NRC INSPECTION MANUAL

APOB

INSPECTION MANUAL CHAPTER 0609 APPENDIX F

FIRE PROTECTION
SIGNIFICANCE DETERMINATION PROCESS

Effective Date: January 1, 2025

TABLE OF CONTENTS

List of Tables

List of Figures

List of Attachments

0609F-01 PURPOSE

The Fire Protection Significance Determination Process (SDP) involves a series of qualitative and quantitative analysis steps for estimating the risk significance of inspection findings related to licensee performance 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 the reactor's ability to safely shutdown if a fire is not promptly extinguished.

0609F-02 OBJECTIVES

Phase 1 of the Fire Protection SDP is primarily qualitative. Phase 1 provides initial characterization of the fire finding and serves to screen out fire findings that may have very low risk significance (Green). If the Phase 1 screening criteria do not screen out a fire finding as Green, then the evaluation process continues to Phase 2.

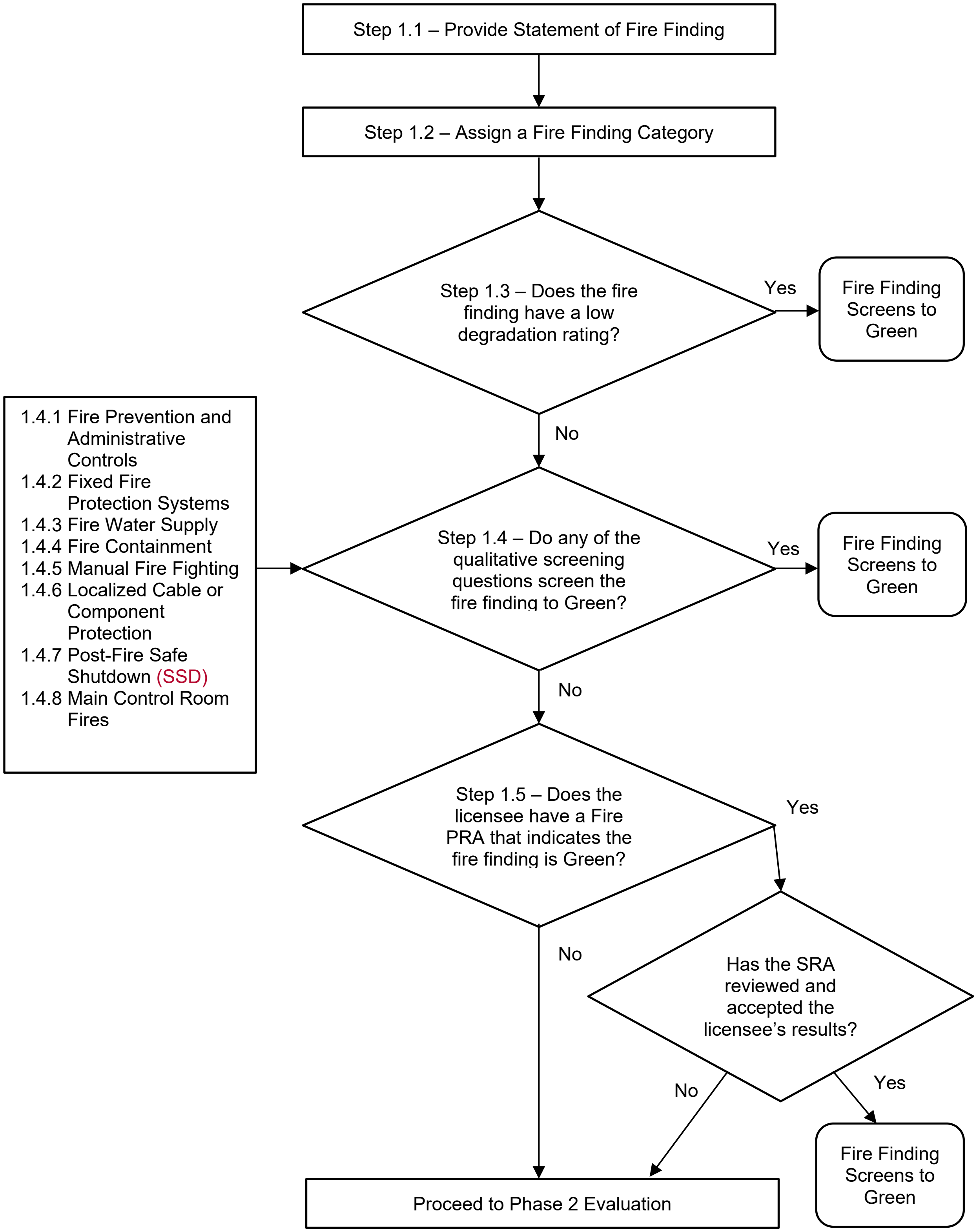
Phase 2 of the Fire Protection SDP is quantitative and based on simplified methods and approaches used in typical fire probabilistic risk assessments (PRAs). The general philosophy of the Fire Protection SDP is to minimize the potential for false-negative findings, while avoiding undue conservatism. The duration (or exposure time) of the degraded conditions is considered at all stages of the analysis. Compensatory measures that might offset (in part or in whole) the observed degradations are considered in Phase 2.

02.01 Fire Protection SDP Phase 1 Overview

Phase 1 of the Fire Protection SDP is a preliminary screening check intended for use by the Resident or Regional Office Inspector(s) to identify fire protection findings with very low risk significance (Green findings). If a fire finding meets a screening criterion, the finding is determined to be of very low risk significance and no Phase 2 analysis is required. If the Phase 1 screening criterion is not met, the analysis proceeds to Phase 2 for further evaluation of risk significance.

Phase 1 of the Fire Protection SDP contains five steps as illustrated in Figure F.1. A fire finding is first characterized (Step 1.1) and assigned a category (Step 1.2) based on the fire protection program (FPP) element that was found to be degraded. The fire finding is then evaluated to determine if it has a low degradation rating (Step 1.3). Low degradation rating fire findings are screened to Green. If the fire finding is not low degradation, the next step (Step 1.4) attempts to screen the finding using a series of qualitative questions based on the finding category assigned in Step 1.2. The final step in Phase 1 (Step 1.5) is for plants that have a fire PRA. The licensee's fire PRA-based risk evaluation may be used to determine whether the fire finding is of very low risk significance.

Figure F.1 – Phase 1 Flow Chart

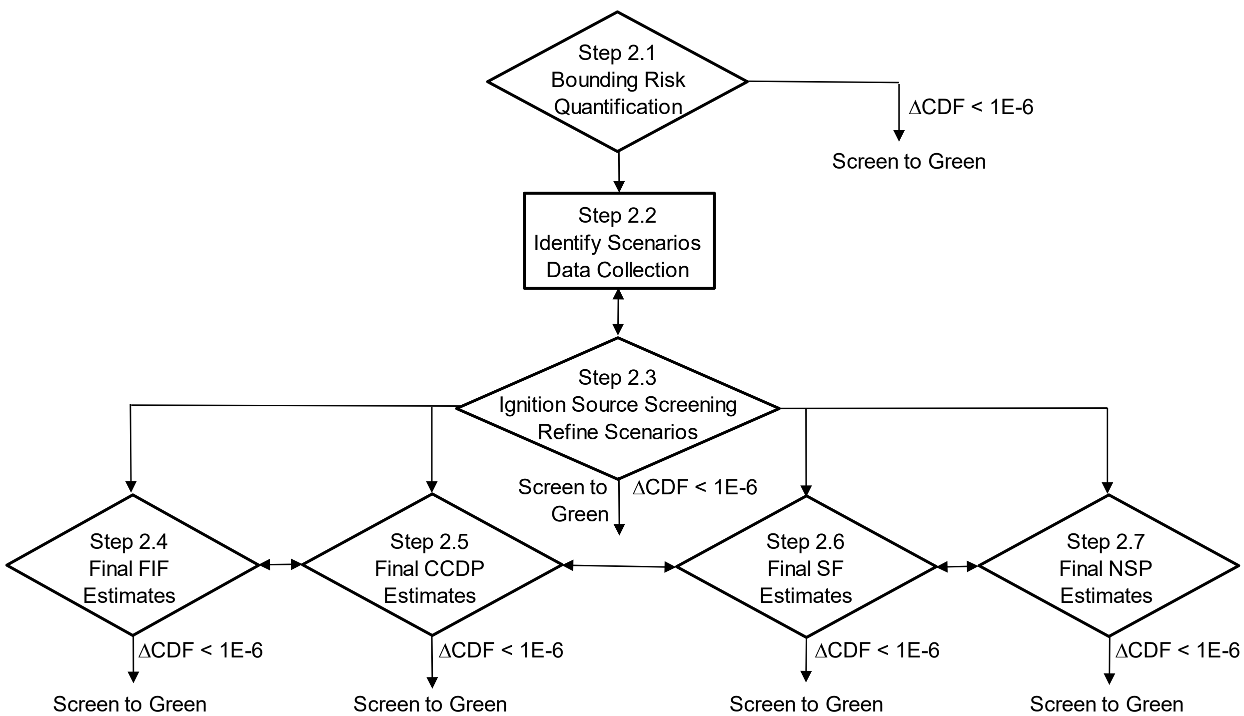


02.02 Fire Protection SDP Phase 2 Overview

Phase 2 of the Fire Protection SDP is a quantitative assessment of the change in core damage frequency (ΔCDF) due to a finding. Phase 2 involves the seven analysis steps illustrated in Figure F.2. The first three steps are intended to be performed in sequence. The remaining four steps can be (partially) completed in any order, and the analyst is encouraged to choose the step which will reduce the bounding ΔCDF as much as possible first, then second, etc., to minimize effort. Each step represents the introduction of new details and/or the refinement of previous analysis results.

The Phase 2 analysis includes six 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 of Green. If at any time the quantitative screening criteria are met, the analysis is considered complete, and any remaining steps need not be performed.

Figure F.2 – Phase 2 Flow Chart



The seven steps in Phase 2 are summarized below:

- Step 2.1 introduces the “six-factor” formula that is used to quantify the risk significance of the finding and calculates a bounding estimate of the ΔCDF based on the Duration Factor (DF) and conservative values for the five remaining factors. These remaining factors are the Fire Ignition Frequency (FIF) and applicable Adjustment Factors (AF), Conditional Core Damage Probability (CCDP), Severity Factor (SF), and Non-Suppression Probability (NSP). The six-factor formula quantifies the ΔCDF as the sum of the risk contributions of all fire scenarios that need to be evaluated for a given finding. However, the bounding ΔCDF estimate obtained in this step is based on the DF, and bounding area-wide values for all other factors.

- Step 2.2 defines discrete stages of fire growth and damage, referred to as Fire Damage States (FDSs), and identifies credible fire scenarios that may need to be considered in the Phase 2 assessment. This step also collects detailed information about the ignition sources, secondary combustibles, equipment and/or cable targets, etc. involved in these scenarios. Each scenario is uniquely defined by the ignition source that starts the fire and the extent of the damage caused by the fire.
- Step 2.3 screens ignition sources that are not capable of causing target damage or ignition of secondary combustibles. Fire scenarios identified in Step 2.2 that are initiated by a screened ignition source do not require further analysis and can be eliminated at this stage.
- Step 2.4 determines the final FIF and applicable AFs for the ignition sources that are not screened in Step 2.3.
- Step 2.5 identifies the damaged target set for each unscreened ignition source and each applicable FDS and quantifies the corresponding CCDP for each scenario.
- Step 2.6 estimates the SF for each unscreened fixed or transient ignition source based on the heat release rate (HRR) required to cause damage to the target set for the fire scenario under evaluation, or to cause ignition of a secondary combustible. Liquid fuel spill and high energy arcing fault (HEAF) fires are assigned an SF that is independent of the HRR required to cause damage or ignition.
- Step 2.7 quantifies the final NSP for each fire growth and damage scenario based on an analysis of the detection and suppression methods available for the scenario and the estimated time required to damage the target sets.

The ΔCDF is re-evaluated at the end of Step 2.1 and the end of Steps 2.3 through 2.7. If the refined ΔCDF is less than 1E-6 at any time in Phase 2, the analysis is complete and the finding screens to Green. When all steps have been completed and the final ΔCDF is still 1E-6 or greater, a Phase 3 assessment is required to determine the final risk significance of the finding.

02.03 Assumptions and Limitations

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 FPP. The Fire Protection SDP is a tool that NRC inspectors can easily use to obtain an assessment of the risk significance of a finding.

The Fire Protection SDP approach has a number of inherent assumptions and limitations, as discussed below. A more detailed discussion of these assumptions and limitations is contained in the Supplemental Guidance/Technical Basis for Appendix F (IMC 0308, Attachment 3, Appendix F).

- The Fire Protection SDP assesses the ΔCDF, rather than the change in large early release frequency (ΔLERF), as a measure of risk significance. Typically, ΔCDF and ΔLERF are assumed to be proportional, such that assessing one is sufficient. However, if a finding increases the likelihood of otherwise low probability events that primarily impact LERF (such as fire-induced spurious opening of a containment isolation valve), ΔLERF may be the more appropriate risk metric. In this case, the SDP analysis should proceed directly to Phase 3.

- 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 FPP 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). In this case, the SDP analysis should proceed directly to Phase 3.
- 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. 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.
- The Fire Protection SDP does not include findings associated with performance of the onsite fire brigade or fire department. Onsite fire brigade findings are evaluated in accordance with IMC 0609, Appendix A.
- The Fire Protection SDP Phase 2 quantitative screening method is mainly intended to support the assessment of issues associated with an individual fire area. However, the Phase 2 process may be appropriate for some issues involving multiple fire areas. It is recommended that additional guidance be sought from a risk analyst in the conduct of such an analysis. A systematic plant-wide search and assessment effort is beyond the intended scope of Phase 2. In such cases, the SDP analysis can proceed directly to Phase 3.
- The Fire Protection SDP Phase 1 qualitative screening process includes a limited set of questions regarding main control room (MCR) fires. However, the Phase 2 quantitative screening method does not currently include explicit treatment of MCR fires or fires leading to MCR abandonment (either due to fire in the MCR or due to fires in other fire areas that would impair the ability to control the reactor from the MCR). The Phase 2 process may be able to address such scenarios, but it is recommended that additional guidance be sought from a risk analyst in the conduct of such an analysis.

0609F-03 STEP 1 – FIRE PROTECTION SDP PHASE 1 SCREENING

Phase 1 of the Fire Protection SDP serves to screen out very low risk-significant findings. This qualitative screening approach is entered when the following items are met:

- The inspection finding clearly states the licensee performance deficiency and the more-than-minor criteria met in accordance with IMC 0612, Appendix B, “Issue Screening”.
- The finding should discuss, as applicable, 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 (i.e., there is no performance deficiency), unless cited compensatory measures or other caveats imposed through the SER remain uncompromised.

The worksheet for recording the Fire Protection SDP Phase 1 screening results is provided in Attachment 1.

Step 1.1 – Provide Statement of Fire Inspection Finding

Provide a clear statement of the fire inspection finding and the noncompliance in Attachment 1.

Step 1.2 – Assign a Fire Finding Category

Assign the fire finding to the finding category that best fits using the guidance in the table below. A fire finding can only be assigned to one category. Record the assigned fire finding category in Attachment 1.

Table 1.2.1 – Finding Categories

Finding Category		Elements Covered by Finding Category
O	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 (other than those described in the Fixed Fire Protection Finding Category below) • Training programs
O	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
O	Fire Water Supply	• Fire pumps • Yard loop piping • Water sources
O	Fire Confinement	• Fire barrier elements that separate one fire area from another • Penetration seals • Water curtains • Fire and/or smoke dampers • Fire doors • Spatial separation (e.g., per App. R Section III.G.2)
O	Manual Firefighting	• Hose stations • Fire extinguishers • Fire pre-plans
O	Localized Cable or Component Protection	• Passive physical features installed for the thermal/fire protection of cables, cable raceways, or individual components • Raceways or component fire barriers (e.g., cable wraps) • Radiant heat shields protecting a component or cable

Table 1.2.1 – Finding Categories		
Finding Category		Elements Covered by Finding Category
O	Post-fire Safe Shutdown (SSD)	• Systems or functions identified in the post-fire SSD analysis • Systems or functions relied upon for post-fire SSD • Post-fire SSD component list (e.g., completeness) • Post-fire SSD analysis (e.g., completeness) • Post-fire plant response procedures • Operator manual actions • Alternate shutdown (e.g., control room abandonment) • Circuit failure modes and effects (e.g., spurious operation issues)
O	MCR Fires	• Postulated fires occurring in the MCR that affect the habitability, equipment, or controls in the MCR

Step 1.3 – Low Degradation Deficiencies

Determine if the fire finding can be assigned a low degradation rating using the guidance in Attachment 2. Provide an explanation of the degradation rating reasoning in Attachment 1.

1.3.1-A Question: Based on the criteria in Attachment 2, is the finding assigned a "Low" degradation rating?
O Yes – Screen to Green, no further analysis required.
O No – Continue to Step 1.4.

Step 1.4 – Qualitative Screening Questions for Individual Fire Finding Categories

Proceed to the step that corresponds to the fire finding category assigned in Step 1.2 and answer the screening questions to determine if the finding is of very low risk significance (Green). There are screening questions for each of the eight finding categories:

- Prevention of fires from starting
  - 1.4.1 Fire Prevention and Administrative Controls
- Rapid detection and suppression of fires that occur
  - 1.4.2 Fixed Fire Protection Systems
  - 1.4.3 Fire Water Supply
  - 1.4.4 Fire Confinement
  - 1.4.5 Manual Fire Fighting
- Protection of the reactor's ability to safely shutdown if a fire is not promptly extinguished
  - 1.4.6 Localized Cable or Component Protection
  - 1.4.7 Post-Fire SSD
  - 1.4.8 MCR Fires

Only evaluate the finding using the screening questions from the assigned fire finding category. If a question does not apply, skip the question and proceed to the next question for that finding category. If it is the last question in the category, proceed to Step 1.5. For each question, indicate your response by checking the circle in Attachment 1. Describe the rationale for the chosen response in Attachment 1.

Step 1.4.1: Fire Prevention and Administrative Controls

1.4.1-A Question: Could the fire finding increase the likelihood of a fire, delay detection of a fire, or result in a more significant fire than previously analyzed such that the credited SSD strategy could be adversely impacted?
O Yes – Continue to next question.
O No – Screen to Green, no further analysis required.

1.4.1-B Question: Does the fire finding adversely affect an area with adequate automatic detection and suppression?
O Yes – Screen to Green, no further analysis required.
O No – Continue to Step 1.5.

Step 1.4.2: Fixed Fire Protection Systems

1.4.2-A Question: Does the degraded or non-functional detection or fixed suppression system adversely affect the ability of the system to protect any equipment important to SSD?
O Yes – Continue to Step 1.5.
O No – Screen to Green, no further analysis required.

Step 1.4.3: Fire Water Supply

1.4.3-A Question: Would adequate fire water capacity (flow at required pressure) still be available for protection of equipment important to SSD in the most limiting location onsite?
O Yes – Screen to Green, no further analysis required.
O No – Continue to Step 1.5 (Phase 2) or Phase 3, as appropriate.

Step 1.4.4: Fire Confinement

1.4.4-A Question: Will the degraded fire confinement element continue to provide adequate fire endurance (including protection from the transmission of flames, smoke, and hot gases) to prevent fire propagation through the fire confinement element, given the combustible loading and location of equipment important to SSD in the fire area of concern?
O Yes – Screen to Green, no further analysis required.
O No – Continue to next question.

1.4.4-B Question: Is there an adequate automatic suppression system on either side of the fire confinement element?
O Yes – Screen to Green, no further analysis required.
O No – Continue to next question.

1.4.4-C Question: If the fire finding involves an open or degraded fire door, is there any equipment important to SSD in the affected fire areas?
O Yes – Continue to the next question.
O No – Screen to Green, no further analysis required.

1.4.4-D Question: If the fire finding involves failure of a fire door to properly latch, but did not affect the ability of the fire door to close, does the fire door protect an area with a gaseous fire suppression system:
O Yes – Continue to Step 1.5.
O No – Screen to Green, no further analysis required.

1.4.4-E Question: If a fire were to spread from one fire area (the exposing fire area) to another (the exposed fire area) due to the degraded fire confinement element, would any additional targets be damaged in the exposed fire area that could impact the credited SSD strategy for the exposing fire area (targets include post-fire SSD components or other plant components whose loss might lead to a demand for SSD (e.g., a plant trip))?
O Yes – Continue to next question.
O No – Screen to Green, no further analysis required.

1.4.4-F Question: Are the additional damage targets sufficiently nearby in the adjoining compartment such that they could be affected by a fire spreading due to the deficiency in the fire confinement element (e.g., a cable that passes through multiple fire areas)?
O No – Screen to Green, no further analysis required.
O Yes – Continue to Step 1.5.

Step 1.4.5: Manual Fire Fighting

1.4.5-A Question: Is the fire finding associated with portable fire extinguishers not used for hot work fire watches?
O Yes – Screen to Green, no further analysis required.
O No – Continue to next question.

1.4.5-B Question: Is the fire finding associated with pre-fire plans?
O Yes – Screen to Green, no further analysis required.
O No – Continue to next question.

1.4.5-C Question: Is the fire area associated with the fire finding protected by an adequate automatic or manual fire suppression system?
O Yes – Screen to Green, no further analysis required.
O No – Continue to the next question.

1.4.5-D Question: For a finding associated with a degraded hose station(s), was an alternative manual suppression method available to suppress the fire such that equipment important to SSD would not be adversely affected?
O Yes – Screen to Green, no further analysis required.
O No – Continue to Step 1.5.

Step 1.4.6: Localized Cable or Component Protection

1.4.6-A Question: Is the area with the degraded fire wrap (cable, cable tray, or component) protected by an adequate automatic detection and suppression system?
O Yes – Screen to Green, no further analysis required.
O No – Continue to next question.

1.4.6-B Question: Is the area with the degraded fire wrap (cable, cable tray, or component) protected by an adequate automatic detection system and a fire wrap that would provide sufficient fire endurance to enable suppression of a fire prior to damage to the target?
O Yes – Screen to Green, no further analysis required.
O No – Continue to Step 1.5.

Step 1.4.7: Post-fire SSD

1.4.7-A Question: For a finding associated with emergency lighting, do operators have adequate alternate lighting (such as flashlights) to perform any necessary time critical/recovery actions?
O Yes – Screen to Green, no further analysis required.
O No – Continue to next question.

1.4.7-B Question: Would the impact of the fire finding be limited to equipment which is not required for the credited SSD success path?
O Yes – Screen to Green, no further analysis required.
O No – Continue to next question.

1.4.7-C Question: Does the fire finding adversely affect the ability to reach and maintain hot shutdown/hot standby or safe and stable conditions using the credited SSD success path?
O Yes – Continue to Step 1.5.
O No – Screen to Green, no further analysis required.

Step 1.4.8: MCR Fires

NOTE: This section only applies if there is no equipment greater than or equal to 440V in the MCR.

1.4.8-A Question: If the finding involves the malfunction (either a spurious operation due to a hot short or the failure to operate due to fire damage) of two or more components located in the main control board (MCB) (MCB includes any panels in the horseshoe area or within the line of sight of the operators), is all of the internal cabinet wiring in the MCB qualified (such as per IEEE-383) and are the components located at least 8.2 feet (2.5 meters) apart?
O Yes – Screen to Green, no further analysis required.
O No – Continue to the next question.

1.4.8-B Question: If the finding involves the malfunction (either a spurious operation due to a hot short or the failure to operate due to fire damage) of two or more components that are not located in the MCB, are the components located in nonadjacent cabinets?
O Yes – Screen to Green, no further analysis required.
O No – Continue to the next question.

1.4.8-C Question: If the finding involves a single fire scenario in the MCR, did the deficiency exist for 1 hour or less?
O Yes – Screen to Green, no further analysis required.
O No – Continue to Step 1.5.

Step 1.5 – Screen Based on Licensee Fire PRA Results

For plants with a fire PRA, the results of the licensee's PRA-based risk evaluation can serve as the basis for screening a finding to Green, provided a Senior Reactor Analyst (SRA) reviews and approves. For this process the licensee has to provide a risk evaluation based on its fire PRA, including the dominant cut sets and information on how the deficiency is modeled. With this information, an SRA may be able to determine whether the licensee's evaluation is acceptable. If the plant does not have a fire PRA or the fire finding cannot be adequately modeled using the plant's existing fire PRA, proceed to a Phase 2 evaluation. If the licensee's risk evaluation indicates that the fire finding has more than a very low risk significance (greater than Green), the SDP risk evaluation should continue to Phase 2 or Phase 3, at the discretion of the SRA.

Step 1.5.1: Screen by Licensee Fire PRA-based Risk Evaluation

Based on results from the licensee's fire PRA-based risk evaluation, evaluate whether a determination can be made that the finding is of very low risk significance. Provide an explanation of the evaluation of the licensee's fire PRA results in Attachment 1.

1.5.1-A Question: Does the plant have a fire PRA capable of adequately evaluating the risk associated with the finding, as determined by an SRA?
O Yes – Continue to the next question.
O No – Continue to Phase 2 evaluation.

1.5.1-B Question: Does the licensee's risk-based evaluation for this fire finding indicate a ΔCDF of less than 1E-6, and is the evaluation result accepted by an SRA?
O Yes – Screen to Green, no further analysis required.
O No – Continue to Phase 2 or 3 evaluation, as determined by the SRA.

0609F-04 STEP 2 – FIRE PROTECTION SDP PHASE 2 SCREENING

The worksheet for recording the Fire Protection SDP Phase 2 screening results is provided in Attachment 1.

In preparation for the analysis, request and review the following licensee documents, as needed:

- The licensee's fire hazards analysis for the fire area(s) to be evaluated
- The post-fire SSD analysis for the fire area(s) to be evaluated
- The licensee's lists of required and associated circuits
- Post-fire operating procedures applicable to the fire area(s) to be assessed
- Documentation for any NRC approved deviations or exemptions relevant to the fire area(s) to be assessed
- Any PRA documentation that can support the analyses for the fire area(s) to be evaluated

Step 2.1 – Bounding Risk Quantification

This step introduces the equation that is used in the Phase 2 risk quantification and helps the analyst to determine which contributing factor(s) in the equation to focus on. It is very unlikely that a finding in the Post-Fire SSD Category will be screened to Green in this step, and the analyst may choose to continue directly to Step 2.2.

Phase 2 of the Fire Protection SDP is a quantitative assessment of the increase in annualized core damage probability (i.e., CDF integrated over an appropriate fraction of a year, subsequently referred to as the ∆CDF) due to a finding. The following six-factor formula is used to estimate the screening ∆CDF:

$$\Delta \mathrm{CDF} \approx \mathrm{DF} \times \sum_{i=1}^{N} \left[\mathrm{FIF}_i \times \left(\prod \mathrm{AF} \right)_i \times \mathrm{SF}_i \times \mathrm{NSP}_i \times \mathrm{CCDP}_i \right] \qquad [1]$$

Where:

N	=	Number of fire scenarios evaluated for a given finding;
DF	=	Duration factor;
FIF_i	=	Fire frequency for the fire ignition source that started scenario i;
AF	=	Ignition source specific frequency adjustment factors;
SF_i	=	Severity factor for scenario i;
NSP_i	=	Non-suppression probability for scenario i;
$CCDP_i$	=	Conditional core damage probability for scenario i.

Equation 1 estimates the screening ∆CDF as the sum of the risk contributions of all fire scenarios that need to be evaluated for a given finding. Only scenarios that are made possible as a result of the finding need to be considered. These scenarios are identified as a function of the finding category assigned in Step 2.2. Equation 1 is based on the assumption that the baseline risk for these scenarios is negligible such that the “adjusted” risk is a reasonable but conservative approximation of the risk increase.

A bounding estimate of the change in CDF value for an entire area due to fires in the area is calculated from the following equation:

$$\Delta \mathrm{CDF} \approx \mathrm{DF} \times \mathrm{FIF} \times \mathrm{SF} \times \mathrm{NSP} \times \mathrm{CCDP} \qquad [2]$$

Where:

FIF	=	Fire ignition frequency for the entire area;
SF	=	Bounding severity factor for the area;
NSP	=	Bounding non-suppression probability for the area;
CCDP	=	Bounding conditional core damage probability for the area.

The sixth factor in Equation 1, AF, is not retained in Equation 2 because the area-wide FIF accounts for any adjustments. If the finding affects multiple areas (e.g., if the finding pertains to a degraded barrier between two areas that contain different risk-significant target sets), a bounding estimate of the change in CDF value can be obtained by summing the ∆CDF estimated according to Equation 2 over all affected areas. A brief discussion and bounding estimates for each of the six factors in the formula are provided in Steps 2.1.1 through 2.1.6. A bounding estimate of the ΔCDF is obtained in Step 2.1.8.

Methods for refining the bounding estimates are described in Steps 2.3 through 2.7. A brief description of these steps can be found after Figure F.2. A refined estimate of the ΔCDF is obtained in Step 2.3 based on the information collected in Step 2.2. Steps 2.4 through 2.7 further refine the factor and ΔCDF estimates. The ΔCDF can be recalculated at any time during the Phase 2 evaluation since the various steps need not be performed sequentially, but can be performed iteratively, i.e., the ΔCDF can be updated each time a step is (partially) completed. Since the SF and NSP rarely reduce the ΔCDF by more than an order of magnitude, the analyst usually should focus on estimating the FIF and CCDP first. If at any time in the process the updated value of the ΔCDF is below 1E-6, the finding screens to Green, and the analysis is complete. If, the ΔCDF is still at least 1E-6 after Steps 2.3 through 2.7 have been completed, the finding is potentially risk-significant and a Phase 3 assessment is required to determine the final risk significance of the finding, which is a function of the final ΔCDF value as shown in Table 2.1.1.

Table 2.1.1 – Risk Significance Based on ΔCDF	
Frequency Range (per yr)	SDP Based on ΔCDF
ΔCDF ≥ 1E-4	Red
1E-4 > ΔCDF ≥ 1E-5	Yellow
1E-5 > ΔCDF ≥ 1E-6	White
< 1E-6	Green

Step 2.1.1: Estimate the DF

DF is the length of time in years (days divided by 365 days/year) that the noted performance deficiency was, or will be, in existence (i.e., the duration of the degradation). In practice, DF may vary between approximately 1E-4 (duration of ~1 hour [1/8760 year]) and 1 (duration of 1 year). The value of DF calculated in this step is used in all risk calculations throughout Phase 2 of the Fire Protection SDP, i.e., there is no further refinement in subsequent steps.

Step 2.1.2: Estimate Bounding Value of the FIF

Any ignition source is assumed to start a fire with a given probability, which is based on plant fire event frequency statistics. This probability is referred to as the FIF. FIF_i applies to the ignition source that initiates fire scenario i. FIFs for a range of ignition sources are tabulated in NUREG-2169 and vary between 3.0E-6 and 1.6E-2. A subset of the NUREG-2169 FIFs, supplemented with updated FIFs for the MCB from NUREG-2178, Vol. 2 and HEAFs from NUREG-2262, are reproduced in Attachment 4, Table A4.1. The fire ignition sources are divided into groups called bins that represent location, causal, and mechanistic factors deemed important to depict frequencies of initiating fire scenarios at different plants. The generic bin definitions, plant operating mode applicability, and associated frequencies were originally developed and provided in NUREG/CR-6850, Vol. 2, and subsequently re-evaluated in NUREG-2169 and more recently in NUREG-2262 for HEAFs.

A bounding FIF value can be obtained by summing the FIFs for all ignition sources in the area under investigation. Generic area-wide FIFs that can be used at this point in the screening process are given in Tables 2.1.2 and 2.1.3 below. Should a finding qualify in two or more generic areas, the FIF that is highest for those areas should be used. Guidance for refining the FIF is provided in Step 2.4.

Table 2.1.2 – Generic Area-Wide Fire Ignition Frequencies	
Area	FIF/reactor-year
Auxiliary Building (PWR)	4E-2
Battery Room	4E-3
Cable Spreading Room (Containing Cables Only)	2E-3
Cable Spreading Room (Also Containing Electrical Enclosures*)	6E-3
Cable Vault (Cables Only)	2E-3
Diesel Generator Room	3E-2
Intake Structure	2E-2
Main Control Room	1E-2
Radioactive Waste Area	1E-2
Reactor Building (BWR)	9E-2
Switchgear Room	2E-2
Transformer Yard	2E-2
Turbine Building	8E-2

* Limited to low voltage electrical components (< 440 V)

Table 2.1.3 – Bounding FIFs for Hot Work and Transient Fires	
Ignition Source	FIF/reactor-year
Welding and Cutting (Hot Work Issues Only)	4E-2
Transients (Combustible Controls Program Issues Only)	5E-3

Step 2.1.3: Estimate Bounding Values of Ignition Frequency AF

At this point in the process, a bounding AF of 1.0 is assumed. If the finding category assigned in Step 1.2 is “Fire Prevention and Administrative Controls”, an increase of the FIF by up to a factor of 10 may be applicable to hot work and transient combustible fires. These increases are accounted for in the generic FIFs for hot work and transient combustible fires provided in Table 2.1.3. Guidance for determining the applicable adjustments to the FIF for hot work and transient combustible fires when not using the bounding FIF estimates in Table 2.1.3 is provided in Steps 2.4.2 and 2.4.3.

Step 2.1.4: Estimate Bounding Value of the SF

SF_i is the probability that the HRR of the ignition source for scenario i is sufficient to cause damage to or ignition of the nearest and most vulnerable target. At this point in the process, a bounding SF_i of 1.0 is assumed. Since ignition sources are screened based on the 98th percentile of the HRR probability distributions, the assigned SF can range from 2E-2 to 1. SF_i, is a function of the type of ignition source and the distance to and characteristics of the nearest and most vulnerable combustible or damage target. Guidance for determining the SF for specific ignition sources is provided in Step 2.6. In the absence of detailed information on the type and location of ignition sources and targets in the area(s) under evaluation, a bounding SF of 1.0 is assumed for the area.

Step 2.1.5: Estimate Bounding Value of the NSP

NSP_i is the probability that fire suppression efforts fail to suppress the fire before the scenario-specific fire damage state is reached. At this point in the process, a bounding NSP_i of 1.0 is assumed. NSP_i can be between 0 (suppression always succeeds before the damage state is reached) and 1.0 (all suppression fails). For cases where fixed fire suppression is not being credited, NSP 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 activated), two suppression paths are considered: success of the fixed suppression system; and failure of the fixed suppression system to activate on demand combined with the response of the manual fire brigade. Guidance for calculating scenario-specific NSPs is provided in Step 2.7. In the absence of detailed information concerning the type and location of ignition sources and targets in the area(s) under evaluation, a bounding area-wide NSP of 1.0 is assumed.

Step 2.1.6: Estimate Bounding CCDP

$CCDP_i$ is the probability that fire-induced damage to plant components and cables in scenario i will lead to core damage. A bounding value for CCDP can be obtained based on an assessment of the unavailability and independence of the designated SSD path for the area(s) under evaluation, as described below. These bounding CCDP values vary from 0.01 to 1.0. Alternatively, a conservative estimate can be determined by the SRA using the plant specific Standardized Plant Analysis Risk (SPAR) models and assuming that all targets that are potentially vulnerable due to the deficiency will be damaged (full room burnout). Additional guidance for refining the CCDP estimate is provided in Step 2.5.

Identify the Designated Post-Fire SSD Path

Identify the designated post-fire SSD path for the fire area(s) under analysis. All plant fire areas should have such an SSD path identified as a part of the plant's FPP. The identified SSD path 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 FPP.
- 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.

Assess the Unavailability Factor for the Identified SSD Path

Assign an SSD unavailability factor to the identified SSD path in its as-found condition. The total unavailability factors to be applied in the screening CCDP evaluation are shown in Table 2.1.4. If remaining mitigation capability meeting the criteria in Table 2.1.4 is not available, the screening CCDP is either assessed as 1.0, or obtained from the SRA. If the CCDP is assessed as 1.0, the evaluation proceeds with Step 2.1.7 (i.e., there is no need to assess the independence of the SSD path). The CCDP can be refined later in accordance with Step 2.5.

Table 2.1.4 – Total Unavailability Values for SSD Path Based Screening CCDP	
Type of Remaining Mitigation Capability	Screening Unavailability Factor
1 Automatic Steam-Driven 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 0.01 when credited as "Remaining Mitigation Capability."	0.01
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 0.01 when credited as "Remaining Mitigation Capability."	0.01
Use of an Alternate Shutdown Strategy: The capability to safely shut down the reactor in the event of a fire using existing systems that have been rerouted, relocated, or modified (alternate or remote shutdown equipment). The probability of alternate or remote shutdown equipment being unavailable due to failure, test, or maintenance is assumed to be 0.1 when credited as "Remaining Mitigation Capability."	0.1

Assess Independence of the Identified SSD Path

Crediting of any SSD path prior to the development of specific fire damage scenarios requires that a high level of independence be verified. Once the designated post-fire SSD path has been identified, verify the following characteristics of this SSD path:

- The licensee has identified and analyzed the SSD systems, structures, and components (SSCs) required to support successful operation of the SSD path.
- The licensee has identified and analyzed SSCs that may cause mal-operation of the SSD path (e.g., the required and associated circuits).
- The licensee has evaluated any manual actions required to support successful operation of the SSD path and has determined that the actions are feasible.
- All manual actions take place outside the fire area under analysis and are specifically identified in the appropriate plant specific procedures. 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.
- The licensee has conducted an acceptable circuit analysis. Any known unresolved circuit analysis issues that could adversely impact the functionality of the designated SSD path are identified.
- No known circuit analysis issues (e.g., a known spurious operation issue) for exposed cables should hold the potential to compromise functionality of the identified SSD path.

    - Cables within the fire area under analysis are not considered exposed if they are protected by a non-degraded raceway fire barrier with a minimum 3-hour fire resistance rating.

- Cables within the fire area under analysis are not considered exposed if they are protected by a raceway fire barrier with a minimum 1-hour fire resistance rating, the area is provided with automatic detection and suppression capability, and none of these elements is found to be degraded.
- Cables in an adjoining fire area are not considered exposed if the fire barrier (rated for at least three hours) separating adjoining fire area from the fire area under analysis is not degraded.
- If the finding category assigned in Step 1.2 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 resistance rating and the area is provided with automatic detection and suppression capability.

- The licensee's compliance strategy for the separation of redundant SSD circuits (i.e., in the context of Appendix R Section III.G.2) are identified. If the finding category assigned in Step 1.2 is "Fire Confinement," any required or associated circuit components or cables that are located in the adjacent fire area(s) separated by the degraded fire barrier element are identified. Also, any supplemental fire protection (i.e., beyond separation by the degraded barrier element) provided for any such cable or components are identified.
- If the licensee has a fire PRA, the SSD strategy should be credited in the PRA. Any aspects of the above that are not credited for the SSD strategy in the PRA should not be credited in this SDP analysis.
- A 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 10 CFR 50 Appendix R Section III.G.2). Table 2.1.5 provides a matrix of independence criteria for the major options under III.G.2.

Table 2.1.5 – SSD Path Independence Check Criteria	
Section III.G.1 or III.G.2 compliance strategy for SSD path	SSD path independence criteria (all criteria for a given strategy must be met)
Physical separation into a separate fire area (III.G.1)	• The fire area boundary separating the SSD path is rated for at least three hours, or is otherwise creditable, and is not impacted by the finding under analysis.
Separation by a 3-hour rated localized fire barrier (e.g., a raceway barrier) (III.G.2.a)	• The fire barrier qualification rating is not in question, and • The fire barrier protecting the redundant train is not impacted by the finding.
Separation of more than 20 ft. plus automatic fire detection and suppression coverage for the fire area (III.G.2.b)	• No intervening combustibles or fire hazards, • The fire detection system is not impacted by the finding, and • The fire suppression system 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 (III.G.2.c)	• 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.
Other means of protection (e.g., exemptions, deviations, reliance on remote shutdown)	• SSD path will not be credited pending further refinement of the SDP fire scenarios.

Estimate the CCDP

If the designated post-fire SSD path meets the established physical independence criteria, its unavailability is credited for all fire scenarios (i.e., CCDP = SSD Unavailability Factor). If any of the independence criteria are not met, the SSD path is not credited (i.e., CCDP =1.0).

NOTE: Later steps include the possibility of crediting the identified SSD path in the context of specific fire scenarios and specific FDSs. Hence, the unavailability 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 later steps.

Step 2.1.7: Effect of the Finding Category

In Step 1.2 the fire finding was assigned to one of the following eight categories:

- Fire Prevention and Administrative Controls
- Fixed Fire Protection Systems
- Fire Water Supply

- Fire Confinement
- Manual Fire Fighting
- Localized Cable or Component Protection
- Post-Fire SSD
- MCR Fires

Since the objective of a Phase 2 assessment is to quantify the ΔCDF due to the deficiencies that resulted in the finding, only scenarios that contribute to this risk increase need to be considered. Consequently, the bounding ΔCDF obtained in Step 2.1.8 may be affected by the finding category. For example, for a finding in the Fire Confinement Category, fire scenarios in the areas on both sides of the degraded barrier may need to be accounted for. A discussion of the effect of the finding category on the fire scenarios that need to be included in a Phase 2 analysis can be found in Attachment 3.

Step 2.1.8: Estimate Bounding Value of ΔCDF

A bounding estimate of the ΔCDF value for the entire area(s) affected by the fire is calculated from

$$\Delta \mathrm{CDF} \approx \mathrm{DF} \times \sum_{j=1}^{M} \left[\mathrm{FIF_j} \times \mathrm{SF_j} \times \mathrm{NSP_j} \times \mathrm{CCDP_j}\right] \quad [3]$$

Where:

M	=	Number of areas affected by the finding
DF	=	Duration factor (from Step 2.1.1);
FIF_j	=	Generic fire ignition frequency for area j (from Table 2.1.2 or 2.1.3);
SF_j	=	Bounding severity factor for area j (from Step 2.1.4);
NSP_j	=	Bounding non-suppression probability for area j (from Step 2.1.5);
$CCDP_j$	=	Bounding conditional core damage probability for area j (from Step 2.1.6).

Use the Risk Quantification Worksheet, Worksheet 2.1.8 in Attachment 1, to calculate the ΔCDF according to Equation 3. For findings in the “Fire Confinement” category, complete a separate table for each area affected, and calculate the total ΔCDF as the sum of the ΔCDF values for each table.

It is very unlikely that ΔCDF for an area, let alone multiple areas, will be below 1E-6. However, the bounding ΔCDF estimate provides an initial indication of the likelihood that the finding can ultimately be screened to Green and helps identify the factor(s) the analysis should focus on to reduce the ΔCDF below the 1E-6 threshold.

Step 2.2 - Identifying Credible Fire Scenarios and Information Gathering

This step defines discrete stages of fire growth and damage, referred to as FDS, and identifies credible fire scenarios that may need to be considered in the Phase 2 assessment. The step also collects detailed information about the ignition sources, secondary combustibles, targets sets, etc., involved in these scenarios.

Step 2.2.1: Initial FDS Assignment

The FDS is 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. FDS0 is not analyzed in the FP SDP as a risk contributor even if the ignition source is also a target, such as an electrical enclosure that will yield a non-zero CCDP by itself (in this case the FDS0 scenario will contribute to the baseline risk regardless of the finding).

FDS1: Fire damage occurs to components or cables protected by a degraded local fire barrier system (e.g., a degraded cable tray fire barrier wrap), or to unprotected components or cables located near the fire ignition source. This damage state also includes ignition of secondary combustibles (cable trays) near the fire ignition source.

FDS2: Widespread fire damage occurs to unprotected components or cables within the fire area of fire origin, to components or cables protected by a degraded local fire barrier system, or to unprotected components or cables due the development of a damaging hot gas layer (HGL).

FDS3: Fire damage extends to a fire area adjacent to the fire area of fire origin, in general, due to postulated fire spread through a degraded inter-area fire barrier element (e.g., wall, ceiling, floor, damper, door, penetration seal, etc.).

The FDS/Finding Category Matrix in Table 2.2.1 below identifies, given the finding category assigned in Step 1.2, which FDSs have the potential of contributing to the ∆CDF and need to be considered in the analysis. The table indicates, for example, that for a finding in the Fire Confinement Category only fires that spread through the degraded barrier to an adjacent compartment have the potential of increasing the CDF over the baseline since FDS1 and FDS2 scenarios are not affected by the finding.

Table 2.2.1 – FDS/Finding Category Matrix

Finding Type or Category:	FDS1	FDS2	FDS3
Fire Prevention and Administrative Controls	Retain	Retain	N/A
Fixed Fire Protection Systems	Retain	Retain	N/A
Fire Confinement	N/A	N/A	Retain
Localized Cable or Component Protection	Retain	Retain	N/A
Post-fire SSD	Retain	Retain	N/A

Step 2.2.2: Information Gathering

The objective of this step is to collect the information needed to perform a fire growth and damage analysis for each credible fire scenario. A scenario is uniquely defined by the ignition source that starts the fire and the extent of the damage caused by the fire (the FDS). Guidance for identifying fire scenarios and for obtaining the necessary information from walkdowns, plan and document reviews, etc., is provided in Attachment 3. Note that for a licensee with a fire PRA, this information should be readily available in the fire PRA documentation. Several worksheets are provided in Attachment 1 to facilitate the data collection process:

- Worksheet 2.2.2a in Attachment 1: This worksheet is used to record general information about the fire area under evaluation. The information in this worksheet includes the dimensions of the compartment and FDS2 target type (for HGL calculations), and a list of relevant ignition sources in the area under evaluation. The latter does not necessarily include all ignition sources in the area, since only those sources that have the potential of starting a fire that causes damage and contributes to the ΔCDF need to be considered. Since no analysis has been performed at this point, it is usually not trivial to determine which sources can be omitted. If the finding is in the “Fire Confinement” category, Worksheet 2.2.2a must be completed for each compartment affected by the finding, typically the two compartments on either side of the degraded barrier.
- Worksheet 2.2.2b in Attachment 1: This worksheet is used to record detailed information about a fixed ignition source or an oil fire, and all targets that are expected to be within its zone of influence (ZOI). A separate form is used for each ignition source.
- Worksheet 2.2.2c in Attachment 1: This worksheet is similar to Worksheet 2.2.2b in Attachment 1 but is used for transient combustibles.
- Worksheet 2.2.2d in Attachment 1: This worksheet contains information about secondary combustibles and details needed for the detection and suppression analysis.

Since most fire scenarios involve a fixed or a transient ignition source, the analyst may find it useful to consult the ZOI tables for these ignition sources during walkdowns. The vertical and radial ZOI for fixed and transient ignition sources are tabulated as a function of the 98th percentile HRR of the ignition source in Attachment 8 (Tables A.01 and A.02). In these tables, the vertical ZOI is provided for ignition sources that are at least 2 ft. from the nearest wall (referred to as “free-burn” or “open” fires) and ignition sources that are within 2 ft. of both intersecting walls of a corner (referred to as “corner” fires).

The 98th percentile HRR and HRR profile parameters of fixed and transient ignition sources can be found in Attachment 5, Tables A5.1-A5.4. Whether an electrical enclosure is considered “open” or “closed” for determining its HRR is based on the criteria developed in NUREG-2178, Vol. 1. A discussion of these criteria can be found on page 3 of Attachment 3.

The 98th percentile HRR and corresponding ZOIs for various fixed and transient ignition sources provided in Tables A.01 and A.02 in Attachment 8 are duplicated in Tables 2.2.2 and 2.2.3 below for the analyst’s convenience.

Table 2.2.2 – 98th Percentile HRR and ZOIs for Electrical Enclosures									
Electrical Enclosures		98% HRR (kW)	Vertical ZOI (ft.)				Radial ZOI (ft.)		
			Open Fire		Corner Fire				
			TP*	TS†	TP*	TS†	TP*	TS†	SE‡
Group 1 Switchgear & Load Centers	Closed	170	6.48	5.24	10.93	8.72	1.65	0.79	3.43
Group 2 MCCs & Battery Chargers	Closed	130	5.82	4.70	9.81	7.82	1.40	0.65	2.96
Group 3 Power Inverters	Closed	200	6.92	5.59	11.66	9.30	1.81	0.89	3.74
Group 4a Large [>50 ft³]	Closed	400	9.13	7.38	15.39	12.28	2.71	1.43	5.42
	Open	1000	13.17	10.65	22.20	17.71	4.55	2.58	8.81
Group 4b Medium [≤50 ft³ and >12 ft³]	Closed	200	6.92	5.59	11.66	9.30	1.81	0.89	3.74
	Open	325	8.40	6.79	14.16	11.30	2.40	1.24	4.85
Group 4c Small [≤12 ft³]	All	45	3.81	3.08	6.43	5.12	0.73	0.28	1.66

* thermoplastic cable, † thermoset cable, ‡ sensitive electronics

Table 2.2.3 – 98th Percentile HRR and ZOIs for Other Ignition Sources								
Other Ignition Sources	98% HRR (kW)	Vertical ZOI (ft.)				Radial ZOI (ft.)		
		Open Fire		Corner Fire				
		TP	TS	TP	TS	TP	TS	SE
Class A Motors [>5 hp and ≤30 hp]	15	2.39	2.01	4.01	3.33	0.24	0.03	0.87
Class B Motors [>30 hp and ≤100 hp]	37	3.38	2.82	5.64	4.67	0.50	0.04	1.44
Class C Motors [>5 hp and ≤30 hp]	100	4.91	4.08	8.16	6.72	1.00	0.29	2.47
Class A Dry Transformers [>45 kVA and ≤75 kVA]	30	3.32	2.77	5.62	4.65	0.11	0.03	1.26
Class B Dry Transformers [>75 kVA and ≤750 kVA]	70	4.49	3.71	7.55	6.19	0.83	0.26	1.98
Class C Dry Transformers [>750 kVA]	130	5.43	4.43	9.02	7.28	1.23	0.53	2.76
Generic Transient Combustibles	278	5.81	4.87	9.62	7.85	1.23	0.45	4.39
Transient Combustible Control Locations (TCCLs)	143	4.40	2.64	7.19	4.58	0.76	0.22	3.08

Switchgear and load centers 440V and above are subject to HEAFs in addition to the possibility of a general or thermal fire. As a result, two ignition scenarios need to be considered for electrical enclosures ≥ 440 V; HEAF and non-HEAF. In addition, for HEAFs in switchgear, fire spread is postulated to switchgear vertical sections that are adjacent to where the HEAF initiated due to the potential for the arc to breach the shared boundary. Additional information for determining the HRR profile of fire spread to adjacent vertical sections if provided in Attachment 5.

For the HEAF scenario in switchgear (electrical enclosures > 1000 V), the vertical and radial ZOI are identical but depend on the fragility of the target. For thermoplastic cable targets, the

ZOI is within 4.5 ft. above the top of the enclosure, and within 4.5 ft. from the edge on all sides of the enclosure. For thermoset cable targets, the ZOI in the vertical and horizontal directions is reduced to 3.5 ft.

The ZOI for the HEAF scenario in load centers (electrical enclosures ≥ 440 V and ≤ 1000 V) is provided in Attachment 3, Table A3.1 as a function of the location of the supply circuit breaker at which the HEAF is postulated and the fragility of the target. All unprotected targets within the ZOI are assumed to be damaged instantaneously when the HEAF occurs and all unprotected secondary combustibles within this region are assumed to ignite instantaneously. The HRR profile for a HEAF fire has no t-squared growth stage. The HEAF fire reaches HRR_{peak} instantaneously at ignition (t = 0 seconds), remains at HRR_{peak} for 480 seconds, and subsequently decays linearly to 0 kW in 1140 seconds.

The ZOI and HRR profile for non-HEAF scenarios is determined in the same manner as for electrical enclosures < 440 V.

<u>Approach for Information Gathering when Targets of Concern Are Not Known</u>

For some findings (e.g., findings in the Fixed Fire Suppression Systems Category), the targets of concern are not known. In this case, it usually is more efficient to do the data gathering iteratively. For example, if a large number of ignition sources are present in the fire area under evaluation, often many will be screened out in Step 2.3. In this case, it would be more efficient to first collect the information that is needed to screen ignition sources, and to gather the remaining information after Step 2.3 has been completed. Specific guidance is provided below:

<u>Identify Ignition Sources</u>

Using Worksheet 2.2.2a in Attachment 1, develop a list of the ignition sources that are present in the area(s) being evaluated. Only ignition sources that have the potential of starting a fire that contributes to the ΔCDF need to be included.

In the specific case of findings categorized as "Fire Confinement" in Step 1.2, the fire ignition sources and associated nearest most vulnerable ignition targets must be identified on both sides of the degraded fire barrier. That is, the scope of Step 2.3 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).

To screen ignition sources that are not capable of releasing heat at a sufficient rate to create a damaging HGL it is necessary to record the floor area and the height of the compartment(s) being evaluated (i.e., compartment volume) on Worksheet 2.2.2a in Attachment 1.

Detailed guidance for the treatment and counting of fire ignition sources is provided in Attachment 4. Fire ignition sources are binned by type or general classifications that are pre-defined in Attachment 3 (HRR bins) and Attachment 4 (FIF bins). All fire ignition sources are assigned to one, and only one, of the identified fire ignition source type bins. Each fire ignition source bin has a corresponding fire scenario characterization bin or bins as identified in Attachment 4, Table A4.1. Cataloging of the fire ignition sources includes a count of the number of fire ignition sources of each type present.

The risk significance of a finding is determined by summing the ΔCDF for all credible fire scenarios in the area(s) being evaluated. However, some fire scenarios are not affected by the degraded conditions, and the corresponding ΔCDF values are equal to zero. Consequently, the ignition sources involved in these scenarios can be omitted from the list. For example, 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.

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). Evidence of transient combustible controls should be noted during information gathering. Additional information regarding acceptable transient combustible controls is provided in Attachment 5.

An ignition source is either considered to be in a corner or free-burning. The corner location is assumed for ignition sources that are within 2 ft. of two intersecting walls. Ignition sources that are not located in a corner are considered to be free-burning or in the open.

For most fire ignition sources, the fire frequency is provided on a per component basis. However, for thermoplastic cables, transients, and hot work, a likelihood rating assignment as low, medium, or high is required. The guidance for assigning these ratings is provided in Attachment 4.

Should a FPP degradation finding be encountered that is very specific to fires involving one or more specific fire ignition sources, then the Fire Protection SDP Phase 2 analysis should be focused on only those specific sources.

<u>Identify Nearest and Most Vulnerable Targets</u>

For each unique fire ignition source, identify the ignition and/or damage targets that will be:

- 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 by direct radiant heating,
- The most fragile thermal damage target in the general fire area (for damaging HGL exposure considerations),
- Secondary combustible materials (vertical stacks of horizontal cable trays) directly above the fire ignition source that might be ignited by the flame zone and/or plume.

Record each ignition and/or damage target and its distance from the appropriate fire ignition source on Worksheet 2.2.2b or 2.2.2c in Attachment 1. If a vertical stack of horizontal cable trays is located above an ignition source, record the number of trays, the width of the trays, and the dominant type of cables in the tray (thermoset, thermoplastic, or Kerite) on Worksheet 2.2.2d in Attachment 1.

Three different types of electrical damage targets are considered; thermoset cables, thermoplastic cables, and sensitive electronics. Only the first two are considered as ignition targets. Kerite cables are assumed to have the same damage thresholds as thermoplastic cables but behave as thermoset cables in terms of ignition and flame spread propensity. Detailed guidance for the identification of targets and their ignition and damage criteria is provided in Attachment 6.

With this approach, Worksheets 2.2.2b and/or 2.2.2c are only partially completed at this stage, i.e., only the nearest and most vulnerable targets are listed. After finishing Step 2.3, the analyst will need to complete Worksheets 2.2.2b, 2.2.2c, and 2.2.2d for the unscreened ignition sources, and add the required information for the other targets that are located within the ZOI of the ignition source.

Approach for Information Gathering when Targets of Concern Are Known

For other findings (e.g., findings in the Localized Cable and Component Protection Category), the targets of concern are known. In this case, the analyst first identifies the ignition sources that may cause damage to one of the known targets or may have the capability of igniting a secondary combustible. These are the ignition sources that are either directly below one of the known targets of concern, directly below a secondary combustible, or within a direct line of sight of a target or secondary combustible. Worksheets 2.2.2a, 2.2.2b, and 2.2.2c can be completed at this stage. For each ignition source that was identified, only one damage or ignition target will be listed on Worksheet 2.2.2a or 2.2.2b. Worksheet 2.2.2d can also be completed at this stage, or its completion can be deferred until after the ignition sources that do not screen in Step 2.3 are known.

Step 2.3 – Ignition Source Screening and Fire Scenario Refinement

Step 2.3.1: Characterize Fire Ignition Sources

For each unique fire ignition source identified in Step 2.2.2, a HRR profile and nominal location are assigned. The HRR profile and gamma distribution parameters for various fixed and transient ignition sources can be found in Attachment 5. These parameters were used to develop table and plot sets A, D, and E in Attachment 8, which allow the analyst to look up the vertical and radial ZOI (Step 2.3.2), SF (Step 2.6.1), and damage time (Step 2.7.1) for a specified ignition source and target type and location in FDS1 scenarios.

Two types of HRR profiles are considered for electrical enclosures ≥ 440 V: one for HEAF scenarios and another one for non-HEAF scenarios. In addition, for HEAFs in switchgear, fire spread is postulated to switchgear vertical sections that are adjacent to where the HEAF initiated due to the potential for the arc to breach the shared boundary. Additional guidance for identifying and characterizing HEAF scenarios using the guidance in NUREG-2262 is provided in Attachment 3. Additional guidance for characterizing the HRR profile of HEAFs is provided in Attachment 5. If the plant has not implemented the process in NUREG-2262, assistance from headquarter fire protection staff may be needed to determine the appropriate method to characterize HEAF scenarios.

A distinction is made between two types of transients. Generic transient fires are postulated throughout the plant except in transient combustible control locations (TCCL). Transient fires in TCCLs are assumed to have a lower HRR profile. Additional information regarding acceptable transient combustible controls is provided in Attachment 5.

Liquid fuel spills can be confined or unconfined. For confined liquid fuel pool fires the area is known. The HRRs for confined pool fires of common fuels as a function of pool diameter are tabulated in Attachment 5, Table A5.5. The HRRs of unconfined liquid fuel spill fires are tabulated for the same fuels as a function of spill volume in Attachment 5, Table A5.6. Confined liquid pool fires and unconfined liquid spill fires are assumed to grow at an infinitely fast rate, i.e., the tabulated HRR is reached without delay at ignition.

Two distinct oil spill fires may need to be considered. The first scenario assumes a spill of 100 percent of the amount of fuel or oil that can be spilled. The second scenario considers a 10 percent spill. A SF of 0.02 is assigned to the first scenario, and 0.98 is used for the second scenario. For confined liquid pool fires it is not necessary to evaluate the two scenarios separately if the containment is large enough to hold 100 percent of the amount of fuel or oil that can be spilled.

Guidance for characterizing the HRR profile of various fire ignition sources is provided in Attachment 5. Guidance for grouping and assigning locations to fire ignition sources is provided in Section 05.02.03 of the technical basis document, IMC 0308 Attachment 3 Appendix F.

Step 2.3.2: FDS1 Ignition Source Screening

Assess the damage/fire spread potential of each fire ignition source using the ZOI tables and plots (table/plot set A) in Attachment 8. Fire ignition sources will be screened out if they meet the following criteria:

1. The fire ignition source cannot cause damage to targets located near the ignition source, and
2. The fire ignition source cannot cause ignition of secondary combustible fuels.

The 98th percentile HRRs of fixed and transient ignition sources are given in Attachment 5, Table A5.1 and Table A5.3, respectively. The vertical and radial ZOI can be determined as a function of the 98th percentile HRR of the ignition source and its location from Tables A.01 and A.02 in Attachment 8. If the ignition source is within 2 ft. of the intersecting walls of a corner, the analyst must use the ZOI for corner fires. If the nearest and most vulnerable damage or ignition target is within the vertical or radial ZOI, the ignition source is capable of damaging and/or igniting the target and it does not screen. The approach is similar for confined liquid fuel pool fires and unconfined liquid fuel spill fires, except that the tables and plots in Figures A.02 - A.13 are used to determine the vertical and radial ZOI.

Use the FDS1 ignition source screening worksheet (Worksheet 2.3.2 in Attachment 1) to perform the FDS1 screening for each ignition source.

Step 2.3.3: FDS2 Ignition Source Screening

Assess the capability of each fire ignition source to release heat at a sufficient rate to create a damaging HGL. The minimum HRR required for the development of a damaging HGL can be determined as a function of compartment floor area, ceiling height, and type of most vulnerable target using the HGL tables and plots (table/plot set B) in Attachment 8.

Use the FDS2 ignition source screening worksheet (Worksheet 2.3.3 in Attachment 1) to perform the FDS2 screening for each ignition source.

Step 2.3.4: FDS3 Ignition Source Screening

For findings in the Fire Confinement Category, Worksheet 2.3.3 in Attachment 1 is also used to screen ignition sources that, possibly in combination with secondary combustibles, are not capable of causing the development of a damaging HGL in the exposed compartment. In this case the two compartments separated by the degraded barrier are combined into one. The floor area of the combined compartment is the sum of the floor areas of the two compartments. The ceiling height is the lower of the ceiling heights in the two compartments. The target type is that in the exposed compartment, i.e., not the compartment where the fire is postulated.

Step 2.3.5: Screening Check

This screening check considers whether or not one or more potentially challenging fire scenarios have 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:

- For findings in the "Fire Confinement" category, if all identified ignition sources on both sides of the degraded barrier screen out in Step 2.3.3, 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 significance determination rating. Subsequent analysis steps need not be completed.
- For findings in other categories, if all identified fire ignition sources screen out in Steps 2.3.2 and 2.3.3, 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 significance determination rating. Subsequent analysis steps need not be completed.
- If one or more fire damage states are retained for any of the ignition sources, then the analysis continues to Steps 2.4 through 2.7, not necessarily sequentially (although they are discussed in sequence for convenience). For findings that are not categorized as "Fire Confinement", include the unscreened ignition source-FDS combinations from Steps 2.3.2 and 2.3.3 in Worksheet 2.1.8 in Attachment 1, starting at row 2. For findings that are categorized as "Fire Confinement", only include the unscreened ignition source-FDS3 combinations from Step 2.3.4.

Step 2.4 – Final FIF Estimates

In Step 2.1, a bounding area-wide FIF was used in the risk calculation. In this step, the fire frequency for each unscreened fire ignition source scenario is refined by multiplying the individual fire frequencies for each type of ignition source by the number of ignition sources in the scenario. The fire frequency for each unscreened fire ignition source is then further refined to reflect adjustments to findings within certain fire prevention and other administrative controls programs, and to take credit for compensatory measures, if appropriate.

Step 2.4.1: Nominal Fire Frequency Estimation

A frequency for each fire ignition source bin on a per component basis has been developed and is provided in Attachment 4. Using the screening results obtained in Step 2.3, record for each fire source, the number of sources retained and the fire frequency per counting unit for each unscreened fire ignition source bin in the Risk Quantification Worksheet (Worksheet 2.1.8 in Attachment 1).

Step 2.4.2: Findings Based on Increase in Fire Frequency

The fire frequency increase is only applicable to certain types of fire ignition sources; namely, hot work fires and transients:

- If the finding category assigned is anything other than "Fire Prevention and Administrative Controls," no adjustment of the nominal fire frequencies is applied. The analysis continues with Step 2.4.4.
- Within the general category of "Fire Prevention and Administrative Controls" findings, only the inspection findings associated with any of the following fire protection DID elements will result in an increase in fire frequency:

- Combustible controls programs,
    - For a fire area nominally ranked as a low or medium likelihood for transient fires, the likelihood rating will be raised by one level of likelihood (i.e., a low likelihood area becomes a moderate area, and a moderate likelihood area becomes a high area) and the fire frequency is adjusted according to the revised likelihood fire frequency value.
    - For a fire area already ranked as a high likelihood area for transient fires, the high likelihood transient fire frequency is multiplied by a factor of 3.
- Hot work permitting and/or hot work fire watch provisions of the FPP,
    - The fire area hot work fire likelihood is set to high, and the hot work fire frequency for high likelihood is multiplied by a factor of 3.

- If a finding within the general category of "Fire Prevention and Administrative Controls" is not against any of the fire protection DID elements listed above, then no adjustment of the fire frequency is applied. The analysis continues with Step 2.4.3.

Record the appropriate changes to likelihood frequencies and AFs in Worksheet 2.1.8 in Attachment 1. Criteria for assigning transient or hot work likelihood ratings are discussed in Attachment 4. The fire ignition frequencies for transient and hot work fires with a low, medium, or high likelihood rating are provided in Attachment 4, Table A4.1.

Step 2.4.3: Adjustment Factors for Compensatory Measures

If any of the following compensatory measures are in place and credited with reducing the frequency of transient fuel or hot work fires for the fire area under analysis, the following adjustments can be made for the appropriate fire ignition source scenarios:

- For transient combustible fire frequency:
    - If a 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 during the exposure period, the low likelihood rating FIF for transient fires from Table A4.1 in Attachment 4 and the TCCL HRR profile discussed in Attachment 5 may be used in the analysis of the transient fire scenario.
- For hot work fire frequency:
    - If hot work is improbable in the fire area and a thorough review of hot work permits issued verified no hot work was performed in the fire area under review during the exposure period, the hot work fire frequency can be set to zero by applying an AF = 0.0 for the hot work fire ignition source scenarios.

Record the appropriate FIF(s) and/or AF(s) in Worksheet 2.1.8 in Attachment 1. If none of the above listed compensatory measures are active for the fire area under analysis, no adjustment to the fire frequency is needed.

Step 2.4.4: Critical Area Adjustment Factors

For each transient and hot work fire scenario, a critical area AF is applied to reflect the likelihood that the fire will occur in a specific location that causes (or has the potential of causing) damage to a target versus all the other plausible locations in the fire area under evaluation. The transient or hot work FIF for the fire area is multiplied by the critical area AF to estimate the fire scenario FIF. That is, the AF reduces the transient or hot work FIF for the entire fire area to that for the specific fire scenario.

Transient Fire Critical Area Adjustment Factor

Calculate the transient fire critical area AF for each transient fire scenario by dividing the "critical" floor area for the scenario by the "plausible" area and record the resulting $AF_{transients}$ value for the scenario in Worksheet 2.1.8 in Attachment 1. The plausible area is the total floor space within the fire area where temporary or permanent storage of transient fuel material is considered plausible. The critical floor area for the specified scenario is a subset of the plausible floor area and is equal to the total floor area where ignition or damage is possible. Additional guidance for determining the critical and plausible floor areas is provided in Attachment 3.

Each transient fire scenario should be assigned its own critical area AF. When summed, the AFs for all transient fire scenarios should not add to more than 1.0. In most cases the sum will be less than 1.0.

Hot Work Fire Critical Area Adjustment Factor

Determine if there is a designated location or locations within the fire area where hot work activities are performed, or where hot work will be undertaken in the vast majority of cases. If such a location exists, then hot work fires should generally be postulated to occur in this location (e.g., within reach of sparks from the hot work).

If hot work activities appear equally likely in several locations, use an approach similar to that discussed for transient fires. That is, identify the locations where it is "plausible" that hot work may occur and "critical" locations where hot work could initiate a fire. Calculate the hot work fire critical area adjustment factor each hot work fire scenario by dividing the "critical" floor area for the scenario by the "plausible" area and record the resulting $AF_{hot\ work}$ value for the scenario in Worksheet 2.1.8 in Attachment 1. Hot work is generally assumed to ignite transient combustibles, exposed cables, or insulation materials. Additional guidance for determining the critical and plausible floor areas is provided in Attachment 3.

Each hot work fire scenario should be assigned its own critical area AF. If multiple hot work fire scenarios are developed, each scenario is assigned a corresponding fraction of the total fire frequency (e.g., if three scenarios are developed, each scenario is multiplied by a factor of 1/3). When summed, the AFs for all hot work fire scenarios should not add to more than 1.0. In most cases the sum will be less than 1.0.

Step 2.4.5: Screening Check

Sum the revised fire frequencies over all identified fire ignition source scenarios to generate an updated estimate of the fire frequency for the fire area(s) under review. If the sum is less than 7E-6, use this value as an estimate of the fire frequency for the area(s) under evaluation.

Recalculate ΔCDF from Equation 1 using the updated estimate(s) of the fire frequency for the fire area(s) under review, and the most recent values for the remaining factors. Record the adjusted ΔCDF value in Worksheet 2.1.8 in Attachment 1.

If the recalculated value of ΔCDF is lower than 1E-6, then the finding screens to Green, and the analysis is complete.

If the recalculated value of ΔCDF exceeds 1E-6, then the analysis continues to another step in the Phase 2 analysis or to Phase 3 if all Phase 2 steps have been completed.

Step 2.5 – Final CCDP Estimates

This step refines the bounding CCDP value that was calculated in Step 2.1.6. Once all the credible fire scenarios have been developed, an SRA can calculate a scenario-specific CCDP based on the equipment affected by the fire. Step 2.5 starts with refining the damaged target sets for the retained FDS1, FDS2, and FDS3 scenarios. Guidance for the identification of targets and their damage and ignition criteria is provided in Attachment 6. Once the damaged target set is known for each scenario, the corresponding CCDPs can be determined by an SRA from the SPAR models. The step concludes with a screening check, which involves recalculating ΔCDF based on the updated CCDPs.

Step 2.5.1: Determine Damaged Target Set and CCDP for FDS1 Scenarios

Skip to Step 2.5.2 if the finding is in the Fire Confinement Category.

Determine the damaged target set for each FDS1 scenario that is retained in the final FDS/ignition source matrix developed in Step 2.3. The set consists of all targets that are within the vertical and radial ZOI. The ZOI tables and plots in Attachment 8 (table/plot set A) are used in conjunction with information about the location of damage targets near the ignition source to identify the damaged targets. Target locations may have been obtained as part of Step 2.2.2, but quite often require an additional walkdown and/or plan review. The FDS1 damaged target set is recorded for each ignition source on Worksheet 2.2.2.b or 2.2.2c in Attachment 1.

Step 2.5.2: Determine Damaged Target Set and CCDP for FDS2 Scenarios

First determine for each FDS2 scenario whether the HRR is sufficient for the generation of a damaging HGL. Two possibilities may need to be considered:

1. The ignition source releases heat at a sufficient rate to generate a damaging HGL.
2. The ignition source is capable of igniting secondary combustibles, and the combined HRR of the ignition source and the secondary combustible exceeds the threshold.

The first case is likely to have been examined in Step 2.3.3. It is unlikely that the HRR of a fixed or transient ignition source alone would exceed the threshold for HGL development. However, the HRR of oil fires can easily lead to the development of a damaging HGL. In addition, it is possible that under unusual circumstances (typically an ignition source fire in a very small compartment and a cable target close to the ceiling) the ignition source may screen for the FDS1 scenario but not for the FDS2 scenario. This anomaly is the result of the fact that the heat soak method is used to determine the vertical ZOI of cable targets, while the minimum HRR required for the development of a damaging HGL is determined based on the assumption of instantaneous damage when the HGL temperature reaches the damage threshold. In this unusual situation, it is permissible to screen the ignition source for the FDS2 scenario.

The second case is more common and requires additional analysis. The screening first involves estimating the minimum HRR required for the development of a damaging HGL from the tables and plots (table/plot set B) in Attachment 8 based on the floor area and ceiling height of the compartment, and the type of damage targets in the compartment. The HRR profile for the ignition source in combination with the applicable cable tray configuration from table/plot set C is then used to determine if and when the minimum HRR is exceeded. Worksheet 2.3.3 in Attachment 1 can be used to facilitate the FDS2 screening process.

If the analysis shows that a damaging HGL can develop, the FDS2 scenario is retained and all targets in the compartment are included in the damage set, except those that are damaged in the FDS1 scenario for the same ignition source. Unless the finding is in the Fire Confinement Category, the HGL scenario is added to Worksheet 2.1.8 in Attachment 1.

Step 2.5.3: Determine Damaged Target Set and CCDP for FDS3 Scenarios

FDS3 is only possible if FDS2 is reached in the exposing compartment. FDS3 is only considered if the barrier is degraded. In this case fires usually need to be postulated on either side of the barrier. The approach to determine whether a HGL can develop in a compartment due to a severe fire in an adjacent compartment is similar to that in Step 2.5.2. The two compartments are combined into one and the minimum HRR for the creation of a damaging HGL is determined from table/plot set B in Attachment 8 based on the total floor area of the two compartments and a representative ceiling height (typically the lower of the two compartments). Worksheet 2.3.3 in Attachment 1 can be used to facilitate the FDS3 screening process.

If a fire involving secondary combustibles in the exposing room is found to cause damaging HGL conditions in the adjacent room, the FDS3 scenario is retained and the targets in the exposed room are included in the damaged target set. The multi-compartment is added to Worksheet 2.1.8 in Attachment 1.

Step 2.5.4: Screening Check

Recalculate ΔCDF from Equation 1 using the updated estimates of the CCDPs obtained from an SRA for the retained fire scenarios in the fire area(s) under review, and the most recent values for the remaining factors. Record the adjusted ΔCDF value in the Worksheet 2.1.8 in Attachment 1.

If the recalculated value of ΔCDF is lower than 1E-6, then the finding screens to Green, and the analysis is complete.

If the recalculated value of ΔCDF exceeds 1E-6, then the analysis continues to another step in the Phase 2 analysis or to Phase 3 if all Phase 2 steps have been completed.

Step 2.6 – Final Fire SF Estimates

This step estimates the fire SF for all unscreened ignition sources identified in Step 2.3.2.

Step 2.6.1: Determine SFs

Estimate the SF for each unscreened fixed or transient ignition source from table/plot sets D and E in Attachment 8. If the nearest and most vulnerable target has a low CCDP, the analyst may choose to determine the SF based on a more risk-significant target in the target set. Worksheet 2.6.1 in Attachment 1 can be used to facilitate the SF determination process. Enter the results on the Worksheet 2.1.8 in Attachment 1. If the finding is in the Fire Confinement Category, the SF only applies to FDS3 scenarios initiated by the ignition source. For findings in another category, the SF applies to FDS1 and FDS2 scenarios.

Each table and plot in set D provides the elevations corresponding to SFs ranging from 0.02 to 0.75 for one of the fixed or transient ignition sources listed in Attachment 5, located either in the open or in a corner. Table/plot set D is used to conservatively estimate the SF for each target or secondary combustible located within the vertical ZOI based on its elevation above the ignition source.

Each table and plot in set E provides the radial distances corresponding to SFs ranging from 0.02 to 0.75 for one of the ignition sources listed in Attachment 5, Tables A5.1 and A5.3. Table/plot set E is used to conservatively estimate the SF for each target or secondary combustible located within the radial ZOI based on its distance from the ignition source.

The SF for HEAFs is equal to 1.0. Two scenarios are considered for liquid fuel spill fires. The first scenario assumes a spill of 100 percent of the amount of fuel or oil that can be spilled, and the second scenario assumes a 10 percent spill. An SF of 0.02 is assigned to the first scenario, and 0.98 is used for the second scenario.

Step 2.6.2: Screening Check

Recalculate ΔCDF from Equation 1 using the updated estimates of the SFs for the retained fire scenarios in the fire area(s) under review, and the most recent values for the remaining factors. Record the adjusted ΔCDF value in Worksheet 2.1.8 in Attachment 1.

If the recalculated value of ΔCDF is lower than 1E-6, then the finding screens to Green, and the analysis is complete.

If the recalculated value of ΔCDF is equal to or exceeds 1E-6, then the analysis continues to another step in the Phase 2 analysis or to Phase 3 if all Phase 2 steps have been completed.

Step 2.7 – Final NSP Estimates

In Step 2.7, the NSP for each fire growth and damage scenario of interest (NSP_i) is quantified. Detailed guidance on this step is provided in Attachment 7. All detection/suppression times will be recorded to the nearest whole minute rounded up. The results of the detection and suppression analysis and the final NSP determination are recorded in the NSP worksheet (Worksheet 2.7) in Attachment 1.

Step 2.7.1: Determine Damage and Ignition Times

For FDS1 scenarios, use table/plot set D in Attachment 8 to conservatively estimate the damage time of the nearest and most vulnerable damage and/or ignition target located within the vertical ZOI based on its elevation above the fixed or transient ignition source. In addition, use table/plot set E in Attachment 8 to conservatively estimate the damage or ignition time of the nearest and most vulnerable target within the radial ZOI based on its radial distance from the fixed or transient ignition source.

For FDS2 and FDS3 scenarios determine the damage time as the time when the combined HRR of the fixed or transient ignition source and cable trays as secondary combustibles (from table/plot set C) reaches the minimum HRR required for the creation of a damaging HGL in the compartment(s) under evaluation. The minimum HRR to create a damaging HGL is determined as a function of compartment floor area, ceiling height, and type of the most fragile thermal damage target in the area(s) under evaluation. The damage time is then determined from the tables and plots in set C in Attachment 8 for the applicable combination of fixed or transient ignition source and cable tray configuration. The same process is used to determine whether a confined or unconfined liquid spill fire can lead to the development of a damaging HGL. In this case the HRR of the fire is determined from Figures A.02, A.03 or A.04 in Attachment 8 for confined spill fires and from Figures A.08, A.09 or A.10 in Attachment 8 for unconfined spill fires.

The damage time for HEAFs and oil fires is assumed to be 0 and 1 minute, respectively.

Step 2.7.2: Fire Detection

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

- Prompt detection by a posted and continuous fire watch ($t_{detection}$ = $t_{ignition}$ = 0, if general rules in Attachment 7 are met)
- Detection by a roving fire watch (½ the duration of the roving patrol)
- Detection by fixed fire detection systems
- Detection by general plant personnel ($t_{detection}$ = 5 minutes if fire area is continuously manned; otherwise $t_{detection}$ is estimated by the analyst absent detection by other means)

Estimate the time to fire detection by using the guidance in Attachment 7. Only one of the above means of detection needs to succeed in order for the fire to be detected. The first and/or most likely mechanism of detection is generally credited.

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. As explained in Attachment 7, fire detection response time is estimated for the fixed and transient ignition sources listed in Attachment 5, Tables A5.1 and A5.3 as a function of the severity factor, ceiling height and radial distance between the source and the detector from Figures F.03-F.30 in Attachment 8. Convert this value to minutes, rounding up to the nearest minute. The tables may indicate that time to detection is infinite (i.e., the system will not actuate). In this case, the time to detection is determined by the other means of fire detection available including detection by plant personnel.

Step 2.7.3: Fixed Fire Suppression Analysis

Assess the performance and actuation timing of fixed fire suppression systems and any findings against a fixed fire suppression system.

NOTE: If the fire area under analysis is not equipped with a fixed fire suppression system or the fixed fire suppression system has been found to be highly degraded, skip Step 2.7.3 and continue the analysis with Step 2.7.4.

Both automatically and manually actuated fixed fire suppression systems will be considered in this step. Two key factors to the fixed suppression assessment are:

- 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.

There are a number of time delays that may apply to gaseous systems, deluge, pre-action sprinklers, or dry-pipe water systems. The time to actual discharge is the sum of the time to actuate the demand signal plus any applicable discharge timing delays. There may also 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 are 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). Additional guidance is provided in Attachment 7.

Activation Time for Sprinkler Systems

As explained in Attachment 7, sprinkler activation time is estimated for the fixed and transient ignition sources listed in Attachment 5, Tables A5.1 and A5.3, respectively, as a function of the severity factor, ceiling height and radial distance between the source and the sprinkler from Figures F.31 - F.61 in Attachment 8. Convert this value to minutes, rounding up to the nearest minute. The table may indicate that time to detection is infinite (i.e., the system will not activate). In this case, no credit is given to the fixed fire suppression system.

If the finding being evaluated involves a moderate degradation to the sprinkler system, credit is given to the system consistent with the as-found condition. The finding may be reflected either as a reduction in general reliability, or through a delayed actuation time. The treatment depends on the nature of the finding as follows:

- If the finding is associated with improper spacing of discharge heads, the actuation timing analysis should reflect the as-found spacing conditions.
- A moderate degradation may involve less than 25 percent of the heads in a water-based fire suppression system being non-functional. In this case, analyze discharge timing assuming that the head nearest the fire source will not function. Assume that the second closest fire discharge nozzle will function. Use the location of this second closest discharge nozzle in estimating response time.
- A moderate degradation finding may imply that the fire suppression system does not provide adequate coverage for some specific subset of the fire ignition sources present. In this case the fire suppression system is not credited in the analysis of FDS1 fire scenarios involving those specific fire ignition sources. The system is credited in the analysis of corresponding FDS2 and FDS3 scenarios and performance is analyzed consistent with the as-found conditions.

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.

Step 2.7.4: Plant Personnel and Manual Fire Brigade

Evaluate the timing associated with manual fire suppression. The manual firefighting response time is based on the application of historical evidence from past fire events. Based on this historical evidence, NSP curve values have been pre-calculated for a number of cases. Select the most representative case from the pre-analyzed set based on the fire type or location. If none of these specific condition curves provide a reasonable match to the conditions of the fire scenario, the "all events" curve should be applied. The mean NSP probability curves for each of the following fire types/locations are provided in Attachment 7.

1. Turbine Generator Fires
2. HEAFs
3. Outdoor Transformer Fires
4. Flammable Gas Fires
5. Oil Fires
6. Electrical Fires
7. Transient Fires
8. PWR Containment (At-Power) Fires
9. Containment (Low Power/Shutdown) Fires
10. Welding Fires
11. Control Room Fires
12. Cable Fires
13. All Events

For each unscreened fire scenario, subtract the fire detection time determined in Step 2.7.2 from the fire damage time determined in Step 2.7.1.

- If the fire detection time subtracted from the fire damage time is zero or negative, then the manual probability of non-suppression (NSP_{manual}) equals 1.0.
- If the fire detection time subtracted from the fire damage time is positive, obtain NSP_{manual} from the tabulated or graphical non-suppression curves as explained in Attachment 7.

Step 2.7.5: Determine Non-Suppression Probabilities

Using the results of the completed Steps 2.7.1 through 2.7.4, estimate the likelihood that fire suppression efforts fail to suppress the fire before the FDS is reached. NSP is assessed on a scenario-specific basis.

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

- For cases where fixed fire suppression systems are not being credited, NSP 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 combined with the response of the manual fire brigade.

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

If the fire area is protected by fixed fire suppression, estimate NSP_{fixed} for each surviving scenario ($NSP_{fixed\text{-}scenario}$) for which the fire suppression system is deemed effective. A look-up table is provided in Attachment 7, and an $NSP_{fixed\text{-}scenario}$ is assigned based on the difference between the predicted time to fire damage (from Step 2.7.1) and the predicted time to suppression system actuation (from Step 2.7.3).

Calculate an estimate of $NSP_{fixed\text{-}scenario}$ for each unscreened fire scenario based on the scenario-specific fire damage and fire suppression times. Record NSP_{fixed} on Worksheet 2.7 in Attachment 1.

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

The value of NSP manual for a given scenario ($NSP_{manual\text{-}scenario}$) is dependent on three factors: the predicted time to fire damage (Step 2.7.1), the predicted time to fire detection (Step 2.7.2), and the selected fire duration curve (Step 2.7.4). Record NSP_{manual} on Worksheet 2.7 in Attachment 1.

Composite Suppression Factor: $NSP_{scenario}$

If the fire area is not covered by fixed fire suppression, or is highly degraded, or is determined to be ineffective for the fire ignition source, then:

$$\mathrm{NSP_{scenario}} = \mathrm{NSP_{manual-scenario}} \quad [4]$$

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

$$\mathrm{NSP_{scenario}} = (0.02 + 0.98 \times \mathrm{NSP_{fixed-scenario}}) \times \mathrm{NSP_{manual-scenario}} \quad [5]$$

If the fire area is covered by a non-degraded CO_2 suppression system, a general reliability of 0.96 is assumed for the fixed suppression system. In this case, the NSP is quantified as follows:

$$\mathrm{NSP_{scenario}} = (0.04 + 0.96 \times \mathrm{NSP_{fixed-scenario}}) \times \mathrm{NSP_{manual-scenario}} \quad [6]$$

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

$$\mathrm{NSP_{scenario}} = (0.05 + 0.95 \times \mathrm{NSP_{fixed-scenario}}) \times \mathrm{NSP_{manual-scenario}} \quad [7]$$

One specific type of degradation that may be identified for gaseous fire extinguishment systems involves the inability of the system to maintain the design concentration of fire suppressant for a sufficient time to assure the complete extinguishment of a deep-seated fire. The required suppressant concentration and maintenance time are established by the system design criteria. This degradation is commonly referred to as an “inadequate soak time.” This can be an issue for Halon and Carbon Dioxide fire extinguishment systems, as well as for other gaseous suppression systems (e.g., Halon replacements).

For the inadequate soak time degradation case, special consideration is required to estimate $NSP_{scenario}$. See Attachment 7 for guidance on calculating $NSP_{scenario}$ involving gaseous fire extinguishment systems that are unable to maintain the design concentration of fire suppressant for a sufficient time to assure the complete extinguishment of a deep-seated fire.

Step 2.7.6: Screening Check

Recalculate ΔCDF from Equation 1 using the updated estimates of the NSPs for the retained fire scenarios in the fire area(s) under review, and the most recent values for the remaining factors. Record the adjusted ΔCDF value in the Worksheet 2.1.8 in Attachment 1.

If the recalculated value of ΔCDF is lower than 1E-6, then the finding screens to Green, and the analysis is complete.

If the recalculated value of ΔCDF exceeds 1E-6, then the analysis continues to another step in the Phase 2 analysis or to Phase 3 if all Phase 2 steps have been completed.

END

Attachment 1: Revision History for IMC 0609, Appendix F

Commitment Tracking Number	Accession Number Issue Date Change Notice	Description of Change	Description of Training Required and Completion Date	Comment Resolution and Closed Feedback Form Accession Number (Pre-Decisional, Non-Public)
N/A	ML23318A434 04/21/2000 CN 00-007	Initial Issue	None	N/A
	ML010750258 02/27/2001 CN 01-005	Revised to add additional guidance in defining fire scenarios, and to evaluate the impact on CDF.		
	ML041700310 05/28/2004 CN 04-016	Revised to introduce a new series of qualitative and quantitative analysis steps for risk informing and thereby estimating the risk significance of fire protection inspection issues. The Phase 1 screening process is enhanced to quickly determine the need for Phase 2 evaluation. The SDP is supported by 8 attachments and a comprehensive basis document.		
	ML050700212 02/28/2005 CN 05-007	Revised to correct typographical errors; change all references from 50th and 95th percentile to 75th and 98th percentile, respectively, for expected and high confidence fire intensity values; add additional applicable correlations from NUREG-1805.		

Commitment Tracking Number	Accession Number Issue Date Change Notice	Description of Change	Description of Training Required and Completion Date	Comment Resolution and Closed Feedback Form Accession Number (Pre-Decisional, Non-Public)
	ML13191B312 09/20/2013 CN 13-022	This update incorporates an expanded Phase 1. This was created in response to a large number of comments we received from the regional senior reactor analysts (SRAs) via the ROP feedback and the Risk Network initiative. Specific key improvements include: (a) inclusion of additional screening questions for each of the fire finding categories based on review of archived fire SDP items, fire data, and expertise that were not available at the previous release of Appendix F, (b) expansion of initial quantitative screening to include a non-suppression probability term, and (c) addition of an option to rely on licensees' fire PRA assessment of fire findings under appropriate oversight.	None	ML12249A185 ML13039A091

Commitment Tracking Number	Accession Number Issue Date Change Notice	Description of Change	Description of Training Required and Completion Date	Comment Resolution and Closed Feedback Form Accession Number (Pre-Decisional, Non-Public)
	ML17089A417 DRAFT CN 17-XXX	Major revision of the entire procedure, including all of the attachments, to update the analysis methods for consistency with the guidance in NUREG/CR-6850 and superseding guidance in NFPA 805 FAQs, NUREG-2169, NUREG-2178, and NUREG/CR-7010. Revisions to Phase 1 include: (a) revision of the screening questions based on inspector feedback, (b) re-ordering of the steps, (c) removal of the initial quantitative screening, (d) addition of main control room fire questions, and (e) removal of fire brigade screening questions. Revisions to Phase 2 include: (a) removal of need to use the Fire Dynamics Tools (FDTs) Spreadsheets, (b) addition of tables and plots for determining zone of influence, hot gas layer, heat release rates for fires involving cable trays, severity factor, damage times, and detector and sprinkler activation times in lieu of using the FDTs, (c) re-organization of the process, (d) removal of moderate degradation rating screening criteria, (e) removal of 75th percentile fire analysis, and (f) update of the ignition source heat release rates, fire ignition frequencies, and manual fire suppression curves. This update includes closure of ROP feedback forms 0609F-1714, 2114, and 0609F1-2168. CA Note sent 7/18/17 for information only, ML17191A681. Issued 10/11/17 as a draft publicly available document to allow for public comments.	November 2017	ML17093A190 0609F-965 ML16165A179 0609F-1343 ML16165A168 0609F-1714 ML18096A456 0609F-2114 ML18096A470 0609F1-2168 ML18096A597

Commitment Tracking Number	Accession Number Issue Date Change Notice	Description of Change	Description of Training Required and Completion Date	Comment Resolution and Closed Feedback Form Accession Number (Pre-Decisional, Non-Public)
	ML18087A414 05/02/18 CN 18-010	Re-issued with new accession number in order to issue as an official revision after receipt of public comments.	Gap training covering changes to the procedure completed November 2017	ML17093A190 0609F-965 0609F-1343 0609F-1714 0609F-2114 0609F1-2168
	ML24150A359 09/05/24 CN 24-024	This revision includes updating IMC 0609 Appendix F, its associated attachments, and the basis document to incorporate updated guidance for modeling transient fires per NUREG-2233, high energy arching faults per NUREG-2262, and electrical enclosure, electric motor, dry transformer and main control room fires per NUREG-2178 Volume 2. This revision also implements the heat soak method in the HRR and ZOI calculations. This revision includes closure of ROP feedback forms 0609F-2423 and 0609F-2462.		ML24155A254 0609F-2423 ML21335A423 0609F-2462 ML22188A115