the form of fixed fire protection systems. The suppression analysis also considers the likelihood of intervention by other plant personnel such as security personnel or fire watches. Some compensatory measures may enhance the fire detection and suppression performance and may also be credited. Finally, some inspection findings will imply degradation of the fire detection and/or suppression capability and therefore may reduce the likelihood that suppression will succeed within a given time.

5.2.7.1 Task 2.7.1: Fire Detection Analysis

The dominant means of fire detection may vary somewhat depending on the type of fire postulated (e.g. hot work fires with a fire watch present), fire location within the room (e.g., proximity to fire detectors). Hence, the fire detection analysis is nominally conducted on a scenario specific basis. However, in practice, the same analysis result will apply to multiple fire scenarios:

> Example: The fire area under analysis has fixed detection installed. There is no finding against the fire detection system, and the system provides full room coverage. In this case, a fire detection time is calculated using the fire characteristics of a typical fire ignition source in the room, and using a typical fire location. The result is applied to all fire scenarios in the room.

The following general rules will be applied in the fire detection analysis:

- Prompt fire detection is assumed for two cases, and in these cases the time to detection is set to zero. The two cases are:
  - Postulated hot work fires so long as a hot work fire watch is posted and there is no finding of degradation against the licensee's hot work permitting and fire watch programs, or
  - Fires postulated in a fire area with a <u>continuous</u> fire watch posted so long as there are no findings against the fire watch and the point of fire origin (the fire ignition source) can be directly observed by the fire watch.

- For other general fire scenarios, it will be assumed that automatic fire detection systems will be the first line of defense in fire detection. That is, if a fixed fire detection system is in place, the response time of that system will determine the fire detection time for all scenarios. This time is estimated using fire modeling correlations such as those included in the USNRC/NRR Fire Dynamics Tools.

- For areas covered by fixed fire suppression system, but not a an independent fixed detection system, the actuation of the suppression system should universally result in a fire alarm signal. Hence, for these cases the time to fire suppression system actuation will be taken as the fire detection time. This time will be adjusted to reflect findings against the suppression system as appropriate.

- Barring any other means of detection, manual detection (detection by plant personnel) will be considered. Manual detection will apply in fire areas that lack fixed detection, in cases where a detection system is found to be highly degraded, or in cases where the detection signal is tied to actuation of a fixed suppression system and that system is found to be highly degraded. The manual detection time is estimated based on a qualitative evaluation of factors such as room occupancy, frequency of routine entry into a room, fire watch rotation periods when applicable, general room accessibility, and fire severity.

Detection by a Continuous Fire Watch

In fire areas with a continuos fire watch posted, prompt detection of fires will be generally assumed:

- For a continuous fire watch (fire watch is maintained constantly within the physical room) the time to detection by the fire watch would be close to or at the time of ignition. No delay in detection is assumed:

$$t_{detection} = t_{ignition} = 0$$

The inspector has the discretion to assess the effectiveness of a fire watch in the context of specific fire hazards. For example, in some fire areas a continuous fire watch posted in a particular location cannot observe the entire fire area. In this case, the inspector may choose to treat the fire area as continuously occupied for "hidden" fire ignition source scenarios and may assign a nominal delay in fire detection for these scenarios.

Detection by a Fixed Detection System

If a fire area is covered by a fixed fire detection system, but is not covered by a continuous fire watch, then the response time of the fixed system will be assumed to dominate the overall fire detection time. Fire detection response time is easily estimated using closed-form empirical correlations. One such correlation which has been included in the NRR fire analysis worksheets is the following:

- Smoke Detector Activation Time - Detector_Activation_Time.xls (Click on Smoke Detector)
- Heat Detector Activation Time - Detector_Activation_Time.xls (Click on FTHDetector)

This correlation is described in detail in Chapters 11 and 12 of NUREG-1805, respectively. Inputs required for use of the correlation are also described in detail in the NUREG, and are summarized as follows:

- For smoke detectors:
  - heat release rate of the fire (kW)
  - ceiling height of the compartment (ft)
  - radial distance from the centerline of the plume (ft)

- For heat detectors:

- heat release rate of the fire (kW)
- listed spacing of detectors (ft)
- activation temperature of detectors (˚F)
- height to ceiling (ft)
- ambient room temperature (˚F)

The spreadsheet will provide detector activation time in seconds. The inspector will convert this value to minutes, rounding up to the nearest minute. The spreadsheets may indicate that time to detection is infinite, i.e., the system will never actuate. In this case, the time to detection is determined by the other means of fire detection available including detection by plant personnel.

Cross-zone detection

In some circumstances, the analysis of a cross-zone fire detection strategy is needed. In a cross-zone strategy, a minimum of two detectors, one on each of two separate detection circuits, must actuate to generate the desired signal. This is most common when the actuation of an automatic fire suppression system is tied to a fire detection signal. Common applications include: pre-action or dry-pipe fire sprinklers, water deluge systems, water curtains, and gaseous suppression systems.

If a cross-zone detection strategy is encountered, the total detection time will be dominated by the detector located farthest from the fire ignition source. The inspector should identify which detectors are assigned to each of the fire detection circuits. The nearest detector in each of the two circuits is then identified. Of these two, the detection time is generally dominated by the detector located further from the fire ignition source (radial horizontal distance from fire center to detector location). Exceptions include:

- cases where one of the detectors is located in a different beam pocket from the fire ignition source,
- cases where one detector has a slower time response that another (e.g., a heat detector will generally respond more slowly than a smoke detector).

The inspector must identify the detector that is the limiting factor in the time response and base the actuation analysis on the time response of that detector.

Detection by a Roving Fire Watch

Fire watches may be implemented by licensees either as a compensatory measure, or as a part of routine plant operation. All fire watches at a minimum provide a fire detection function. Hence, if a fire area is covered by a roving fire watch, and is not covered by an operational fixed fire detection system, then the fire watch recurrence frequency is used to estimate the time to fire detection. When crediting a fire watch with detection, the detection time is assumed to be one-half the recurrence time. The following examples illustrate this approach:

- For a roving fire watch on a 15 minute recurrence schedule (roving patrol) the time to detection by the fire watch is assumed to be ½ the duration of the roving patrol
  $t_{detection}$ = 7.5 minutes
- For an hourly fire watch:
  $t_{detection}$ = 30 minutes

The detection time by general plant personnel should also be checked consistent with the discussion immediately below. The lowest manual suppression time dominates the process and is taken as the final estimate.

Detection by General Plant Personnel

In the absence of a fixed fire detection system (or a fire detection signal tied to actuation of a fixed fire suppression system), or given a highly degraded fixed detection system, detection of the fire will be assumed to occur by plant personnel. One of three factors will be utilized:

- If the fire area is continuously manned by plant personnel (but not by a fire watch) the fire detection time will be assumed to be 5 minutes.
- In the absence of any other means of detection, a maximum fire detection time of 15 minutes will be assumed.

Again, the dominant manual detection time will be the least of these values and is taken as the final detection time. Hence, in no case should the manual detection time be assumed to be greater than 15 minutes

5.2.7.2 Task 2.7.2: Fixed Fire Suppression Systems

General rules to be applied in the fixed suppression system analysis include the following:

- The actuation of a non-degraded, fully functional fixed fire suppression system that is deemed by the inspector to be effective for the fire ignition source scenario (e.g., properly positioned to apply suppressant to the ignition source) will be assumed to disrupt the development of the fire scenario. That is, if such a system actuates, it will be assumed the fire growth will be arrested and no further fire damage will occur.

- The inspector is expected to make judgements as to whether or not the suppression system, degraded or not, will be effective against the specific fire threat being postulated. That is, is the system installed and configured such that a fire involving each specific fire ignition source will be controlled given actuation of the suppression system. If the inspector judges that the system will not be effective (e.g., the system provides partial coverage, and a specific fire ignition source is outside the coverage zone, or the fire source is such that the fire suppression system would likely be overwhelmed), then the system will not be credited on a scenario-specific basis (e.g., it might be credited in some scenarios and not in others).

- The assessment of any fixed fire suppression system includes application of a nominal system reliability factors (generally a random failure probability of 0.02 is applied). Those cases where the fire suppression system fails on demand fall back on manual fire fighting provisions (see Task 2.7.3). Recovery of the failed fire suppression system will not be considered in the SDP Phase 2 analysis.

- If the inspection finding is against a fixed fire suppression system, the finding may result in allowing only partial or no credit to the system. The degradation may be reflected as a reduction in overall reliability or a delay in actuation time.

- If the fixed fire suppression system is automatically actuated, the time to actuation will be calculated based on engineering correlations (see Section 5.2.7.2).

- If the fixed fire suppression system is manually actuated, the time to actuation will be based on the estimated fire brigade response time, plus a nominal period of two minutes to assess the fire situation and actuate the system.

- Fixed gaseous suppression systems have discharge delay timers. The actuation time for such systems will be the estimated time to a valid actuation demand signal (estimated using engineering correlations) plus the discharge delay time.

- Gaseous fire suppression systems that are degraded due to an inability to maintain adequate concentration will be credited with providing some time delay in the progress of the fire (based on the demonstrated suppressant soak time that is available). However, manual fire response will be needed to complete fire suppression.

- Credit will be given to gaseous suppression systems that provide a multiple discharge capacity (this typically requires manual actions to initiate a repeated discharge).

- There are a number of time delays that may apply to gaseous systems, deluge, pre-action sprinklers, or dry-pipe water systems. These delays must be accounted for. In general, the correlation for actuation time is applied. This time reflects the time that a demand signal is generated. The time to actual discharge is the sum of the time to actuation of the demand signal plus any applicable discharge timing delays. Delays to be considered are:
  - For gaseous suppression systems there will be a built-in timer that delays discharge to allow for personnel evacuation. The inspector should determine this time (typically on the order of 30 seconds to 2 minutes).
  - There may be a delay for cross zoned detection system, i.e., the automatic suppression system will not begin actuation sequence until after the second detector is actuated. If cross-zoning is used, the detection time analysis should be reviewed to ensure that the cross-zone detection criteria is met. The time to generation of the actuation signal will be dominated by the slower detector (typically the detector farther from the fire ignition source).
  - Also, there may be a time lag for suppressant to get to the hazard (for example, low pressure CO_2 may have to travel an extended distance) or for pipes to fill with water prior to discharge (dry or preaction systems). If the delay is not know use 1 minute, if it is known the delay should typically be between 30 and 60 seconds.

The correlation for estimating sprinkler activation time is described in detail in Chapter 10 of NUREG-1805. The following spreadsheet from the CD ROM is used:

- Detector_Activation_Time.xls (Click on Sprinkler)

Inputs for Calculating Smoke Detector Activation Time are described in Section 10.5 of NUREG-1805 and are summarized as follows:

- heat release rate of the fire (kW)
- activation temperature of the sprinkler (˚F)
- distance from top of fuel package to ceiling (ft)
- radial distance from plume centerline to sprinkler (ft)
- ambient air temperature (˚F)
- sprinkler type

The spreadsheet will provide sprinkler activation time in seconds. The inspector converts the value to minutes, rounding up to the nearest minute. The spreadsheets may indicate that time to detection is infinite, i.e., the system will never actuate. In this case, no credit is given to the fixed fire suppression system (PNS_{fixed} = 0.0).

5.2.7.3 Task 2.7.3: Plant Personnel and the Manual Fire Brigade

Fire suppression by manual fire fighting is assessed based on historical evidence provided by fire event data. In Task 2.7.3 the inspector must select one of the pre-calculated fire duration curves to be applied to each scenario. The same curve may be used for multiple scenarios if appropriate, or different curves may be chosen for each scenario.

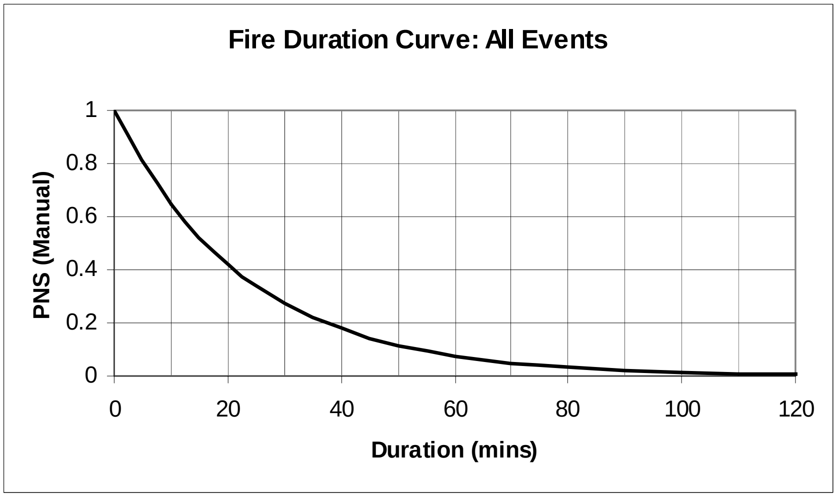
Note that the inspector is not expected to perform additional analysis of the raw fire event data, rather, they are expected to apply one or more of the pre-calculated curves as appropriate to the fire scenarios being analyzed.

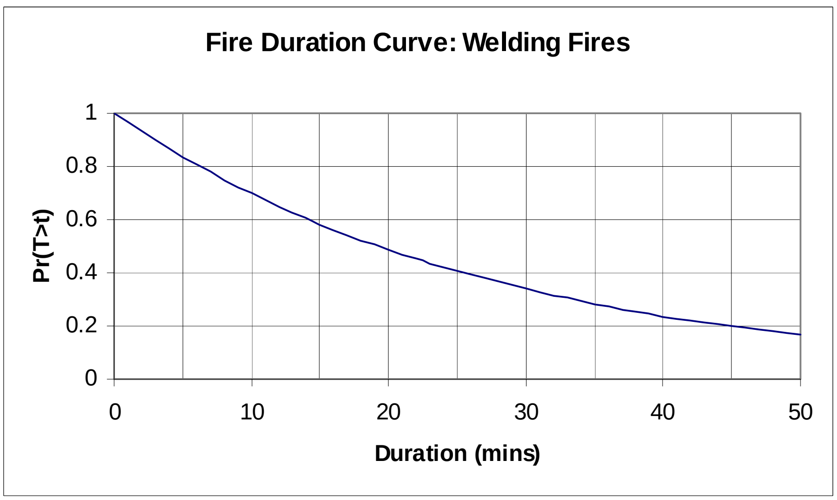
Note that in no case should the inspector attempt to generate a new fire duration curve to suit a particular analysis. The various pre-calculated curves for specific conditions should cover the vast majority of fire scenarios. If none of these specific condition curves provide a reasonable match to the conditions of the fire scenario, the inspector should apply the "all fires" curve. The "all fires" curve represents a composite analysis of all of the events that went into each of the other individual fire duration curves.

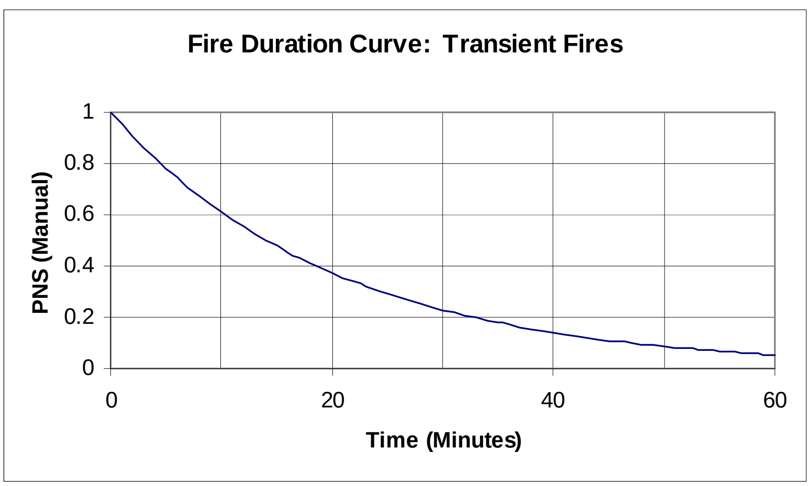
Note that some of the curves apply to fires in a particular location (e.g., the main control room fire curve). However, most are applicable to particular fire ignition source scenarios. There should be a nearly one-to-one match between the curves and the fire ignition source categories. The cases that are covered by these pre-calculated curves are as follows:

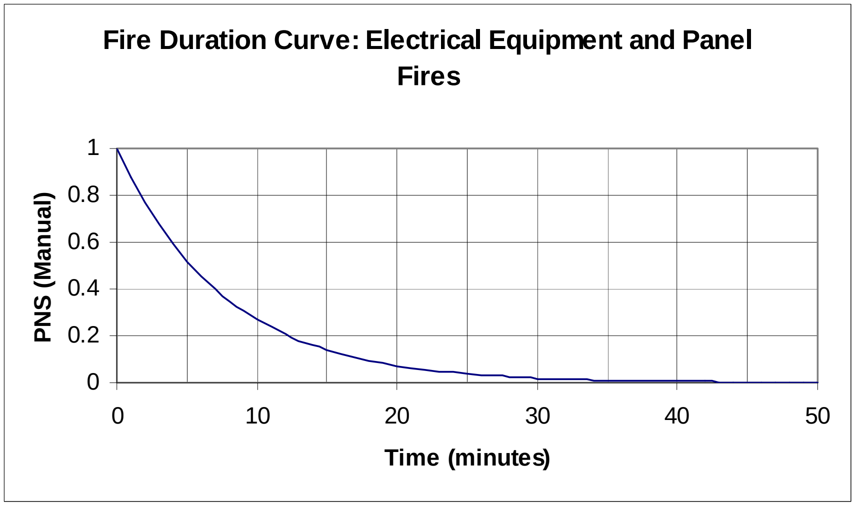
- Hot work (welding) fires
- Transient fires
- Electrical equipment fires
- Self-ignited cable fires
- Turbine generator
- Main Control Room
- PWR containment
- Transformer/switchyard
- Flammable gas
- Oil fires
- All events

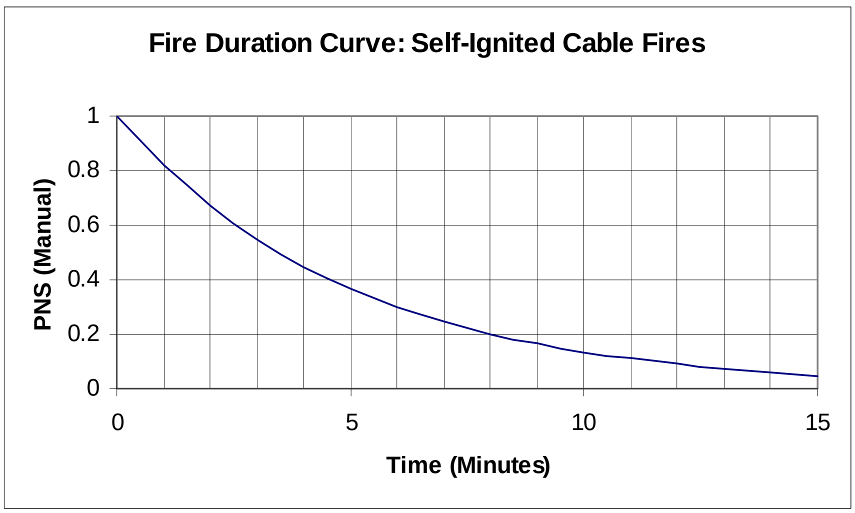
The fire duration curves are presented in Figures 5.2.2a-z. REVISION NOTE: The analysis of the fire duration data continues. Draft curves for the above cases are provided. Some of these curves are expected to be re-calculated as the final data analysis tasks are completed.

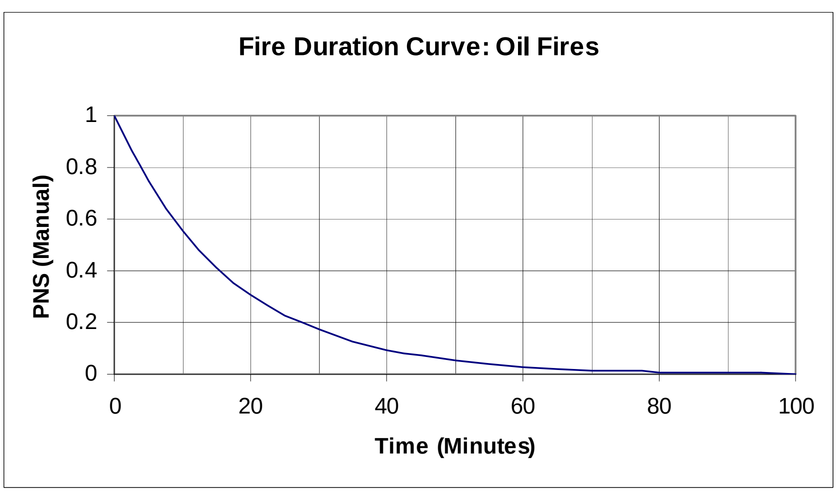

Fire Duration Curve: All Events
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
Duration (mins)

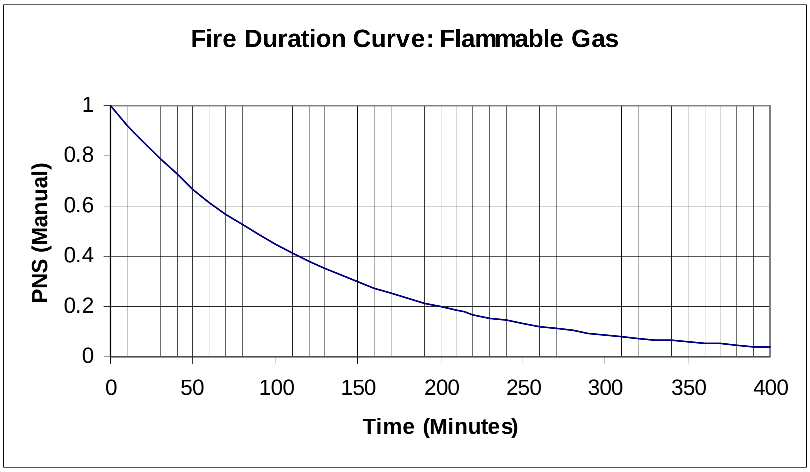

Fire Duration Curve: Welding Fires
Pr(T>t)
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
Duration (mins)

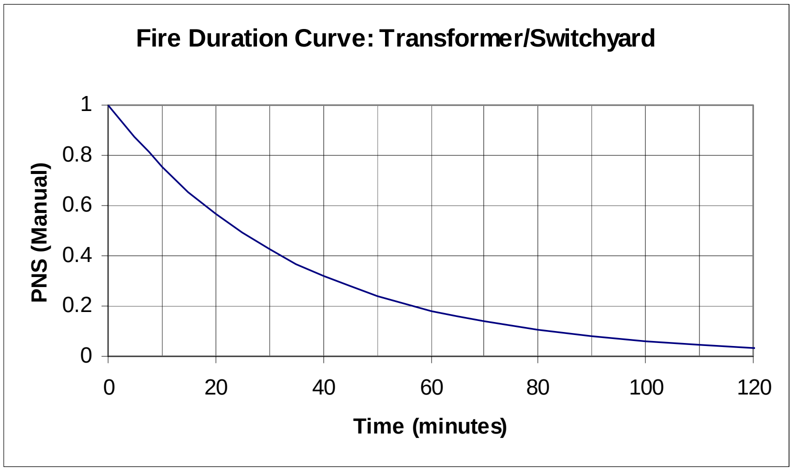

Fire Duration Curve: Transient Fires
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
20
40
60
Time (Minutes)

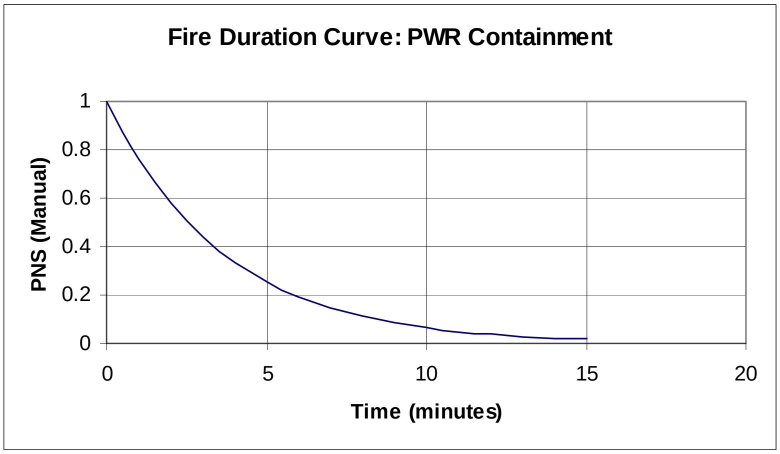

Fire Duration Curve: Electrical Equipment and Panel Fires
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
Time (minutes)

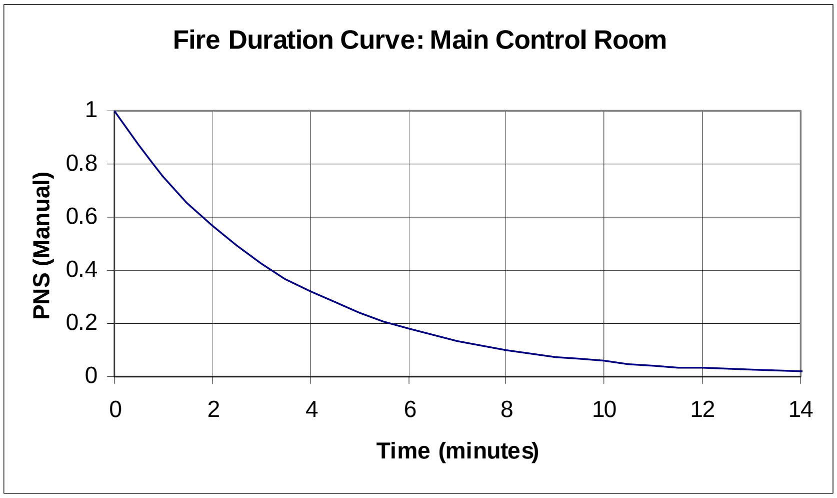

Fire Duration Curve: Self-Ignited Cable Fires
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
5
10
15
Time (Minutes)

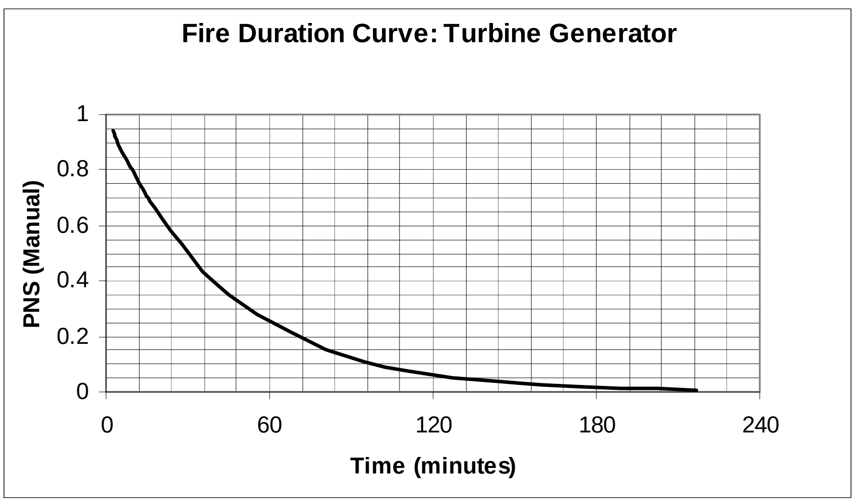

Fire Duration Curve: Oil Fires
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
Time (Minutes)


Fire Duration Curve: Flammable Gas
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
400
Time (Minutes)


Fire Duration Curve: Transformer/Switchyard
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
Time (minutes)


Fire Duration Curve: PWR Containment
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
Time (minutes)


Fire Duration Curve: Main Control Room
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
14
Time (minutes)


Fire Duration Curve: Turbine Generator
PNS (Manual)
1
0.8
0.6
0.4
0.2
0
0
60
120
180
240
Time (minutes)

5.2.7.4 Task 2.7.4: Probability of Non-Suppression

The purpose of Task 2.7.4 is to estimate the overall probability of fire suppression failure. It is important to note that failure in this context means that suppression was not achieved before the FDS of interest is reached. Fire suppression will eventually be achieved for all fires, but if the FDS is reached before suppression, then in the SDP context, fire suppression has failed to prevent fire-induced damage consistent with the postulated FDS scenario.

Fixed fire suppression systems:

Both the estimates of fire damage time and the time to fixed suppression system suppressant discharge contain considerable uncertainty. Hence, the probability that the fire suppression system suppresses the fire prior to critical damage is not based on a simple comparison of the time to damage versus time to suppressant discharge. Rather, a probability of non-suppression is assigned based on the “margin” between time to damage and time to suppressant discharge.

The time margin/likelihood relationship is described in Table 5.2.13. The first column presents the difference in minutes between the time to damage and the time to suppressant discharge. If the two times are close, or damage occurs before suppressant discharge, a high likelihood of damage will be assumed (PNS approaches 1.0). If the time to suppression is shorter than the time to damage, the PNS value decreases reflecting a higher likelihood of suppression success. As the time difference reaches 10 minutes, PNS approaches zero. Note that in quantification, the likelihood that the fire suppression system fails on demand is explicitly treated.

Table 5.2.13: Probability of non-suppression for fixed fire suppression systems based on the absolute difference between damage time and suppression time.

Time Delta: (t_{Damage} - t_{suppr})	PNS_{Fixed}
0 and Negative Nos.	1.0
1 Minute	.95
2 Minutes	.80
4 Minutes	.5
6 Minutes	.25
8 Minutes	.1
10 Minutes	0.0

Manual fire suppression:

The following process is repeated for each fire scenario:

- As directed in Section 4.4.7.4, subtract the fire detection time from the fire damage time.
- Using the appropriate fire duration curve selected in Task 5.2.7.4, read across the x-axis to the modified time from the above step.

- Transfer up to the corresponding point of the fire duration curve, and read across to the left to estimate the PNS_{Manual}.

<u>Final Roll-up:</u>

The values for PNS_{Fixed} and PNS_{Manual} are combined for each fire scenario using one of the following formulas. In the case of no fixed fire suppression system, the manual non-suppression probability is the only contributor, and is taken as the final PNS. If a fixed suppression system is present and credited, then the two PNS values, fixed and manual, are combined. In this case, the reliability of the fixed fire suppression system is also considered.

- If the fire area is not covered by fixed fire suppression, or if an installed fixed fire suppression system is highly degraded, then:

$$PNS_{scenario} = PNS_{manual\text{-}scenario}$$

- If the fire area is covered by wet-pipe sprinklers, a general reliability of 0.98 is assumed for the fixed suppression system. In this case, the overall PNS is quantified as follows:

$$PNS_{scenario} = (0.98 \times PNS_{fixed\text{-}scenario}) + (0.02 \times PNS_{manual\text{-}scenario})$$

- If the fire area is covered by a dry-pipe sprinkler or deluge system, or by a gaseous suppression system, a general reliability of 0.95 is assumed for the fixed suppression system. In this case, the overall PNS is quantified as follows:

$$PNS_{scenario} = (0.95 \times PNS_{fixed\text{-}scenario}) + (0.05 \times PNS_{manual\text{-}scenario})$$

The inspector chooses the appropriate case from the above set, and calculates the overall PNS value for <u>each</u> fire scenario. These values are carried forward to Task 2.7.5 and a final screening check is performed.

5.2.7.5 Task 2.7.5: Finding Screening Check

No specific guidance in support of this task is currently provided.

5.2.8 Step 2.8: Analysis of Plant Safe Shutdown Response

In this step, the CCDP, conditional on the occurrence of the fire growth stage resulting from the fire scenario is evaluated. As discussed in Section 2.6.1, the first task is to identify which of the worksheets are to be used. This step identifies the type of transient caused by the fire scenario, and the worksheet identifies those functions and systems required to respond to the transient.

In using the notebooks, the credit for the initiating event is set to 0, since they are being used in this instance to estimate a conditional core damage probability.

The modification of the notebooks to deal with the equipment failed by, the fire is straightforward, and follows the standard practice when using the notebooks. The only complication is that more equipment is failed than typical in an internal events SDP application, The area that is more complicated is the incorporation of the human actions, specifically ex-control room actions, that are specific to fire response, in that they are called for by the fire response procedures. Three types of ex-control room actions are considered:

- those that are taken as precautionary measures to prevent spurious actuation of equipment that is required to remain as is to enable the safe shutdown functions to be performed (e.g., removing power from a valve to prevent it potentially changing state),

- those that are taken to locally manipulate an SSC or operate a function due to a loss of control as a result of the fire (either directly or by procedure),

- operations from the remote shutdown panel because of abandonment of the control room (these may include actions as several locations). A subset of this is the so-called SISBO procedure, where loads are shed and selectively reloaded locally, even if there is still command and control in the control room. What is important here is the restoration of the functions.

<u>Precautionary Measures</u>

The probability of the spurious actuation leading to failure of the safe shutdown function is the product of the spurious actuation and the HEP. A conservative assessment is that the spurious actuation occurs with the probability of the HEP.

The way in which these failures are incorporated into the assessment of CCDP depends on the impact of the spurious actuation on the plant.

- If the impact of the spurious actuation is simply to fail a safe shutdown function, this can be handled quite simply by comparing the credit for the function obtained from the worksheet, given the available equipment, with the HEP evaluated using Table 5.2.14, and using the more conservative as the credit for the function in the worksheet.

- If, on the other hand, the consequence of the spurious actuation is to create effectively a new initiating event (e.g., open PORV), this requires consideration of a different notebook, one assuming success of the ex-control room action, the other failure. The CCDP would be the weighted sum of two notebooks, the weights being the complement of the HEP and the HEP respectively.

- If there are many such actions, such as are found in the so-called SISBO plants, it may be necessary to proceed directly to a Phase 3 analysis.

<u>Manual Control Actions</u>

This group of actions includes those for which there is local control of a function, while there is command and control from the control room. Credit should normally only be given if this is a recognized consequence of the fire, or is a consequence of following a fire response procedure, and there is some procedural guidance. Remote shutdown operations are discussed below.

The incorporation into the SDP notebooks of manual control of a function that is normally automatic is straightforward. It merely requires comparing the HEP evaluated using Table 5.2.15 with the hardware credit for that function, taking into account the SSC assumed available given the fire. When there is more than one function that must be manually controlled dependency must be taken into account. This may require a phase 3 analysis.

Remote Shutdown Operations

The simplest way to incorporate the remote shutdown operations into the notebooks is to include a single HEP up front whose failure represents core damage frequency. Then, the notebook for the appropriate event tree can be applied to evaluate the hardware portion of the failure, taking credit only for that equipment that can be operated from the remote shutdown panel. SSCs taken out of service should not be credited, i.e., the operators have been assumed to be successful.

The following tables provide a method to provide screening estimates for HEPs. They are based on work done earlier by the Office of Research, but modified a little to match more closely the PSFs used in the SPAR-H model. They are intended to give reasonable credit (1E-02) only when all factors are optimal. Table 5.2.14 may be used for a function performed at a specified location, for both situation when communication with the control room is needed or not. It may also be applied for control room abandonment scenarios when there is no remote shutdown panel (RSP) (using the appropriate "nature of task" row, the maximum credit is -1). This same table can be used for manual actions where the action is performed in more than one location. The factors are assessed for each location, and the most challenging for each factor is used. In addition, the resources should be assessed. If more than one operator is involved they have to be available and able to communicate. If only one operator, then the travel time between locations has to be adequate.

Table 5.2.15 is used for the case of control room abandonment when there is a RSP.

Table 5.2.14

Manual Actions Evaluation Table for Actions at a Remote Location				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Direct Physical Effect of Fire (Ergonomics)	Location and fire area well separated			γ
		Operator must pass through areas affected by fire environment to reach location		2β
	No barrier or potentially significant leakage between location and fire area	Dense smoke, high temperature, and/or CO_2 impact in location	No credit for SCBAs	α
Functional Considerations (Ergonomics)	Accessibility restricted, e.g., a ladder, or special tool required	tools properly staged		γ
		tools must be brought in		β
	Lighting failed	emergency lighting or flashlights available		γ
		neither emergency lighting nor flashlights available		α
Procedures	Procedures specific to this activity	Procedures posted at the location, and all required actions addressed and achievable at location		γ
		Must be obtained from control room	adjust to β if time is limited	γ/β
	No specific procedure or procedure unclear			2β
Training/Experience	Realistic training on scenario			γ
	Little or no hands-on (vice desktop) training			β

Communications (Ergonomics)	Performance of task requires communication between operator and control room (or an operator at another location)	communication unhindered by noise, interference		γ
		communication difficult because of fire or location (noise, lighting, etc.)		β
Nature of Task (Complexity)	Simple task involving a change of state of an SSC			γ
	task requiring several subtasks, but all in the same general location	Procedures available and clear		γ
	Multiple tasks at different locations		In the absence of an RSP for example, it is assumed that severla tasks are performed a t diverse locations, requiring a significant degree of coordination.	2β
	Control task (e.g., maintaining AFW)	indications available locally		β
		Indications not available locally		2β
Time available	Time Adequate to reach location and perform activity		include time needed to obtain procedure if applicable	γ
	Time limited			β
	Time inadequate or barely adequate			α

Notes on application of Manual Actions Evaluation Table:

Select HEP credit based on the following rules:
- If any row is α, then use 0
- If the sum of rows evaluated as β or 2 β is ≥ 3 β, then assume equivalent to α and use 0
- If all categories are γ, then use a credit of 2
- Otherwise (i.e., if the sum of rows evaluated as β or 2 β is β or 2 β), then use a credit of 1

Table 5.2.15

Manual Actions Evaluation Table for Actions at RSO				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Direct Physical Effect of Fire (Ergonomics)	RSO and all areas where local actions take place are well separated from the fire location			γ
		Operator must pass through areas affected by fire environment to reach RSO or other areas where local actions are taken		2β
	No barrier or potentially significant leakage between RSO or other required locations and fire area	Dense smoke, high temperature, and/or CO_2 impact in location	No credit for SCBAs	α
Functional Considerations (Ergonomics)	Lighting failed at any required location	emergency lighting or flashlights available		γ
		emergency lighting or flashlights not available		α
	Local actions required for essential functions	all equipment accessible		γ
		accessibility limited		β
		not accessible		α
Procedures	RSO procedure	Procedures available at RSO panel and all necessary location, and all required actions addressed		γ
		Must be obtained from control room or RSO location	adjust to β if time is limited	γ/β
Training/Experience	Realistic training on scenario			γ
	Little or no hands-on (vice desktop) training			β

Nature of Task (Complexity)	Control task (e.g., maintaining AFW)	indications available locally		β
		Indications not available locally	requires gaining information from operators stationed throughout the plant. Communications good.	β
			requires gaining information from operators stationed throughout the plant. Communications problematic.	2β
Time available	Time Adequate to reach location and perform activity		include time needed to obtain procedure if applicable	γ
	Time limited			β
	Time inadequate or barely adequate			α

Notes on application of Manual Actions Evaluation Table:

Select HEP credit based on the following rules:

- If any row is α, then use 0
- If the sum of rows evaluated as β or 2 β is ≥ 3 β, then assume equivalent to α and use 0
- If all categories are γ, then use 2
- Otherwise (i.e., if the sum of rows evaluated as β or 2 β is β or 2 β), then use 1

Use the most limiting of the factors (e.g., if the local actions that are essential to success are in inaccessible places, use α).

Spurious Operation of Required or Associated Circuits

Circuit analysis issues associated with required or associated circuits may be significant since a fire in combination with spurious operations may cause the loss of critical SSCs that may be difficult or impossible to restore. The spurious operations may defeat safety systems or cause systems to operate in a destructive manner. In this case, the probability of a spurious may be the dominant risk.

When a known circuit analysis issue related to spurious operation of required or associated circuits exists, a simplified version of the CDF change formula is used.

$$CDF \approx DF * \sum_{i=1}^{n} f_i \times SF_i \times AF_{i,2.4.2} \times AF_{i,2.4.3} \times PNS_i \times PSA_i \times POR_i$$

DF = Duration Factor
$\sum_f$ = Fire Frequency
SF = Severity Factor
AF = Frequency Adjustment Factors from Tasks 2.4.2 and 2.4.3
PNS = Probability of Non-Suppression
***PSA* = Probability of Spurious Operation**
***POR* = Probability of Operator Recovery**

The simplified formula is used in lieu of the Phase 2 Worksheets. Note that the CCDP factor is replaced with product of the factors PSA and POR. The steps below describe how to determine these two factors.

Note: For fire scenarios that include findings against associated circuits where the notebook method is expected to be significant, then the values of Step 1.0 and Step 2.0 should be summed prior to determining CDF.

Step 1: Circle the appropriate specifications of the cable in question, circle one item on each row.

Cable Type	Thermo-Plastic	Thermo-Set	Armored	Unknown
Failure Type	Intra-Cable	Inter-Cable	Unknown	
Cable in Conduit	Yes	No		

Step 2: Determine Probability of Spurious Actuation (PSA) from Attachment 1, using the information in Table 5.2.16 (derived from ML031970013), to determine *PSA* Factor.

__________ Enter *PSA* Factor

Step 3: Determine Probability of Operator Recovery (*POR)* using appropriate tables in Attachment 2 or 3.

__________ Enter *POR* Value (between 0.01 and 1.0)

Step 4: Determine CDF of degraded condition.

Probability of spurious operation PSA

Table 5.2.16: 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	
Cable type known, no other information known (NOI)	.6	.6	.15
Inter-cable interactions only	.02	.20	.002*
In conduit, cable type known, NOI	.30	.6**	
In conduit, inter-cable only	.01	.20**	
In conduit, intra-cable	.075	.075**	

* Assumed, actual value probably lower

** 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.

Probability of operator recovery (POR)

Consult Tables 5.2.17 and 5.2.18 for guidance.

5.2.9 Step 2.9: Final Quantification and Color Assignment

No specific guidance in support of this Step is currently provided.

Table 5.2.17: Manual Actions Evaluation Table for Actions at a Remote Location				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Direct Physical Effect of Fire (Ergonomics)	Location and fire area well separated			γ
		Operator must pass through areas affected by fire environment to reach location		2β
	No barrier or potentially significant leakage between location and fire area	Dense smoke, high temperature, and/or CO_2 impact in location	No credit for SCBAs	α
Functional Considerations (Ergonomics)	Accessibility restricted, e.g., a ladder, or special tool required	tools properly staged		γ
		tools must be brought in		β
	Lighting failed	emergency lighting or flashlights available		γ
		neither emergency lighting nor flashlights available		α
Procedures	Procedures specific to this activity	Procedures posted at the location, and all required actions addressed and achievable at location		γ
		Must be obtained from control room	adjust to β if time is limited	γ/β
	No specific procedure or procedure unclear			2β
Training/Experience	Realistic training on scenario			γ
	Little or no hands-on (vice desktop) training			β
Communications (Ergonomics)	Performance of task requires communication between operator and control room (or an operator at another location)	communication unhindered by noise, interference		γ
		communication difficult because of fire or location (noise, lighting, etc.)		β
Nature of Task (Complexity)	Simple task involving a change of state of an SSC			γ
	task requiring several subtasks, but all in the same general location	Procedures available and clear		γ

	Multiple tasks at different locations		In the absence of an RSP for example, it is assumed that severla tasks are performed a t diverse locations, requiring a significant degree of coordination.	2β
	Control task (e.g., maintaining AFW)	indications available locally		β
		Indications not available locally		2β
Time available	Time Adequate to reach location and perform activity		include time needed to obtain procedure if applicable	γ
	Time limited			β
	Time inadequate or barely adequate			α

Notes on application of Manual Actions Evaluation Table:

1. Apply table to specific plant fire scenario.
2. Select column in Fire SDP “Risk Significance Estimation Matrix” based on the following rules:

- If any row is α, then use column "0" in Matrix
- If the sum of rows evaluated as β or 2 β is ≥ 3 β, then assume equivalent to α and use column “0" in Matrix
- If all categories are γ, then use column "-2" in Matrix
- Otherwise (i.e., if the sum of rows evaluated as β or 2 β is β or 2 β), then use column "-1" in Matrix

This same table can be used for manual actions where the action is performed in more than one location. The factors are assessed for each location, and the most challenging for each factor is used. In addition, the resources should be assessed. If more than one operator is involved they have to be available and able to communicate. If only one operator, then the travel time between locations has to be adequate.

Table 5.2.18: Manual Actions Evaluation Table for Actions at RSO				
Category	**Task and Scenario Characteristics**	**Performance Shaping Factors**	**Comments**	**Evaluation**
Direct Physical Effect of Fire (Ergonomics)	RSO and all areas where local actions take place are well separated from the fire location			γ
		Operator must pass through areas affected by fire environment to reach RSO or other areas where local actions are taken		2β
	No barrier or potentially significant leakage between RSO or other required locations and fire area	Dense smoke, high temperature, and/or CO_2 impact in location	No credit for SCBAs	α
Functional Considerations (Ergonomics)	Lighting failed at any required location	emergency lighting or flashlights available		γ
		emergency lighting or flashlights not available		α
	Local actions required for essential functions	all equipment accessible		γ
		accessibility limited		β
		not accessible		α
Procedures	RSO procedure	Procedures available at RSO panel and all necessary location, and all required actions addressed		γ
		Must be obtained from control room or RSO location	adjust to β if time is limited	γ/β
Training/Experience	Realistic training on scenario			γ
	Little or no hands-on (vice desktop) training			β
Nature of Task (Complexity)	Control task (e.g., maintaining AFW)	indications available locally		β
		Indications not available locally	requires gaining information from operators stationed throughout the plant. Communications good.	β
			requires gaining information from operators stationed throughout the plant. Communications problematic.	2β

Time available	Time Adequate to reach location and perform activity		include time needed to obtain procedure if applicable	γ
	Time limited			β
	Time inadequate or barely adequate			α
Notes on application of Manual Actions Evaluation Table: 1. Apply table to specific plant fire scenario. 2. Select column in Fire SDP “Risk Significance Estimation Matrix” based on the following rules: • If any row is α, then use column "0" in Matrix • If the sum of rows evaluated as β or 2 β is ≥ 3 β, then assume equivalent to α and use column “0" in Matrix • If all categories are γ, then use column "-2" in Matrix • Otherwise (i.e., if the sum of rows evaluated as β or 2 β is β or 2 β), then use column "-1" in Matrix				

Use the most limiting of the factors (e.g., if the local actions that are essential to success are in inaccessible places, use α).

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

Pending

6.1.1.2 Fixed Fire Detection & Suppression Degradation

Pending

6.1.2.3 Fire Barrier Degradation - Inter-Compartment and Local

Pending

6.1.2.4 Safe Shutdown Findings

6.1.3 Step 1.3: Initial Qualitative Screening Check

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 assigned colored Green. Question 1 accomplishes this.

The second question screens to green findings 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.).

6.1.4 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; 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 inoperable. 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 inoperable, 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 compartment 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 for a moderate degradations against the fire prevention or administrative controls programs, the PRA approach would assess a minimum of two orders of magnitude reduction to reflect other non„degraded DID elements.

- 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 inspector 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 bench-marking 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.

The basis for disallowing ex-control room manual actions in this CCDP screening process is to prevent the credit of a train of equipment for mitigating core damage which requires manual recovery from fire-induced or random failures of that train of equipment; and to prevent credit for a train of equipment mitigating core damage where manual actions are designed to prevent fire-induced failure (spurious actuation) of that train of equipment.

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 compartment:

- 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 likely substantially 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 it's basis remains largely unchanged. In Step 2.1, the inspector 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 FDS's 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.

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 inspectors is broadly consistent with similar lists applied in general PRA practice. To illustrate the differences between the SDP and typical fire PRA practices, Table 6.2.1 provides a comparison between the fire ignition source bins defined for the RES/EPRI Fire Risk Requantification Study (Ref: USNRC JCN J6037).

Table 6.2.1: Comparison of the fire ignition source bins used in the Fire Protection SDP to those defined in the Fire Risk Requantification Study.		
Fire Risk Requantification Study	**Fire Protection SDP**	**Notes**
Containment Specific Sources:		
Reactor Coolant Pumps (PWR - Containment)		Same Treatment
Reactor Feed Pumps (BWR - Containment)		
Turbine Building Fire Sources:		
Turbine Generator Set - Exciter		Same Treatment
Turbine Generator Set – Oil		
Turbine Generator Set - Hydrogen		
Main Feedwater Pumps		
Boilers		
Transformers:		
Transformer Yard - leading to LOSP	Yard Transformers (all fires)	SDP combines all large outdoor transformer fires into a single bin. Consequences (e.g., LOSP or propagation to TB) are determined on case-specific basis.
Transformer Yard - propagating to TB		
Transformer Yard - other fires		
Indoor Transformers		Same Treatment
Fires Caused by Hot Work (welding or cutting):		
Transient: PWR-Containment	Hot Work Fires (Welding and Cutting)	The Requantification Study bins hot work fires based on location and whether cables or other combustibles were ignited. SDP Combines all hot work fires into a single bin.
Cable Fire: PWR-Containment		
Transient: BWR-Containment		
Cable Fire: BWR-Containment		
Cable Fire: Turbine Bld.		
Transient Fire: Turbine Bld.		
Cable Fire: Other Locations		
Transient Fire: Other Locations		
Transient Fires (not caused by hot-work):		
Location: PWR-Containment	Transients (not hot work)	The Requantification Study bins transient fires by location. SDP Combines all transient fires into a single bin
Location: BWR-Containment		
Location: Turbine Bld.		
Location: All Other		
Electrical Cabinets:		
Location: PWR Containment	Electrical Cabinets - General Types and Locations Excluding MCR, MCR Support, and Switchgear	The Requantification Study bins cabinets by location and type. SDP combines most cabinets into a single bin for fire frequency. Switchgear are
Location: BWR Containment		
Location: Auxiliary Bld.		
Location: Reactor Bld.		
Application: Diesel Generators		

Table 6.2.1: Comparison of the fire ignition source bins used in the Fire Protection SDP to those defined in the Fire Risk Requantification Study.

Fire Risk Requantification Study	Fire Protection SDP	Notes
Location: Cable Spreading Rm.		retained as a separate group because of energetic arcing fault potential.
Location: Intake Structure		
Location: Turbine Bld.		
Type: Fire Protection Panels		
Type: Battery Chargers		
Type: Switchgear		Same Treatment
Location/Type: Control Panels including Main Control Room Electrical Cabinets	Main Control Room Control Panels	SDP practice is same as Requant. Study. For clarity, explicit discussion of MCR support panels not within the MCR itself is provided.
	Other Control Panels including Main Control Room Support	
Other Electrical Fire Sources:		
Battery Fires		Same Treatment
Electric Motors (not associated with a pump, compressor, or ventilation system)		
Dryers		
Non-Qualified Cable Runs		
Pumps:		
Aux B PWR Pumps	Other Pumps (all pumps not covered by other bins)	SDP combines these general pumps into a single fire frequency bin.
Reactor B BWR Pumps		
Intake Structure-Fire Pumps		
TB-Other Pumps		
Misc. Plant Wide Components:		
Diesel Generators		Same Treatment
Reactor Protection System - Motor Generator Sets		
H2 Recombiner (BWR)		
Hydrogen Storage Tank		
Misc. Hydrogen Fires		
Generators – Emergency Gas Turbine Generators		
Air Compressors		
Ventilation Subsystems		
Misc. other limited fire sources		
Intake Structure-Others	Not explicitly treated in SDP	These four bins include a very small number of fires that did not fit in other bins. Exclusion in SDP is not significant given small number of events.
Radwaste Area-Misc. Comp		
PWC-Junction Box NQ cable		
PWC-Junction Box Q cable		

Note that the SDP has in various cases combined similar bins to simplify the SDP process. In each case, the differences in fire frequency for member of the combined bins were found to be small.

Note that four specific categories of events included in the requantification study have been excluded from the SDP process. These four bins were defined in order to capture a very small number of fire events that did not fit neatly into other bins. Neglecting these events in the Fire Protection SDP introduces a minimal error.

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 inspector 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.

Note that in general, 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[3]. 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 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 IPEEE's 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

[3]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.

to both aspects of the IEEE-383 test standard are thermoset materials.[4] 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.

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

Summary of Basis

- The recommended SDP practice does not 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.
- 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

[4] 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.

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 (ibid). 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[5], generally corresponding to thermoplastic cables, of 218°C (425°F)[6]. 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.

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 (425F and 700F) reflect commonly applied screening values for the damage thresholds for minimum damage/ignition thresholds for thermo-plastic and thermo-set cables respectively.

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[5]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.

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

The ignition temperatures have been assumed equal to the damage temperature based on USNRC-sponsored testing from the late 1980's (NUREG/CR-XXXX) 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 inspector 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 generic plant-wide fire frequency is based on the analysis of fire event data. The fire event database used is up-to-date and, of the available databases, provides the most complete descriptions of the recorded fire events. The data has been culled and analyzed using accepted methods of Bayesian analysis, and using USNRC-staff recommended approaches to assessing the applicability of various pedigrees of event data.

For the SDP process, the fire frequency analysis has been simplified to a modest extent as compared to general fire PRA practice. The nominal fire frequency estimates are based on a component level analysis. That is, the approach assigns a fire frequency to each individual fire ignition source (generally the electrical equipment). The total fire frequency is the sum of the frequencies for the individual sources. This approach makes it quite simple for the inspector 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 inspector 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.

Beyond this simplification, the approach is fully consistent with the Fire Risk Requantification Study practices in particular.

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 or failure to implement a fire watch at all are considered high degradations because they remove both early detection and suppression capability. Other deficiencies, such as not having a proper or operable fire extinguisher were considered moderate degradations because they only represented loss of immediate suppression capability but not immediate detection. A method of recovery from not having an operable fire extinguisher is to be within 30 ft of a properly identified operable 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 moderate 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 watchers. 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. A high degradation will be factored into the risk analysis by removing the credit provided by the fire watch. Moderate degradations will result in the removal of the square root of that value.

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. Such a finding may increase combustible loading assumptions for fire modeling, however.

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 compartment in which they are found by a factor of 10.

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 varies also. 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

PENDING

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 Task 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 inspector 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 Plant Damage State Scenarios

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

6.2.5.3 Task 2.5.3: 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.

6.2.5.4 Task 2.5.4: 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

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

$$1/(\text{time to damage : seconds}) = 3.343E\text{-}05 \times (\text{Temp: °C}) - 1.044E\text{-}02$$

Using this relationship, a table of time to damage values was generated as presented in Section 5.2.6. Note that the results of the linear regression were adjusted modestly for values that fell outside the data range where extrapolation is necessary.

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.

In order to provide a more consistent analysis basis for use in the SDP, the very short damage times at the two lower exposure temperatures were neglected. 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:

$$1/(\text{time to damage : seconds}) = 3.488E\text{-}05 \times (\text{Temp: °C}) - 7.467E\text{-}03$$

Using this relationship, a table of time to damage values was generated. Again, results of the linear regression were adjusted for values that fell outside the data range where extrapolation is necessary.

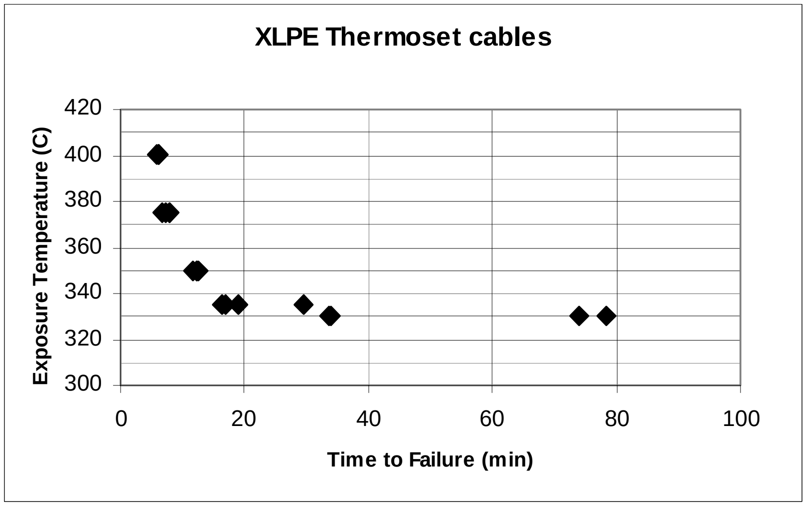

Figure 6.2.1: Raw time to damage chart for thermoset XLPE cables.

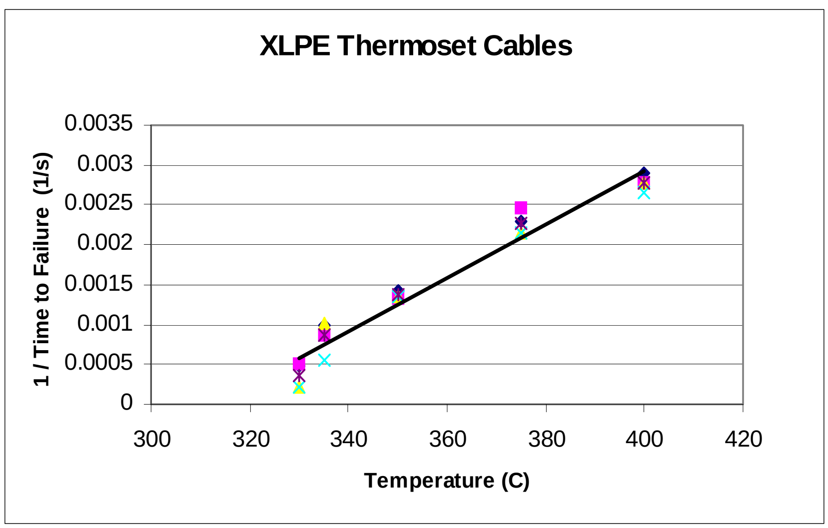

Figure 6.2.2: damage time plot for thermoset cables with linear regression curve shown.

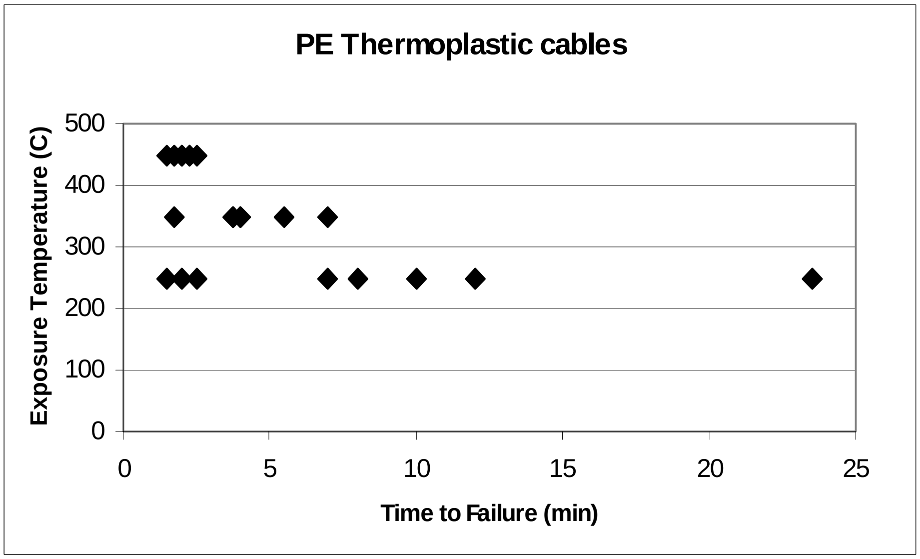

Figure 6.2.3: Raw time to damage plot for thermoplastic PE cables.

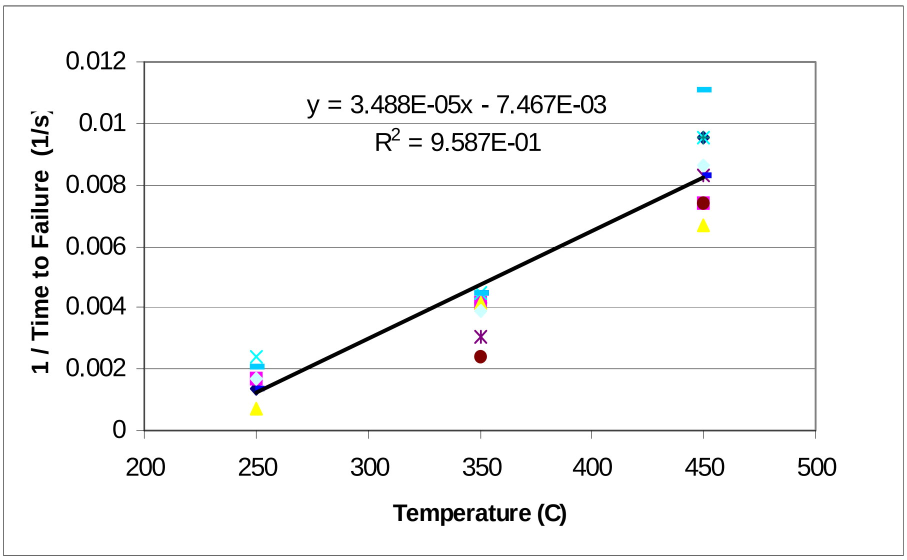

Figure 6.2.4: Time to damage plot for thermoplastic cables showing linear regression curve.

Failure Time-Temperature relationship for thermoset cables.		
Exposure Temperature		Time to Failure (minutes)
°C	°F	
330	625	28
350	660	13
370	700	9
390	735	7
410	770	5
430	805	4
450	840	3
470	880	2
490 (or greater)	915 (or greater)	1

Failure Time-Temperature relationship for thermoplastic cables.		
Exposure Temperature		Time to Failure (minutes)
°C	°F	
205	400	30
220	425	25
230	450	20
245	475	15
260	500	10
275	525	8
290	550	7
300	575	6
315	600	5
330	625	4
345	650	3
355	675	2
370 (or greater)	700 (or greater)	1

Radiant Exposures - Thermoset Cables

PENDING

Radiant Exposures - Thermoplastic Cables

PENDING

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 (425°F and 700°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 immanent. 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^{2}s).

- 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^{2}s). Hence, use of a piloted ignition screening criteria of 11 kW/m^2 (1.0 BTU/ft^{2}s) 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^{2}s) 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^{2}s).
    - 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

Pending

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

Pending

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 inoperable).

Detection by a Continuous Fire Watch

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 (draft for public comment).

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 (draft for public comment).

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 not 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

PNS_{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.)

$\underline{PNS}_{Manual}$

See Section 6.2.7.3 above.

$\underline{PNS}_{Scenario}$

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

Pending

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 EXAMPLES

Pending: Chapter 7 will provide examples to illustrate the analysis process for both Phase 1 and Phase 2. These examples will be developed during planned table-top exercises.

8.0 REFERENCES

PENDING