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A Framework for Low Power/Shutdown Fire PRA

Final Report

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A Framework for Low Power/Shutdown Fire PRA

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ABSTRACT

This document presents a probabilistic risk assessment (PRA) framework for quantitatively analyzing fire risk in commercial nuclear power plants during low power and shutdown (LPSD) conditions, including the determination of core damage frequency (CDF) and large early release frequency (LERF). It is expected that future updates will be made to this document as experience is gained with LPSD quantitative risk analyses of both internal events and fires.

This LPSD fire PRA framework is intended to be used in combination with an at-power fire PRA performed using the method documented in Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research (RES) publication NUREG/CR-6850 and Electric Power Research Institute (EPRI) publication TR-1011989, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities." This LPSD fire PRA framework directly parallels that at-power fire PRA method with respect to the structure and objectives of its technical analysis tasks, addressing those aspects of the at-power fire PRA that require unique treatment in the context of low-power or shutdown conditions. This LPSD fire framework also requires a LPSD internal events PRA; that is, both the at-power fire PRA and the LPSD internal events PRA are needed as starting points for conducting a LPSD fire PRA using the framework described in this document.

The NRC developed this LPSD fire quantitative risk framework as a first step in providing analysts with the methods needed to support a quantitative approach for estimating fire risk during LPSD conditions. While current LPSD safety analyses for fires under National Fire Protection Association Standard 805 (NFPA 805) focus on qualitative, defense-in-depth methods, it is envisioned that applications in the future may evolve to be more quantitative. At present, this framework can provide an alternative for the analysis of LPSD fire risk in situations where qualitative methods are not appropriate, or where activities such as planning for an outage could benefit from risk reduction insights that could be gained from a quantitative analysis. It could also prove essential for the analysis of situations involving unusual, complex plant operating states (POSs). The framework has been exercised via a tabletop involving two volunteer power plants, but a full implementation of the methods described here has not yet been undertaken. The document also serves as a "gap analysis" highlighting areas of technical challenge that will likely be encountered in an actual implementation and identifying methodology development needs to fill out the framework into a full methodology.

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Methods for the application of Probabilistic Risk Assessment (PRA) to internal fire events during at-power operation of Nuclear Power Plants (NPPs) have evolved based on an extensive development process that began in the 1970s. Recently, existing fire PRA methods and evolutionary advances were consolidated through a collaborative effort between the U.S. Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research (RES) and the Electric Power Research Institute (EPRI). This work led to publication, in 2005, of the *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities* [1]. Even these most recent fire PRA methods continue to evolve based on their application by industry and on the communication of lessons learned to both industry and the NRC.

In contrast, fire PRAs for Low Power and Shutdown (LPSD) conditions have been conducted in only a few cases and all of the known analyses were based on methods and data that pre-date the RES/EPRI at-power fire PRA method. Methods for conducting such studies have not previously seen the same level of development as have the at-power methods and no comprehensive source for analysis guidance compatible with the current state-of-the art fire risk methods (e.g., [1]) is known to exist prior to this document. The LPSD fire PRA framework presented here is presented as an extension of, or supplement to, the RES/EPRI at-power fire PRA method. That is, the LPSD framework relies extensively on the extension of at-power analysis methods and results to LPSD conditions. As a result, documentation of the methodology as presented here focuses on those elements where the at-power methods should be adapted or extended to address LPSD conditions.

What is documented here is referred to as an analysis *framework*, rather than a *methodology*, because the approaches described do not yet represent a full, complete and tested set of analysis tools. This document establishes an overall structure for the LPSD fire PRA analysis, describes areas where existing methods can be applied directly, and outlines suggested approaches to areas of the analysis that present new and unique challenges. The document also serves as a "gap analysis" highlighting areas of technical challenge that will likely be encountered in an actual implementation. It also identifies areas of analysis challenge where more development work will be needed to fill out the framework into a full methodology. As with any new method, pilot applications are also recommended to help prove, and improve, the viability of both the overall process and specific analysis approaches. With the support of the Nuclear Energy Institute (NEI) and EPRI the framework was exercised via a tabletop exercise involving two volunteer power plants; namely, Seabrook Nuclear Power Plant and Peach Bottom Atomic Power Station. However, to date, no complete pilot applications have been undertaken.

LPSD plant operating states (POSs) potentially include a broad range of conditions for power, temperature and pressure levels. This framework assumes that LPSD PRA might nominally include plant operations at roughly the 30% power level and lower; hence, the LPSD conditions encompass a very broad spectrum of potential operating conditions. As explained in the body of this report, the distinction between at-power, low power, and shutdown plant operating states is an area where methodological approaches are evolving.

ACKNOWLEDGMENTS

The initial planning of this project was started in 2005 as the publication process for the joint RES/EPRI fire PRA methodology (NUREG/CR-6850, EPRI TR 1011989) was nearing completion. The next logical step was to extend fire risk methods to cover low power and shutdown conditions. Originally planned as a collaborative effort under the NRC/RES-EPRI Memorandum of Understanding (MOU) for Fire Research, much like the effort that produced the at-power consensus method, the project experienced repeated delays due to funding limitations and other research priorities. Efforts on the NRC portions of the project, which focused on primarily quantitative methods of analysis, began in earnest in 2008. The EPRI efforts, which were expected to focus on alternative qualitative or semi-quantitative approaches, were never initiated as a part of the joint MOU project. The first full version of this report was produced during the summer of 2009. A series of NRC staff reviews and one round of peer review comments by EPRI followed culminating in a draft for public comment issued in late 2011 (76 FR 81998). At the request of industry, the public comment period was extended into early 2012 and comments received were processed over the next few months. At the request of the Office of Nuclear Reactor Regulation (NRR), a public meeting to discuss those comments and responses was held at NRC RES Office in Rockville, MD on October 2012 (ML12310A418). During that public meeting, industry representatives suggested that a tabletop exercise be conducted in lieu of a full pilot application. The NRC agreed and a tabletop exercise was organized involving two volunteer plants, Seabrook and Peach Bottom. The tabletop exercise was conducted in March 2013 and this final version of the document incorporates the insights gained from that exercise.

The authors acknowledge the contributions of Dr. Mardy Kazarians of Kazarians and Associates to the development of this document. Mardy was a key contributor to the development of the initial drafts of this document. We also wish to thank Jeff Mitman of NRR for his support in developing this document. Jeff provided us with many background references relative to low power and shutdown risk analysis, the developing LPSD PRA standard, and plant operations. He supported us through the early development stages during a series of conversations on these subjects and during our tabletop exercise. In the same vein, we also thank Dr. Ray Gallucci of the NRR staff for his support during both the public comment period and the tabletop exercise. We also acknowledge Dr. Ron Boring of Idaho National Laboratory and Dr. Susan Cooper of the RES staff. Ron contributed to early drafts of the report in the area of human reliability analysis and Susan provided follow-up HRA support throughout the revision and publication process. We also acknowledge the contributions made by Ken Kiper, Rich Turcotte, Megan Woods, Hugh Hawkins and the staff at Seabrook Nuclear Power Station as well as Donald Vanovero, Kiang Zee (ERIN), Cliff Sinopoli, Josh Meisel and the staff at Peach Bottom Atomic Power Station who participated in the tabletop exercise and provided many substantial insights into the practical challenges associated with industries' efforts to implement and utilize PRA tools for LPSD plant operating modes. Rick Wachowiak of EPRI and Victoria Anderson of NEI were instrumental in setting up the tabletop exercise and recruiting the two volunteer plants, and for that support we are also grateful. We also offer our thanks to those individuals and organizations that commented on the draft report during the public comment period. These comments helped to improve the report and ultimately led to the tabletop exercise which also improved report quality. Finally, we gratefully acknowledge the support and patience of our original NRC technical monitor, Hugh 'Roy' Woods, and our more recent technical monitor, Felix Gonzalez, both of the NRC Office of Nuclear Regulatory Research.

ABBREVIATIONS AND ACRONYMS

ADAMS	Agency-wide Documents Access and Management System
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BWR	Boiling Water Reactor
CCDP	Conditional Core Damage Probability
CDF	Core Damage Frequency
CFR	Code of Federal Regulations
CLERP	Conditional Large Early Release Probability
dc	Direct current
EOP	Emergency Operating Procedure
EPRI	Electric Power Research Institute
FAQ	Frequently Asked Question
FEDB	Fire Events Database
FEP	Fire Emergency Procedure
HEAF	High Energy Arcing Fault
HEP	Human Error Probability
HFE	Human Failure Event
HRA	Human Reliability Analysis
HRR	Heat Release Rate
ICDP	Incremental Core Damage Probability
ID	Identifier
ILERP	Incremental Large Early Release Probability
IS	Ignition Source
LCO	Limiting Condition of Operation
LERF	Large Early Release Frequency
LOCA	Loss of Coolant Accident
LPSD	Low Power and Shutdown
MCB	Main Control Board
MCR	Main Control Room
MG	Motor-Generator
NEI	Nuclear Energy Institute
NFPA	National Fire Protection Association
NPP	Nuclear Power Plant
NRC	Nuclear Regulatory Commission
PAU	Physical Analysis Unit
POS	Plant Operating State
PRA	Probabilistic Risk Assessment
PWR	Pressurized Water Reactor
RCP	Reactor Coolant Pump
RES	The Office of Nuclear Regulatory Research (at NRC)
RG	Regulatory Guide
RISC	Risk Informed Standards Committee
RPS	Reactor Protection System
SRV	Safety Relief Valve
T/G	Turbine/Generator
ZOI	Zone of Influence

1 INTRODUCTION

1.1 Introduction and Purpose

Methods for the application of Probabilistic Risk Assessment (PRA) to internal fire events during at-power operation of Nuclear Power Plants (NPPs) have evolved based on an extensive development process that began in the 1970s. Recently, existing fire PRA methods and evolutionary advances were consolidated through a collaborative effort between the U.S. Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research (RES) and the Electric Power Research Institute (EPRI). This work led to publication, in 2005, of the *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities* [1] (referred to in this document more simply as either "the RES/EPRI at-power fire PRA method" or "reference [1]"). Even these most recent fire PRA methods continue to evolve based on their application by industry and on the communication of lessons learned to both industry and the NRC. Many of the currently operating U.S. NPPs are actively engaged in the conduct of fire PRAs driven, in part, by licensee decisions to transition to the alternative risk-informed, performance-based fire protection rules as embodied in National Fire Protection Association (NFPA) Standard 805 [2] and the Code of Federal Regulations (CFR) Section 10CFR50.48(c) [3].

In contrast, fire PRAs for Low Power and Shutdown (LPSD) conditions have been conducted in only a few cases and all of the known analyses were based on methods and data that pre-date the RES/EPRI at-power fire PRA method. Methods for conducting such studies have not previously seen the same level of development as have the at-power methods and no comprehensive source for analysis guidance compatible with the current state-of-the art fire risk methods (e.g., [1]) is known to exist prior to this document. The framework presented here is presented as an extension of, or supplement to, the RES/EPRI at-power fire PRA method [1]. That is, the LPSD framework relies extensively on the extension of at-power analysis methods to LPSD conditions. As a result, documentation of the framework as presented here focuses on those elements where the at-power methods should be adapted or extended to address LPSD conditions.

What is documented here is referred to as an analysis *framework*, rather than a *methodology*, because the approaches described do not yet represent a full, complete and tested set of analysis tools. This document establishes an overall structure for the LPSD fire PRA analysis, describes areas where existing methods can be applied directly, and outlines suggested approaches to areas of the analysis that present new and unique challenges. The document also serves as a "gap analysis" highlighting areas of technical challenge that will likely be encountered in an actual implementation. It also identifies areas of analysis challenge where more development work will be needed to fill out the framework into a full methodology. As with any new method, pilot applications are also recommended to help prove, and improve, the viability of both the overall process and specific analysis approaches. With the support of the Nuclear Energy Institute (NEI) and EPRI the framework was exercised via a tabletop exercise involving two volunteer power plants; namely, Seabrook Nuclear Power Plant and Peach Bottom Atomic Power Station. However, to date, no complete pilot applications have been undertaken.

1.2 Scope

LPSD plant operating states (POSs) potentially include a broad range of conditions for power, temperature and pressure levels. For reference, the draft *American National Standard Low Power and Shutdown PRA Methodology*[1] [4] defines key terms relevant to LPSD PRAs as follows:

(1) "Low Power - Power levels at which major secondary components are out of service as a plant shuts down or starts up. This is typically a transition mode to/from hot/cold shutdown. Designated as Startup in a boiling water reactor (BWR) when transitioning from cold shutdown to power operations."

(2) "Low power: a POS (or set of POSs) during which the reactor is at reduced power, below at-power conditions. In this POS, the power level may be changed as the reactor is shutting down or starting up. The power level that distinguishes full power and low power is the power level below which major plant evolutions are required to reduce or increase power (e.g., taking manual control of feedwater level)."

(3) "LPSD evolution: a series of connected or related activities, such as a reduction in power to a low level, or plant shutdown, followed by the return to at-power plant conditions. LPSD evolutions are modeled as a series of POSs. Outage types are a general type of a shutdown evolution, and a refueling outage is a specific example. Reducing power to 30% in order to conduct maintenance or an operational activity is another example of a low-power evolution. LPSD evolutions are characterized by a transition down to the POS where the activity is conducted, followed by a transition back to full power."

Note that even though these definitions all come from the same document, they are not entirely consistent. It is anticipated that the final revisions of the draft LPSD PRA standard will resolve the differences and settle on final definitions for these terms. Generally, the differences in phrasing are relatively minor and this framework adopts these definitions with the intent of maintaining consistency with this quality standard. Consistent with these excerpts and for general purposes, this framework nominally assumes that LPSD PRA might include plant operations at roughly the 30% power level and lower.

One insight gained from the tabletop exercise is that the 'line' between at-power and low power modes of operation is not clearly defined in current practice. A firm definition 'low power operations' in terms of a specific power level may not be forthcoming. To illustrate, the Seabrook internal events LPSD PRA defines 30 POSs ranging from de-fueled to at-power steady-state plant operations. Three POSs were defined to cover mode 1 and 2 plant operations at various power levels including startup and shutdown transition states as well as at-power steady state operations. In particular, they defined one POS for operations at greater than 70% power and two POSs to cover lower-power plant operation; one for operation below 30% and a second for operations between 30% and 70% power. The plant response models for these three POSs were quite similar but reflect differences in the availability of certain plant equipment (e.g., turbine driven pumps or low pressure systems). Both tabletop plants expressed the opinion that there is a much greater distinction relative to plant response modeling between low power POSs and shutdown POSs than there is between low power POSs and at-power operations.

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[1] The cited quotes are based on the joint American National Standards Institute (ANSI) and American Nuclear Society (ANS) standard ANSI/ANS-58.22-200x, DRAFT #8C, for the Risk Informed Standards Committee (RISC) Reballot & Public Review, June 2008. At the time the current document was prepared, this was the most recent version of the LPSD PRA standard available. The reader should be aware that the standard is a document in transition and should review updated versions, as available, for wording changes.

It was clear from these discussions that different approaches are being taken to defining POSs and that no single approach has yet emerged as "accepted practice." Further development in this area must be anticipated. In the long term, at-power operations may well be considered simply another POS, and one of the two tabletop plants strongly advocated for this position. In the context of this framework, the distinctions are relatively unimportant because the framework assumes that a POS set has been defined (e.g., by the LPSD internal event analysis) and that the task of the LPSD fire PRA is to analyze the impact of fires given that same set of POSs (see further discussion in Section 2.2 below). Note, however, that this document has adopted current common language which distinguishes at-power operations from LPSD operations.[2]

Regardless of the approach taken, one factor to be recognized is that LPSD conditions encompass a very broad spectrum of potential operating conditions. At one end of the POS spectrum, the reactor may be producing power with the control rods partly out, pressure and temperature of the main cooling loop very close to at-power conditions, and decay heat cooling systems not yet functioning (due to system pressures). At the other end of the POS spectrum, LPSD includes refueling outage conditions where all the rods are inserted, the main reactor vessel is open and flooded with refueling pool borated water, and the reactor is at near-ambient temperature. During refueling, depending on the maintenance needs, only one decay heat removal loop may be available for a limited time and plant modification activities could be underway.

1.3 Document Organization

An overview of the LPSD fire PRA framework is provided in Section 2 below. The overview defines the tasks of the framework. The selection of POSs and the equations for estimating overall plant core damage frequency (CDF) and large early release frequency (LERF) are discussed in Section 3. Section 4 provides a detailed discussion of each technical element of the analysis framework. Note that the subsections within Section 4 follow the same ordering as the chapters and technical tasks as defined in Volume 2 of the RES/EPRI at-power fire PRA methodology [1].

[2] The one exception to this observation is with regard to fire frequencies. That is, the fire frequencies presented in reference [1] are interpreted here as covering, at a minimum, both modes 1 and 2 (at-power and low power operations). A complementary set of shutdown fire frequencies has been calculated where needed. See Section 4.6 and Appendix A for further discussion.

2 OVERVIEW OF LPSD FIRE PRA FRAMEWORK

2.1 Structural Overview

An internal fire event during LPSD operations can occur from either an equipment item malfunction (e.g., a short in a switchgear may lead to arcing inside the device, rapid release of energy, and ignition of switchgear internals) or a transient combustible or activity (e.g., welding done for repair or plant upgrade). These are the same two types of fire events considered in at-power fire PRA. It is possible that the characteristics of a LPSD fire event (e.g., intensity or amount of fuel available) may be different from a similar class of events during at-power operation. However, the underlying fire behaviors of interest remain the same (e.g., ignition of combustible materials leading to plume formation, radiant heating, and other potentially damaging effects).

Furthermore, the nature and characteristics of many of the most common fire ignition sources (e.g., electrical cabinets and equipment) as well as the nature of the fire damage targets (e.g., electrical cables) will likely remain the same regardless of the plant operational state even though the specific targets of concern may be different (e.g., cables associated with RHR rather than cables associated with main feedwater). Therefore, in principle, the methodology, and indeed many of the analysis results, developed for at-power fire PRA [1] should be applicable to LPSD conditions. Clearly some of the parameters and conditions will need to be adjusted to reflect the special conditions of LPSD POSs (e.g., new fire ignition sources, equipment that is de-energized and out of service, breached fire barriers, and the POS-specific damage targets that are of primary interest) but the LPSD fire PRA should not be viewed as starting with a blank sheet of paper.

The framework presented in this document is structured to coincide with the RES/EPRI at-power fire PRA method [1]. Therefore, the discussions provided in this document assume that the reader is familiar with that method and the related data as presented in reference [1]. The task elements of the RES/EPRI at-power fire PRA method are each discussed. These discussions focus on the differences introduced by virtue of the LPSD perspective. Note that for some task elements the differences are quite minor or even nonexistent.

The RES/EPRI at-power fire PRA methodology defines 16 technical task elements and provides a detailed discussion, supporting data, and other information for each task. Figure 1 (presented at the end of Section 2) is the flow chart used in the RES/EPRI at-power fire PRA method to illustrate the interrelationship among the different tasks of the methodology. The same set of tasks and flow chart apply to LPSD fire PRA. Each task is discussed separately below in Section 3.

The RES/EPRI at-power fire PRA method assumes that certain information will be available based on prior completion of a corresponding plant internal events PRA. If an internal events analysis is not available, then the fire PRA analyst is responsible for developing and validating the required information. Similarly, the LPSD fire PRA framework assumes that certain information will be available based on prior completion of a LPSD internal events PRA. The information that is assumed to be available includes:

- Definition of LPSD POSs that will be addressed in terms of core power level, core cooling system pressure and temperature, equipment status (functional or under maintenance), special activities (e.g., maintenance and plant upgrade), status of barriers (e.g., doors propped open to allow certain activity, etc.);
- A list of initiating events for each POS as defined in the LPSD internal events PRA (e.g., loss of service water, loss of direct current (dc) power, etc.);

- A plant response model for each LPSD initiating event and for each relevant POS of interest (recognizing that POSs and initiators may be grouped for common treatment);
- A list of equipment and their failure modes of interest to the LPSD internal events PRA; and
- Human error scenarios integrated in the LPSD internal events plant response model.

It is also assumed that an at-power fire PRA has been completed and is available. Information assumed to be available based on the at-power fire PRA includes:

- Plant partitioning results which divide the plant into fire compartments or, equivalently, into physical analysis units (PAUs);[3]
- The listing of equipment included in the at-power fire PRA plant response model (i.e., selected equipment per Task 2 of the RES/EPRI at-power fire PRA method);
- The listing of cables associated with selected equipment;
- Any additional initiating events that are specific to the fire analysis;
- Equipment and ignition source counting/weighting results;
- Control circuit failure modes and effects analysis reports; and
- Component and cable mapping/routing results for the circuits in the circuit analysis report.

If any of this information is not available, the analyst should generate the needed information.

2.2 Key Assumptions and Potential Limitations

This framework is based on a number of key assumptions, and these key assumptions have implications for both the scope of the framework and for potential limitations to application of the framework. These key assumptions and the associated implications are summarized as follows.

- **Assumption 1:** The LPSD framework assumes that an at-power fire PRA has been completed consistent with the general approach defined by the RES/EPRI at-power fire PRA methodology.
    - *Impact of this assumption on the framework:* The LPSD framework takes as given that certain analysis tasks have already been completed and will, at most, require review and updating to address the LPSD conditions. For example, it is assumed that the task of identifying and counting fixed fire ignition sources within the plant has been completed. Hence, the LPSD analysis should only consider changes that might be associated with LPSD conditions (e.g., changes in the operational status of equipment, changes in the nature and likelihood of transient fuel sources that might be introduced during an outage, etc.).
    - *Implications:* This assumption is thought to carry few practical implications. An early conclusion reached by the authors was that it is wholly impractical to perform an analysis of LPSD fire risk without first completing an assessment of the at-power fire risk. An analyst attempting to conduct a LPSD fire analysis without first completing an at-power fire analysis would, in effect, be forced to do nearly all of the work associated with an at-power fire risk study simply to establish the required input for beginning the LPSD risk study.

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[3] NUREG/CR-6850, EPRI 1011989 [1] uses the phrase “fire compartments” and the American Society of Mechanical Engineers (ASME) PRA quality standard [11] uses the phrase “physical analysis units.” The differences are largely semantic in nature and this method document has adopted the language of the PRA standard in this regard.

- **Assumption 2:** The LPSD fire PRA framework assumes that a LPSD PRA has already been completed for internal event accident initiators.

  - *Impact of this assumption on the framework:* This parallels an equivalent assumption made in the RES/EPRI at-power fire PRA methodology; namely, that an at-power internal events PRA has been completed prior to conducting the at-power fire PRA. In general, the impact on the LPSD fire PRA framework is also the same; namely, the LPSD fire PRA framework calls for the analyst to build a fire plant response model beginning from the corresponding model developed for the LPSD internal events PRA. The fire framework thereby focuses on incorporating required changes and additions to address those aspects of plant response that are unique to fire (e.g., fire-induced spurious actuation of plant equipment, potential new initiators or sequences, and fire response procedures).

  - *Implications:* The most significant implication of this assumption is that the LPSD fire PRA framework assumes that the relevant POSs to be evaluated will have been defined in the LPSD internal events PRA. This framework assumes that, at least nominally, the same set of POSs is then carried forward to the fire PRA. Based on this assumption, this document does not explicitly address the process or criteria by which the POSs will actually be defined. Defining LPSD POSs is an analytical challenge with far-reaching implications and is the focus of substantial debate in the more general PRA community.

  The resolution of this challenge lies beyond the scope of this document. It is also acknowledged that the fire analysis will present unique challenges with respect to POS definition. This framework, for example, recommends that the LPSD fire PRA characterize and quantify the fire-specific plant configuration changes that occur with respect to each POS analyzed (e.g., breaching of fire barriers, staffing by plant personnel and contractors, introduction of new transient combustibles, increased hot work, fire protection system unavailability, maintenance activities, etc.). The implied work scope could become burdensome if a high level of detail for all possible POSs is sought. Methods for the management of the work scope challenge will likely develop through practical application, but cannot be defined a-priori. One general approach that might be especially helpful would be screening methods that would define the subset of POSs to be included in, or conversely excluded from, the quantitative fire analysis; but again, the more general state of POS definition guidance is not yet mature enough to support development of such screening approaches.

  One concept for the treatment of LPSD POSs is for the analyst to define an "average" outage state or, more likely, a finite set of average states that collectively reflect the major phases of a typical outage. This type of approach would present additional challenges to the LPSD fire PRA. In particular, the analyst would need to define corresponding "average" conditions relative to the fire analysis. For example, fire suppression system availability would need to reflect, in aggregate at least, planned system outages. As a second example, the multi-compartment analysis will need to reflect any expectation that credited fire barriers might be removed (e.g., hatch covers) or compromised (e.g., breaching of penetration seals for maintenance) during the course of an "average" outage. To further complicate this problem, some of these factors may be correlated and that too would need to be accounted for. For example, a fire suppression system may be taken out of service during welding operations which is the exact time welding fires would be expected to occur.

  Similar challenges will arise given that POSs are defined based on grouping similar outage states into a common POS treatment. This approach clearly has potential merit with respect to limiting analysis scope, but will also introduce similar challenges with respect to properly reflecting the fire defense in depth state given various potentially correlated changes to the fire protection program over the course of a given POS. Indeed regardless of the approach taken to POS definition, the analyst will have to reflect changes that will inevitably occur over the course of each POS relative to the introduction of unique fire sources or fuels, and the posture or status of fire protection systems and features.

Other challenges will also arise relative to walkdowns and the identification of LPSD systems and functions, as well as fire hazards and the status of fire protection systems and features. POSs defined on the basis of the internal events analysis should readily translate to the LPSD fire PRA, but in some cases the fire-relevant plant conditions may not change between POSs, and conversely, they may change over the course of a single POS. This implies that the fire analysis may introduce both unique challenges, and potentially, unique opportunities for grouping of POS's and the coordination of plant walkdowns.

- **Assumption 3:** Development of detailed human reliability analysis (HRA) quantification methods for application to the LPSD fire PRA lie beyond the scope of this document.

    - *Impact of this assumption on the framework:* This parallels an equivalent assumption made in the RES/EPRI at-power fire PRA methodology; namely, that post-fire HRA methods will rely upon general practice for HRA in other contexts and that specific guidance for application to fire conditions will be developed by the HRA community. This document does not explicitly address HRA quantification methods.

    - *Implications:* HRA is a unique area of methodology development whose implications extend well beyond the boundaries of a fire PRA. HRA quantification in the context of general LPSD plant operations is an active area of debate and development in the HRA technical community. A joint effort is already well underway between RES and EPRI to develop fire HRA quantification guidance for at-power fire PRA applications (see further discussion in Section 4.12). The LPSD fire PRA framework assumes that the HRA community will ultimately develop LPSD analysis guidance and will extend that guidance to include the treatment of fire conditions. Section 4.12 discusses prior LPSD HRA analyses and applications, the updated EPRI-RES fire HRA guidance and considerations relevant to the application of that guidance to LPSD applications. However, the resolution of the LPSD HRA challenge lies beyond the scope of this document.

- **Assumption 4:** LPSD Fire frequencies are estimated based on past plant experience in the same manner that fire frequencies were estimated for the RES/EPRI at-power fire PRA methodology and using the same root database (i.e., the EPRI fire event database (FEDB)).

    - *Impact of this assumption on the framework:* The development of a new FEDB or the gathering of substantially new information for incorporation into the existing FEDB lie beyond the scope of this project. Hence, this framework followed the approach used in the RES/EPRI at-power fire PRA methodology. If the RES/EPRI at-power fire PRA methodology concluded that the frequency of fires for a given fire source was not dependent on the POS, this framework has made the same assumption (i.e., the fire frequency for many ignition source bins reflects fires occurring during all modes of plant operation). New fire frequencies are calculated only for those ignition source bins where the RES/EPRI at-power fire PRA methodology concluded that the LPSD fire frequency might vary substantially from the at-power fire frequency (e.g., transients and hot work fires).

    - *Implications:* The existing FEDB has limitations that make it difficult to parse fire events to the extent that might be considered desirable. While this was also true for the RES/EPRI at-power fire PRA methodology, there are some unique implications in the context of LPSD conditions. In particular, while there are some exceptions, the fire event database does not generally identify the specific POS that a plant was in when a particular fire occurred. Rather, the vast majority of records only classify the POS as either at-power or shutdown (or they fail to specify a plant state at all). As a result, it is not currently possible to provide estimates of fire frequency that are POS-specific. An RES/EPRI collaborative effort is underway to expand and improve the EPRI FEDB. The planned improvements should afford some opportunity to improve the ability to parse fire events.

Another implication of this assumption is that the fire frequencies presented in this report distinguish between power operations versus shutdown (i.e., rather than 100%-power versus LPSD). That is, the at-power fire frequencies provided in reference [1] are interpreted as being applicable to both mode 2, low power, and mode 1, 100% power, conditions. This is an artifact of how the original at-power fire frequencies were calculated. Fire events that occurred during plant start-up in particular were counted as contributors to at-power fire frequencies. Also note that both of the tabletop plants suggested that this approach was actually a more appropriate reflection of plant operations.

- **Assumption 5:** Consistent with the LPSD PRA standard [4][4], the LPSD fire PRA end states considered here are limited to CDF and LERF.

    - *Impact of this assumption on the Framework:* While the framework presented here could be extended to include other end states, it should be emphasized that this document makes no attempt to address any end states other than CDF and LERF.

    - *Implications:* During certain LPSD POSs, depending on the specific conditions, radionuclide release may occur from events other than core damage (the focus of at-power PRA). For example, during a refueling outage coolant boiling in the core, uncovering the core, or fuel bundle mishandling could be considered as possible end-states for a risk analysis. Consistent with the standard [4], these alternative end states lie outside the scope of this framework. Also consistent with the standard [4], this document excludes consideration of potential release scenarios associated with either the spent fuel pool or on-site dry cask storage of spent fuel.

2.3 General Observations from the Tabletop Exercise

The tabletop exercise resulted in many insights that have been incorporated into the general text of this document. In addition to specific text revisions and additions, several general observations regarding low power and shutdown fire PRA were also identified. This section briefly discusses these more general observations. Note that corresponding text changes related to these observations have also been made in relevant sections of the document.

Observation 1: An additional factor to be considered is that many of the plant analyses and procedures used to support an at-power PRA are aimed specifically mode 1 and 2 operations and may provide less detailed direction when it comes to shutdown operations (modes 3-5). With respect to fire, the at-power fire PRA benefits greatly from the post-fire safe shutdown analysis performed to assure regulatory fire protection program compliance. However, the goal of that analysis is to demonstrate the ability, given a fire, to achieve hot shutdown within 24 hours and cold shutdown within 72 hours. Fires occurring while the plant is already in a shutdown mode do not fall within the scope of this analysis. To carry this example further, some plants will designate one train as the protected Appendix R safe shutdown train for

[4] At the time the current document was prepared, reference [4] was the most recent version of the LPSD PRA standard available. The reader should be aware that the standard is a document in transition and should review updated versions, as available, for wording or scope changes.

all fires and will protect that train from fire damage essentially throughout the plant.[5] During an outage, the designated Appendix R train may be out of service for maintenance at the time of a fire. The potential vulnerability of the alternate in-service train to fire damage may not have been considered as a part of the safe shutdown analysis because the protected train is maintained as available during power operations (e.g., within the bounds of technical specification limits on equipment outages). Overall, the LPSD fire PRA cannot expect to reap similar benefits from the fire protection program safe shutdown analysis and operating procedures that are gained by at-power fire PRA.

Observation 2: There will be a greater reliance on operator recovery actions during LPSD operations given that there are fewer automatic plant response functions available. This, coupled with the fact that operating procedures will be less detailed, means that for LPSD PRA the ability to credit operator recovery actions beyond the plant procedures will be important to obtaining realistic risk insights. This will present analysis challenges because the current PRA Standard [5] and HRA common practice establish limits on what can be credited in the PRA. *Something* (e.g., a procedure, skill-of-the-craft) must exist in order for PRA to give credit to an operator manual action. That is, HRA only credits actions that are either proceduralized or that can be argued to fall within skill-of-the-craft operator capabilities. In the LPSD context, given less detailed procedural guidance, skill-of-the-craft actions will likely be more important and more challenging to assess.

Observation 3: Based on input from several participants in the tabletop exercise, it appears that common practice is to maintain fire protection program requirements during shutdown operations as they are for power operations. This includes fire brigade staffing, combustible controls and hot work permitting programs (although more such permits may be issued during shutdown operations), and the availability of fire protection systems. Further, it appears that most plants schedule routine fire protection maintenance and surveillance testing during power operations in order to ensure system availability during an outage and to avoid conflict with other scheduled outage activities. The implications of this insight are discussed in Section 4.11, but generally imply, for example, that the extension of at-power fire protection system availability/reliability factors to shutdown conditions would likely be appropriate if not conservative.

Observation 4: There are significant implications relative to the analysis goal of treating outage-specific versus average-outage plant risk that present unique challenges to the fire PRA that this framework does not fully address. In particular, if an average-outage approach is taken, then balancing fire protection posture changes over the course of an outage will present particular challenges. If specific posture changes (e.g., removal of floor hatches) can be tied to specific POSs and can be considered common practice for those POSs, then the analysis will be relatively straight-forward. However, challenges will arise when such ties cannot be made or are less clear-cut. The analysis may need to define fractions of time spent in a given fire protection posture and weigh risk implications across POSs accordingly. This framework has not delved very deeply into the issues of average outage approaches in the fire protection context. Rather, it tends towards treatments based on consideration of specific fire protection postures (and posture changes) in the context of a POS with the presumption that specific configuration results will be weighed by exposure time (or fraction of total POS time) when supporting an average-outage analysis.

Observation 5: Some participants in the tabletop exercise expressed the opinion that the possibility of POS grouping presents unique challenges, and opportunities, relative to the fire analysis. In particular, it may be possible to group POSs relative to fire protection posture and/or fire risk implications in ways that may be unique from those applied from an internal events perspective. This possibility has not been explored in this framework document. By the same token, some also observed that the POS set defined

[5] Referring to 10CFR50.48 Appendix R - protection of one equipment train throughout the plant is a common Appendix R compliance strategy.

from the context of internal events should be reviewed to ensure that the same set does, in fact, cover the potential effects of fire induced damage to plant equipment and cables. This document generally assumes that this will be true, and that the internal events POS set can be used directly by the fire PRA. No specific examples to the contrary were offered.

Observation 6: As with the at-power fire PRA, spurious operation of plant equipment caused by fire-induced cable failures will need to be considered as a part of the LPSD fire PRA. One common practice for at-power analyses is the use of an industry expert panel approach to this analysis[6]. That is, generic lists of spurious operation events, including multiple spurious operations (MSO) have been developed based on generic plant characteristics. The generic lists are supplemented based on a plant specific review by knowledgeable experts. Currently, there is no complementary set of LPSD MSO combinations. Development of an expert panel approach to MSO analysis suitable to the LPSD fire PRA would likely be highly beneficial.

[6] See, for example, NEI 00-01, *Guidance for Post Fire Safe Shutdown Circuit Analysis*.

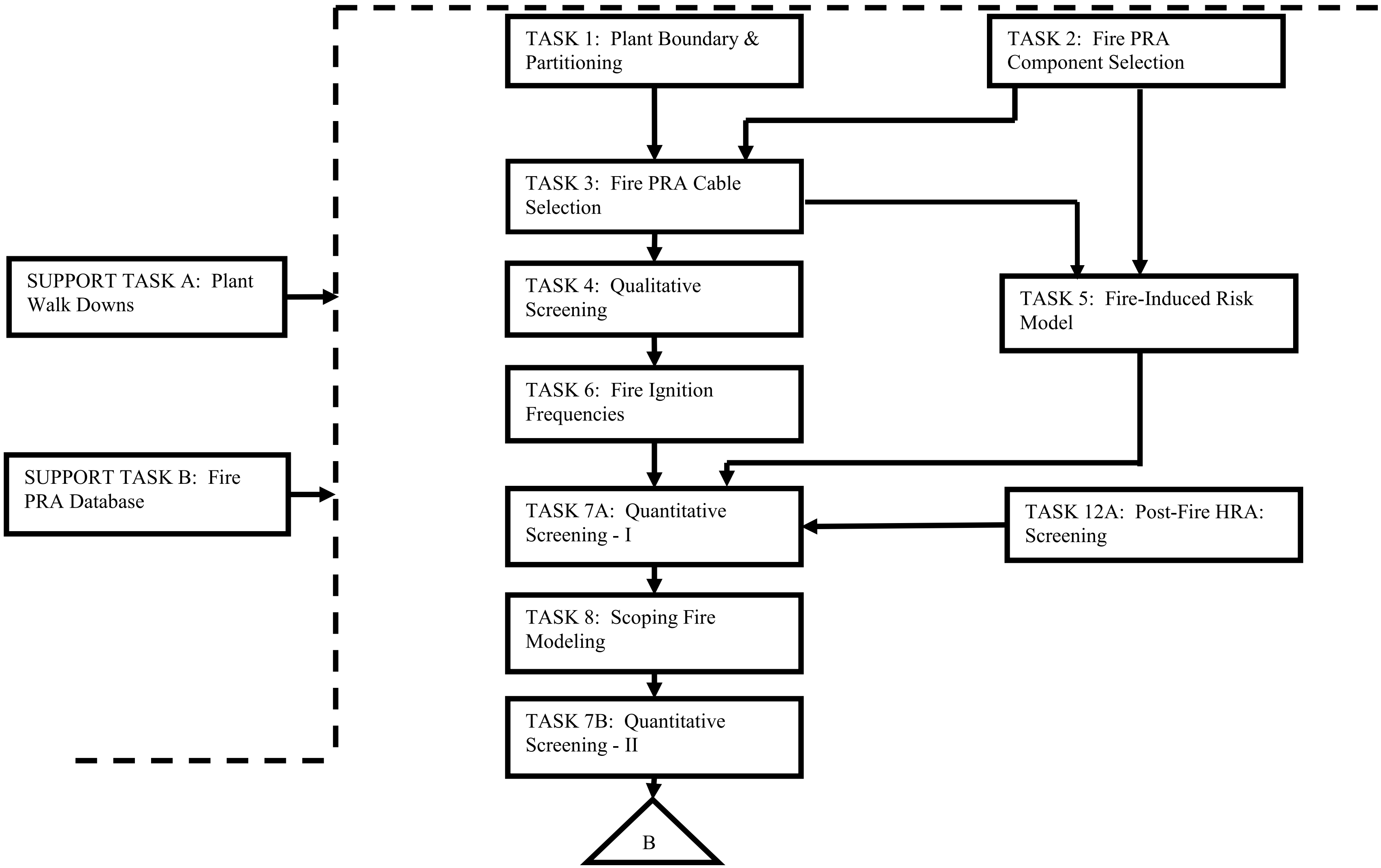

Figure 1: Fire PRA Process and Module Structure (part 1 of 2).

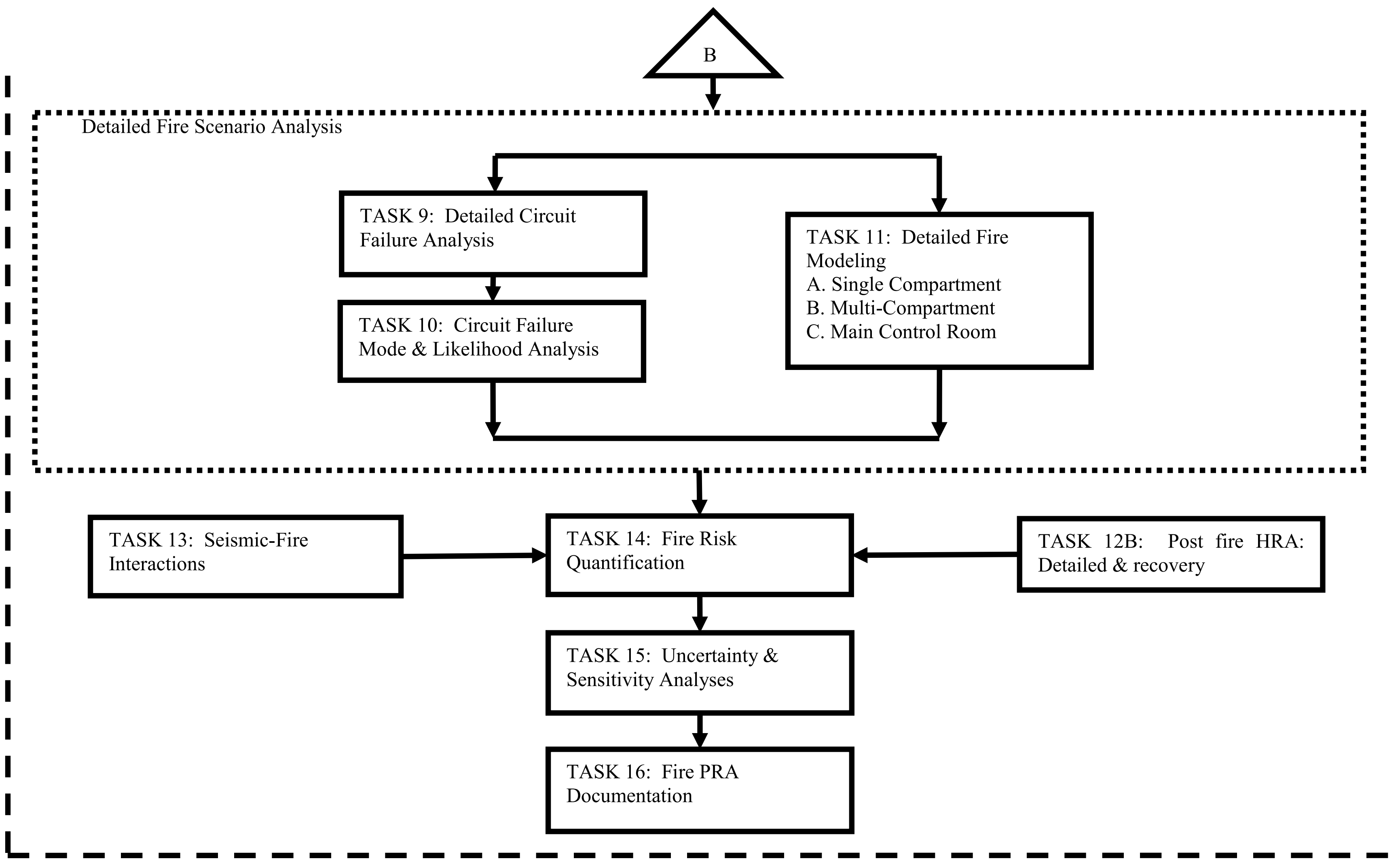

Figure 1: Fire PRA Process and Module Structure (part 2 of 2).

3 LPSD PRA CDF AND LERF

A key challenge of LPSD PRA, both for internal events and fire, is the definition of the POSs to be analyzed. There are many possible solutions to this challenge. This document takes no position as to the 'correct' solution. Whatever approach is ultimately taken, this framework assumes that a POS set will be defined as a part of the plant's internal events LPSD PRA and that the defined POS set will be equally valid and inclusive so as to serve the needs of the LPSD fire PRA. It is therefore assumed that the analyst will have a set of POSs defined prior to attempting LPSD fire PRA effort. Two general approaches to defining the POSs are anticipated. The POS set could be "complete" so as to cover all possible POSs in substantive detail. The set could also be a limited, well defined grouping of POSs intended to represent a typical outage or for use in a focused-scope analysis. This framework is neutral to this aspect of the analysis. The approach taken to defining POSs for analysis will clearly impact the scope of the analysis, but will not alter the fundamental nature of the fire PRA framework. Instead, the choice of approach will be driven by the objectives and intended applications of the analysis.

An evaluation based on a more complete set of POSs will facilitate modeling of actual plant configurations and equipment status changes that could increase, or reduce, fire risk. For each POS that exists there may be special plant configurations that are unique to a specific outage (e.g., steam generator replacement, large transformer replacements, or diesel generator overhauls). These special plant configurations will require particular consideration since initiators and mitigating equipment may vary from the original POS. PRA models for each POS should also reflect each special configuration.

If the objective of the analysis is to estimate the total risk over the course of an outage sequence (e.g., from the beginning of plant shutdown from power to the point of restart), the CDF and LERF calculations should be repeated for each POS and combined according to the following equation:

$$CDF\Sigma POS = \Sigma_i \; CDFPOS(i) \times ft_{POS(i)}$$

Where:

CDFΣPOS : The total CDF of all POSs combined in number of events per reactor year

CDFPOS(i): The instantaneous[7] CDF of specific POS(i)

$ft_{POS(i)}$: The fraction of time that each POS exists

If a specific one-time POS under a specific set of conditions is analyzed, the CDF and LERF should be estimated using the same equation, except that only one POS is considered. Therefore, we can write:

$$CDF_{POS(i)} = CDFPOS(i) \times ft_{POS(i)}$$

Where:

$CDF_{POS(i)}$: The CDF of POS(i) in number of events per reactor year

CDFPOS(i): The instantaneous CDF of specific POS(i)

$ft_{POS(i)}$: The fraction of time that POS *i* exists

The same set of equations applies to LERF calculations where CDF is simply replaced with LERF.

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[7] The instantaneous CDF is simply the CDF estimate at a given point in time considering the current status of the reactor and of plant equipment (e.g., including time-specific rather than generic equipment availability/outage configurations). The value is commonly expressed in terms of an annual frequency which effectively assumes that the existing configuration would continue for a whole year. The term "instantaneous risk" is synonymous with other terms such as "point-in-time risk" and "configuration specific risk."

4 DETAILED FRAMEWORK

4.1 Task 1: Plant Boundary Definition and Partitioning

The purpose and scope for this task remains the same as presented in reference [1]. This section provides supplemental guidance for conducting the plant boundary definition and partitioning tasks in support of the LPSD fire PRA. As in the at-power fire PRA, the plant is divided into a number of PAUs. The analysis then considers the impact of fires in a given PAU, and fires that might impact multiple PAUs. This practice supports both the organization of the PRA information and analysis, and provides a framework for reporting risk results.

Task 1 establishes the process for defining the overall plant boundary and partitioning of the plant into PAUs. The product of this task will be a list of PAUs that encompasses the nuclear power plant under analysis.

Analysts have two choices: (1) use the same set of PAUs as per the definitions established in the at-power fire PRA or (2) redefine the PAUs based on the barrier configurations and conditions specific to the POS. Both approaches have merits but this report advocates for maintaining the PAU definitions as per the at-power fire PRA with few exceptions. This approach ensures that plant locations are identified consistently among the analyses and will allow the results for the same plant location under different operating conditions to be quickly and easily identified. If the PAU boundaries are redefined, then tracking results becomes far more difficult and burdensome. The two significant exceptions to this recommendation are as follows:

(4) The analysis should verify that the at-power fire PRA plant boundary encompasses all plant areas of potential interest to the LPSD fire PRA. If it does not, then the global analysis boundary is expanded and new PAUs are defined.

(5) The analysis should consider the treatment afforded the containment structure in the at-power fire PRA and determine if an alternative treatment is appropriate. Containment fires are relatively rare while the plant is at at-power operation. For those BWRs with inerted containment, the guidance in reference [1] recommends that fires during at-power operation are not analyzed (no fire frequency is assigned to these containments per the guidance in reference [1]). During LPSD operations, these conditions can change and the changes could impact containment partitioning decisions.

The primary challenge to the LPSD fire PRA with respect to Task 1 is that the partitioning elements that defined the compartments in the at-power fire PRA (e.g., walls, ceilings/floors, spatial separation, etc.) are subject to modification during LPSD plant operations. For example, equipment hatches in ceilings/floors may be removed, normally closed doors may be propped opened, fire barrier penetrations may be breached (e.g., to support equipment or cable work), the containment structure may be open, and for BWRs, containment will no longer be inerted. The LPSD fire PRA will need to define and address such changes, but this need not force changes to previous (i.e., at power) partitioning decisions. Rather, changes in the status or integrity of a credited partitioning feature or element can be addressed during Task 11, and in particular Task 11c - the multi-compartment fire analysis (see Section 3.11 for additional discussion).

If the decision is made to alter the partitioning of any plant locations, the analysis should (1) define the partitioning changes and (2) provide a concise mapping between PAUs as defined in the at-power fire PRA and in the LPSD fire PRA. As in the at-power fire PRA, the LPSD PAUs should collectively encompass all locations within the global analysis boundary with no exclusions and no overlap between compartments (the set of PAUs is both complete and exclusive).

In Section 1.3.1 of reference [1]; the guidance cautions the analyst to avoid "excessive partitioning" and an over-reliance on multi-compartment fire scenarios as significant contributors to plant fire risk. If the recommendations discussed above are followed (i.e., the same PAU definitions are retained from the at-power analysis), then it is likely that there will be more contributing multi-compartment scenarios for LPSD than the at-power fire PRA. This is because normally closed fire barriers and other partitioning features may be opened during LPSD operations. This is inevitable, and is not considered to detract from the quality or validity of the LPSD fire PRA provided appropriate treatment is afforded to the relevant multi-compartment fire scenarios (i.e., in Task 11c).

The same procedure as that described in reference [1] for at-power fire PRA applies here as well with the following clarifications.

- Step 1: Selection of Global Plant Analysis Boundary:

  This task begins with an assessment of the global plant analysis boundary definition established in the at-power fire PRA. The guidance provided in reference [1] seeks a liberal definition of the global plant analysis boundary. Hence, for most analyses it is considered unlikely that the boundary will need to be expanded to suit the LPSD fire PRA; however, the LPSD analysis should determine whether the global plant analysis boundary should be expanded to encompass new areas of the plant. The definition of the global plant analysis boundary may need to be expanded if any locations excluded from the at-power analysis are identified as potentially relevant to the LPSD analysis. For example, the unit under analysis may establish electrical ties via temporary cabling to a sister unit during shutdown that would not be present while at power (e.g., to make up for de-energized power supply busses undergoing maintenance during the shutdown). If these ties meet the criteria for equipment/cable selection and the corresponding areas of the sister unit were outside the global analysis boundary for the unit's at-power fire PRA, then the LPSD fire PRA global analysis boundary should expand accordingly.

  As with the at-power fire PRA, the LPSD fire PRA global plant analysis boundary should encompass all areas of the plant associated with both normal and emergency reactor operating and support systems, and power production (e.g., the turbine building). The unique aspect of this assessment for the LPSD analysis is that the terms "normal and emergency reactor operating and support systems" should encompass all defined POSs to be considered in the analysis rather than just at-power conditions. This holds the potential to introduce plant locations that were deemed outside the scope of the at-power fire PRA.

  Selection of the LPSD fire PRA global plant analysis boundary should begin with the at-power fire PRA global plant analysis boundary. A review should be performed to identify any locations excluded from the at-power global analysis boundary that might contribute to LPSD risk. In particular, the LPSD fire PRA plant analysis boundary should encompass all locations, including qualifying locations associated with a sister unit at a multi-unit site, that house any of the LPSD fire PRA components and cables identified in Tasks 2 and 3 (see next two sections).

- Step 2: Plant Partitioning:

  The discussions provided in Section 1.5.2 of reference [1] apply in full to the LPSD fire PRA. As a general practice, this framework recommends that the PAUs (i.e., the plant partitioning results) as developed for the at-power fire PRA be applied without modification to the LPSD fire PRA with two specific exceptions:

  (1) For any new locations added to the global analysis boundary in Step 1, partition those locations into PAUs consistent with the guidance in Section 1.5.2 of reference [1].

  (2) It is recommended that a review of the containment structure be performed to assess whether or not additional partitioning is appropriate.

With respect to item (2) above, in a typical at-power fire PRA the containment structure is either not analyzed in detail (i.e., in the case of those plants whose containments are inerted during plant operations) or analyzed in limited detail (e.g., due to the relatively low frequency of fires inside containment during power operations that can affect core cooling). These conditions (inerting and low fire frequency) may not apply to LPSD operations and the analyst should anticipate that a more thorough examination of containment fires will be required. Hence, the purpose of item (2) above is to ensure that due consideration is given to the potential analytical needs of the containment fire analysis during the plant partitioning task. As always, partitioning decisions are ultimately up to the analyst but additional partitioning of the containment structure should be considered.

- Step 3: Compartment Information Gathering and Characterization:

The discussions provided in Section 1.5.3 of reference [1] apply in full to the LPSD fire PRA.

- Step 4: Documentation:

The discussions provided in Section 1.5.4 of reference [1] apply in full to the LPSD fire PRA. In addition, the analyst should take particular care to document any changes in plant partitioning made to support the LPSD fire PRA as compared to the at-power fire PRA. If any partitioning changes are made, task documentation should define those changes and provide a mapping of LPSD PAUs to at-power fire compartments.

4.2 Task 2: Fire PRA Component Selection

4.2.1 Background

The objective of Task 2 is to create the LPSD fire PRA component list[8]. This list identifies the plant components that will be modeled in the LPSD fire PRA. The component list also identifies plant equipment for which the corresponding cables (power, control and instrumentation – see Task 3) need to be identified and located.

This task builds upon foundations of equipment selection established by the at-power fire PRA. It also builds upon foundations established in a corresponding internal event LPSD PRA. Hence, as noted in Section 2, these two analyses are considered critical inputs to this task. If either analysis is not available, the analyst faces a substantial additional burden to generate the information that would normally be imported from these analyses and that effort lies outside the scope of this document.

Given the wide range of possible POS conditions, essentially all of the components selected for inclusion in the at-power fire PRA will also be relevant to the LPSD fire PRA and should be retained in the LPSD fire PRA component list. However, component selection will need to be augmented with additional components unique to the conditions posed by the specific POSs, or POS groups[9], associated with shutdown and with equipment outages during LPSD conditions (e.g., loss of the redundant train of a system to a fire while the other train is out of service for maintenance).

The process for generating the LPSD fire PRA component list is fundamentally the same as the at-power analysis. The analyst, however, should consider each POS separately to ensure that potential accident initiators and mitigating equipment relevant to each POS are properly accounted for.

Overall and for each POS, or POS group, the component list needs to span:

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[8] As in the at-power procedure, the terms "equipment" and "component" as used here are considered synonymous and are meant to include plant components such as valves, fans, pumps, indicators, alarms and other electrical, electronic, and mechanical devices as appropriate. The terms generally exclude electrical cables as these are dealt with explicitly (see Task 3, Section 4.3).

[9] The potential for grouping POSs is discussed in Section 4.5 below.

(1) equipment that, if affected by a fire, will cause an initiating event such that the appropriate fire-induced initiators can be defined;

(2) all equipment necessary to support those mitigating functions and operator actions that are credited in the analysis in response to any initiator; and

(3) equipment that can be a source of undesirable responses adverse to safety during a fire-induced accident sequence, (e.g., fire-induced spurious operations).

The considerations cited for the selection of equipment in Section 2.2 of reference [1] are fully applicable to the LPSD fire PRA. In addition, it is recommended that the LPSD fire component list include the following:

(1) all components included in the at-power fire PRA, and

(2) all components credited in the Internal Events LPSD PRA, and in particular, equipment associated with electrically diverse systems.

The input to Task 2 is much the same as those identified in Section 2.4.1 of reference [1] with the following additions:

(1) Task 2 includes the mapping of identified components to plant locations (e.g., fire areas and/or PAUs). It is strongly recommended that the LPSD fire PRA use the same plant boundary and compartment definitions and location identification nomenclature as established in the corresponding at-power fire PRA. If the global analysis boundary is expanded to accommodate the needs of the LPSD fire PRA, then the additions should be clearly documented (e.g., identify locations that were deemed outside the scope of the at-power fire PRA but are included in the LPSD fire PRA). This approach will greatly simplify the process of component tracing and location documentation.

(2) The internal events LPSD PRA model for the specific POSs under consideration and the corresponding equipment lists are a required input.

(3) Plant procedures applicable to the POSs being considered (e.g., emergency operating procedures, fire procedures, annunciator response procedures) are required in addition to at-power operating procedures.

(4) The analysis will need to review plant Technical Specifications to determine possible limiting conditions of operation (LCOs) applicable to each defined POS (see Task 2 Step 3).

4.2.2 Procedure

The steps that follow provide a method to create the LPSD fire PRA component list. The step structure is identical to that provided in Section 2.5 of reference [1]. As with the at-power fire PRA, as a practical matter, the LPSD fire PRA component selection task is an iterative process. Hence, as other tasks are performed, there may be reason to revisit and redo portions of Task 2 during the development, screening, and eventual quantification of the LPSD fire PRA.

- Step 1: Identify Internal Events LPSD PRA Sequences to be included (and those to be excluded) in the LPSD fire PRA Model.

This step for the fire LPSD task is identical to the corresponding step as described in Section 2.5.1 of reference [1] with one modification. For the purposes of the LPSD fire PRA, Step 1 reviews accident sequences from the *at-power fire PRA and the internal events LPSD PRA* (rather than only the internal events *at-power* PRA.)

Possible Elimination of Sequences and Equipment - The identification of sequences that could generally be eliminated from the LPSD fire PRA is similar to the corresponding analysis element in reference [1] with the following additions:

(1) In determining which sequences and equipment to include, or potentially exclude, from the LPSD fire PRA, consider all sequences included in the at-power fire PRA and those included in the internal events LPSD PRA.

(2) It is recommended that all components included in the at-power fire PRA be retained for (i.e., not eliminated from) the LPSD fire PRA with few exceptions. In essence, the at-power fire PRA will already have established component locations and will have identified and traced related cables. Hence, there is likely little benefit to be gained by excluding such components from the fire LPSD analysis especially given that the LPSD fire PRA will include low-power (e.g., startup) POSs that will be quite similar in nature to the at-power plant configuration. If any components that were included in the at-power fire PRA are excluded from the LPSD fire PRA, the exclusion should be noted and explained, including a discussion of the potential impact of these exclusions on the risk results.

(3) As in the at-power fire PRA, justification for the exclusion of any sequences or equipment and the resulting impact on the "reduced" PRA model should be noted. In particular, the analyst should take care not to eliminate sequences or equipment that could adversely affect equipment credited in the LPSD fire PRA. For example, elements of an electric power distribution system may be considered for elimination (e.g., dc power distribution system elements). However, the analyst should be careful not to eliminate those parts of the system that may be needed for proper functioning of credited equipment items (e.g., instrumentation loops).

Possible Additions of Sequences and Equipment - Considerations relative to the addition of sequences and equipment are essentially the same as for the corresponding analysis element in the at-power fire PRA with the following clarifications:

(1) As was the case for the at-power fire PRA as compared to the at-power internal events PRA, some sequences that were screened out of the internal events LPSD PRA based on low frequency of occurrence may need to be retained in the LPSD fire PRA. The bases for such additions would be similar to those leading to additions to the at-power fire PRA. Specifically, a search should be conducted, in concert with carrying out all the steps of this procedure, for new functional challenges in the plant not otherwise accounted for especially because of fire-induced spurious actuation considerations.

- For example, spurious actuation of a high pressure pump while the reactor vessel is closed but in cold shutdown may lead to pressurizer safety relief valve (SRV) lift for some PWRs. If the valve were to stick open, recovery actions may be needed to prevent a LOCA (i.e., isolation of the SRV). Spurious actuation of the pump may have been deemed of sufficiently low probability in the internal events LPSD PRA that the sequence may have been screened out. However, fire-induced spurious actuation of the same pump (e.g., due to control cable failures) might be likely enough to warrant retention of the sequence (e.g., pursuant to a detailed HRA for the potential recovery actions).
- As a second example, the potential for reactivity insertion may have been screened from the internal events analysis but may need to be reconsidered for fire events given the potential for fire-induced spurious operations.

A review should be conducted for such scenarios originally eliminated from the internal events LPSD PRA to determine if new components should be added to the LPSD fire PRA component list implying that those components, their failure modes, and the associated sequences would be included in the LPSD fire PRA plant risk model (see Task 5). Particularly when considering the possible effects of spurious operations, new accident sequences and associated components of interest beyond those considered in the Internal Events LPSD PRA may be identified that should be addressed in the LPSD fire PRA. Each POS should be considered individually to determine applicability. Typically, new sequences might arise as a result of spurious events that:

- cause a loss of coolant accident (LOCA), e.g., drain down events;
- adversely affect plant pressure control, e.g., letdown or safety relief valve events;
- cause loss of cooling to core; or
- introduce other "new" scenarios that may not be addressed in the internal events LPSD PRA.

(2) As with the at-power fire PRA, a review of the fire emergency procedures (FEPs) or similar fire-related instructions as such instructions apply to various LPSD POSs should be conducted (see also Task 12). In particular, fire-specific manual actions designed to preclude or overcome spurious operations will likely not have been addressed in the Internal Events LPSD PRA. For example:

- An FEP may require shutdown of a pump from the switchgear to avoid spurious actuation of the pump and pump damage due to cavitation. This may cause demands on the pressurizer SRV and lead to sequences not modeled in the Internal Events LPSD PRA.
- Fire specific manual actions may cause an unintentional failure of a safety function or a subset of that functional response. For example, a proceduralized action may be to trip a power supply thereby disabling ("failing") certain equipment in the plant.
- As with at-power considerations, the likely timing of the operator action as compared to when the affected component is needed should also be considered.

- Step 2: Review the Internal Events LPSD PRA Model Against the Fire Safe Shutdown Analysis:

The impact of Step 2 on the LPSD fire PRA is likely to be more limited than the impact of this step on the at-power fire PRA. However, this step does retain some relevance to the LPSD fire PRA and should not be neglected.

The fire safe shutdown analysis addresses regulatory requirements to demonstrate that, in the event of a plant fire, the plant will retain the ability to achieve hot-shutdown (or hot-standby) and ultimately to achieve and maintain cold shutdown. Hence, the safe shutdown procedures will overlap some of the POSs that will likely be defined in the LPSD fire PRA. To the extent that this overlap exists, Step 2 should be completed.

The underlying steps (i.e., steps 2.1 through 2.5) are executed largely consistent with the treatment afforded in the at-power fire PRA. The most significant difference is that the review compares the fire safe shutdown analysis to the plant risk model developed for the internal events *LPSD* PRA rather than the treatment provided in the internal events *at-power* PRA. The reconciliation effort in steps 2.1 through 2.4 compares the fire safe shutdown analysis to the internal events *LPSD* PRA rather than to the internal events *at-power* PRA. When reconciling system or equipment differences due to end-state and mission considerations, the fire safe shutdown analysis will likely not deal at all with various POSs associated with the LPSD fire PRA. In particular, the fire safe shutdown analysis will typically not address any aspects of plant operations during refueling stages of a plant shutdown. When considering specific review of manual actions, the reconciliation effort should compare the fire safe shutdown analysis to the internal events LPSD PRA rather than to the internal events at-power

PRA. Also, with respect to manual actions to be credited in the LPSD fire PRA, considerations should include both the need to achieve and maintain safe shutdown (e.g., given an automatic or manual trip from a low-power POS) and the need to maintain safe and stable conditions during other non-power POSs (e.g., refueling evolutions).

- Step 3: Identify Fire-Induced Initiating Events Based on Equipment Affected:

The role of this step in the analysis is essentially identical for the LPSD fire PRA as for the at-power fire PRA. That is, to the extent the above steps have not already done so, this step addresses that equipment which, if affected by a fire, could cause an initiating event (e.g., forced shutdown of the plant from a low power state or a drain down event for other shutdown evolutions). As in the at-power analysis, the goal of Step 3 is to identify what initiator(s) will likely occur if a fire in any given compartment affects equipment identified on the LPSD fire PRA component list. For guidance, see Section 2.5.3 of reference [1] with the following clarification: In addition to the considerations applicable to the at-power fire PRA, for the LPSD fire PRA, consideration also extends to equipment whose failure would compromise the ability to maintain a safe and stable condition for each POS being considered. It is anticipated that new initiating events may need to be identified stemming from the specific conditions imposed by the POS. It must be noted here again that this guidance is focused on CDF and LERF. Other radionuclide release possibilities are not considered as part of the scope of this document.

- Step 4: Identify Equipment with Potential Spurious Actuations that may Challenge the Ability to Safely Maintain the Plant During Each POS:

The role of this step in the analysis is essentially identical for the LPSD fire PRA as for the at-power fire PRA. This step is aimed at further expanding the LPSD fire PRA component list, and thus potentially the LPSD fire PRA plant risk model (Task 5), to include adequate consideration of the potential for harmful fire-induced spurious actuations. For guidance, see Section 2.5.4 of reference [1] with the following clarifications:

(1) In addition to the considerations applicable in the at-power fire PRA, for the LPSD fire PRA it also extends to equipment whose spurious actuation would compromise the ability to maintain a safe and stable condition for each POS being considered.

(2) The systematic review of potential spurious actuation concerns is conducted on the basis of accident sequence types and related mitigation system functions included in the internal events LPSD PRA plant risk model rather than the internal events at-power PRA plant risk model.

(3) Table 2-2 of reference [1] presents (illustrative only) examples of how single and multiple spurious actuation failures might be important for some accident sequences. In addition to those examples provided for at-power conditions, the LPSD PRA should include consideration of spurious actuations impacting secondary-side cooling functions because these either may not have been considered, or may have been considered and screened out, during the at-power fire PRA.

- Step 5: Identify Additional Mitigating, Instrumentation, and Diagnostic Equipment Important to Human Response:

The goal of this step in the LPSD fire PRA is identical to that of the corresponding step in the at-power fire PRA [1]. Namely, the goal is to expand the LPSD fire PRA component list, and thus potentially the LPSD fire PRA plant risk model (Task 5) to include other mitigating equipment, instrumentation, and diagnostic equipment necessary for human actions if not already addressed in previous steps for each POS. The structure and role of the underlying steps (5.1 and 5.2) remains unchanged.

- Step 5.1: Identify Human Actions of Interest: See Section 2.5.5.1 of reference [1] for guidance with the following clarifications:

(1) The identification of human actions gives consideration to those human actions credited in the internal events *LPSD* PRA rather than those actions credited in the internal events *at-power* PRA.

(2) The review of human actions should consider all relevant plant procedures for all POSs being considered. This should include both general plant operations and any fire-specific procedures as available.

- Step 5.2: Identify Instrumentation and Diagnostic Equipment Associated with both Credited and Potentially Harmful Human Actions: See Section 2.5.5.2 of reference [1] for guidance. The following is an alternative example to those offered in reference [1] that should be included during the performance of Step 5.2:

(1) The LPSD fire PRA will need to consider the potential role of the plant's alternate shutdown panel in LPSD operations. If, for example, a main control room (MCR) fire were to occur during a shutdown evolution, the analysis will need to assess what benefit could be gained through use of the alternate shutdown panel(s) to control some of the plant systems.

- Step 6: Include "Potentially High Consequence" Related Equipment:

As the final analysis step in performing Task 2, consideration is given to equipment associated with potentially high consequence events. The goal is to ensure that such events are not be prematurely screened, but are analyzed in more detail to determine their risk significance.

High consequence events for at-power conditions are potentially relevant to low-power operations as well. These are defined per Section 2.5.6 of reference [1] (list items (a) and (b) in that section). To the extent that such events are relevant to low-power operations they should be considered consistent with the at-power fire PRA guidance. In addition to (a) and (b) in reference [1], for the purposes of the LPSD fire PRA, consideration of potentially high consequence events should be extended to include events where:

(c) one or more related component failures, including spurious operations, where at least one failure/spurious operation is induced by a fire, and that by themselves result in core damage when the reactor vessel and secondary containment structure are open (i.e., no primary or secondary containment). An example might include a fire-induced spurious operations (e.g., spurious opening of a valve draining to the suppression pool or spurious start-up of a high capacity pumping system) resulting in a rapid drain-down of the refueling cavity while containment is open.

- Step 7: Assemble LPSD fire PRA component list:

As in the at-power fire PRA, the final step is to assemble the LPSD fire PRA component list. This list is generally maintained in a supporting database. The most important elements of the database will be the component identifiers and the location of the component. This effectively defines the PRA damage targets within each PAU in terms of components. Section 2.5.7 of reference [1] provides recommendations relative to the type of information that should be recorded for each item on the component list. Similar information will be needed to support the LPSD fire PRA, but this information will also need to extend to all POSs being considered. Some component characteristics (e.g., equipment identifier (ID), description, locations, system designation, and type) will remain the same regardless of the plant operating state. However, others (e.g., the normal position/status, desired position/status, failed electrical position, and failed air position) will change depending on the POS. It is recommended that the database structure be expanded to capture, as relevant, variable aspects of each component identified and the relevant entries as applicable to each identified POS. Additionally, there could be temporarily-staged equipment (e.g., auxiliary diesel), which may be a part of the safe plant operation during a POS. These new equipment items would need to be added to the list.

The general expectation is that the component list will be developed at the level of major plant components (e.g., motors, valves, pumps, etc.). It is not expected that the list would be developed at a sub-component or relay level. Under Task 3 the cables and power supplies associated with these components will also be identified. This will effectively extend the available information to include, in a general sense, sub-component locations and functions (e.g., supporting control circuitry, power supply chains, and routing information).

4.3 Task 3: Fire PRA Cable Selection

The approach and process for identifying cables of potential interest to the LPSD fire PRA is essentially identical to that applied to the at-power fire PRA as documented in Section 3 of reference [1]. However, the following clarifications should be noted:

- Any and all cables selected for inclusion in the at-power fire PRA will likely be included in the LPSD fire PRA. Any exceptions to this general practice should be identified and justified.
- The cable identification process considers the equipment and components identified in Task 2 of the LPSD fire PRA rather than the set of equipment identified in the corresponding at-power fire PRA. The LPSD fire PRA equipment list may contain new components not included in the at-power fire PRA and the cable selection process should be repeated for these new components. If, as part of maintenance activities during a POS, for equipment on the component list, temporary cables are installed or existing cables are re-routed, those cables should be added to the list.
- It is recommended that the analyst review past practice regarding the use of temporary cables to determine if: (1) there are common practices in this regard, (2) if temporary cable use is tied to specific POSs, (3) if temporary cable use results in any degradation of fire protection features (e.g., opened doorways or hatches), and (4) if any compensatory measures are implemented to compensate for fire protection degradations. This aspect of the review will likely require input from the plant fire protection program staff.
- The at-power cable selection results should also be reviewed to ensure that component failure modes that may not have been of interest to the at-power fire PRA but that have unique implications to the LPSD POSs are identified and addressed. This might, for example, include the re-introduction of cables leading to spurious equipment actuations that were considered benign in the at-power analysis but which might not be benign in the context of one or more LPSD POSs. For example, the spurious operation of valves associated only with shutdown cooling systems might have little or no impact on at-power operations, but might compromise core cooling during one or more LPSD POS. Hence, it is possible that components, and their associated cables, that were properly screened out from the at-power fire PRA would need to be added to the LPSD fire PRA equipment and cable lists.
- Cable selection considers the potential impact of cable failures in the context of each POS being considered in the LPSD fire PRA.
- Power supply coordination may not be assured during shutdown operations based on coordination studies performed based on the at-power plant configuration if the configuration of the power supply chain is modified. For example, temporary power supplies or power feed cables used to provide alternative power sources to plant equipment were likely not considered in at-power electrical coordination studies. A coordination review for temporary power supply arrangements should be completed for equipment credited for post-fire plant response during shutdown.

The final outcome of this task is a set of entries in the fire PRA Database identifying the cables of interest in terms of associated component serviced by the cable, cable function, and cable locations (see Section 3.5.6.1 of reference [1] for further detail). This information establishes the PRA damage targets in each PAU in terms of cables.

It is common practice in fire PRA for at-power applications that Tasks 6 and 9 are performed in concert. That is, the cable selection and tracing efforts often are performed concurrent with a look forward to the deterministic cable failure modes and effects analysis. This practice will likely continue in the context of the LPSD fire PRA.

4.4 Task 4: Qualitative Screening

The purpose of this task is to qualitatively screen PAUs before the quantitative analysis is initiated. Since CDF and LERF are the focus of the LPSD fire PRA, the method and criterion provided in Chapter 4 of reference [1] are applicable to the LPSD fire PRA. The criterion provided in reference [1] is repeated here:

- Screen a PAU if the compartment does not contain any of the equipment (including circuits and cables) identified in Tasks 2 and 3, and
- In concert with Section 2.5.3 of the Task 2 procedure, the compartment is such that fires in the compartment will not impact plant status. For example, there would not be a reactor trip if the reactor is critical or loss of decay heat cooling if the reactor is in cold shutdown.

It was suggested during the tabletop exercise that an inclusionary approach be taken for shutdown operations in particular as an alternative to the exclusionary approach applied to at-power fire PRA. That is, following the at-power approach would require systematically reviewing all fire locations within the global analysis boundary and excluding (screening out) locations that do not contain any components or cables relevant to a given POS. As an alternative, it was suggested that identifying those locations that do contain potentially relevant cables and equipment might be more effective and more efficient in the LPSD context. The objective would generally be the same regardless of approach; namely, to identify locations where fires might either compromise or create a demand for plant systems important to maintaining plant nuclear safety. The at-power analysis recommends use of an exclusionary approach because relatively few locations are expected to meet the exclusionary criteria and those locations are likely to be somewhat obvious to identify (e.g., office buildings, security access areas, parking lots, warehouses, etc.). For shutdown conditions in particular, a more limited subset of the global analysis boundary may be of interest, especially for some specific POSs. Hence, an inclusionary approach to identifying the locations that contain relevant equipment and cables might prove more effective at reaching the same goal. This approach has not yet been tested.

As in the case of at-power fire PRA, these criteria are specifically intended to allow the qualitative screening of PAUs that do not contain any of the equipment or cables identified in Tasks 2 and 3, but where a prolonged fire might lead operators to implement alternative or preemptive measures to maintain the POS or to place the plant in a more stable condition. That is, the at-power methodology assumes that a PAU where a fire cannot directly threaten any of the fire PRA equipment or cables will not represent a substantive contributor to fire risk even if operators might take preemptive actions to, for example, trip the plant. For this case the fire represents just one more potential source of a plant trip with no loss of mitigating equipment, scenarios already captured in the internal events PRA. Analogous situations are likely for LPSD conditions. For example, if a fire were to occur during plant startup, operators might choose to initiate a preemptive trip even though no important plant systems or equipment have been lost or are threatened. The criteria above would allow for the screening of such PAUs so long as there is no direct threat to the LPSD fire PRA equipment or cables identified as important to the POS(s) associated with plant startup.

Other analogous situations are likely to occur for other modes of shutdown plant operations. For example, if a fire were to occur in an unimportant plant location while the plant was engaged in Mode 6 fuel movement, operators might choose to temporarily suspend fuel movement but would likely not transition from Mode 6 to some other operating mode. If a temporary suspension of work activities is the only potential impact of a fire in a given plant location, then the intent of the framework would allow for the qualitative screening of that location in the context of that particular POS. Said another way, the framework is intended to allow for qualitative screening of plant locations in the context of a given POS provided there is no potential impact to plant equipment (including spurious operations) relied on to maintain safe operations within that POS and where a fire would not force an unplanned POS transition (e.g., a trip from low power conditions).

It should be noted that compartments qualitatively screened in this task will be reexamined in Task 11 for the potential for affecting adjacent compartments in the multi-compartment fire analysis.

Compartments that would be qualitatively screened out in this task and later in Task 11 as part of the multi-compartment analysis are concluded to be of little risk significance to be tracked for risk contribution.

4.5 Task 5: Fire-Induced Risk Model

In this task the plant model is put together using event trees and fault trees for calculating the CDF and LERF of LPSD fire PRA. The same procedure as for at-power fire PRA applies here. The same modeling approaches (i.e., either fault tree linking or event trees with boundaries [1]) can be used for LPSD conditions. It is considered unlikely that, in practicality, a single plant response model can be developed with sufficient flexibility to encompass all LPSD POSs. Instead, the expectation is that some finite number of plant response models will be needed. The actual number would depend on how the POSs are defined and if the defined POSs can be grouped in the context of plant response modeling. The intent for the LPSD fire PRA would be to follow the approach taken to, and precedents set in, the internal events LPSD analysis; that is, it is generally expected that a complementary *fire* plant response model will be needed for each POS plant response model developed in the internal events LPSD analysis. In other words, this task may need to be repeated for each internal events POS plant response model separately. If the *complete* set of LPSD POSs (i.e., the average or typical outages as discussed in Section 3.0 above) is of interest, a separate model should be developed for each POS of the set. Similarly, if a one-of-a-kind outage is under consideration, the model should reflect the specific conditions of that outage and corresponding POSs.

One challenge for LPSD modeling is that only one train of plant equipment may available at any given time with the other train (or trains) out of service for maintenance. Further, the available train may switch (e.g., from train A to train B) either from outage to outage or over the course of a single outage. The plant response model will need to reflect such subtleties because fires may present unique challenges depending on which train(s) are available. Cable and equipment locations *will* vary by train, and fire protection features *may* vary by train. For example, one train may be designated at the "Appendix R" train with higher levels of passive and active fire protection throughout the plant or train protection may be location dependent. Support system dependencies (e.g., electrical power) will also likely be train-dependent.

For the at-power PRA model, in addition to emergency operating procedures (EOPs), the analysts may use FEPs to establish the chain of events in response to an initiating event. In the case of LPSD, practices will vary from plant to plant. Some plants may develop specialized EOPs and FEPs to address specific conditions of the POS or a one-of-a-kind outage. Those EOPs and FEPs should be consulted when developing the plant model for LPSD fire PRA (see Section 4.2.2 for further detail). If MCR evacuation is part of a fire scenario, the specific conditions of the LPSD POS should be considered when using the FEP for such events. Plant management may need to be consulted to ensure that POS specific procedures and guidelines are incorporated in the development of the LPSD fire PRA model.

Similar to at-power fire PRA, an internal events model serves as the starting point for this purpose. That is, this framework assumes that an internal events LPSD PRA model for the specific POS of the study does exist. The same approach can be used as in the at-power case defined in reference [1] to arrive at the LPSD fire PRA plant model. A set of initiating events applicable to the fire analysis should be identified first and then the internal events analysis event trees and fault trees are modified as necessary to establish the set of fire-induced failures and operator errors that could lead to core damage or large early release. Similar to the at-power case, the process may include temporary changes to the Internal Events LPSD PRA that are later modified as PAUs and fire scenarios are screened from further analysis. In the temporary models, conservative measures are incorporated to expedite the analysis, which are later refined and applied to risk significant scenarios.

As noted above, the same procedure described in reference [1] applies here. The assumptions, input from other tasks and output to other tasks remain the same. When analyzing a specific POS, especially in the case of one-of-a-kind outage, it is possible that only a small part of the plant could be affected. For those cases, the analyst may elect to limit the analysis only to those parts of the plant. The same procedure should apply regardless of the scope of the analysis with the following clarifications:

- Step 1–Develop the Fire PRA CDF/CCDP Model:

  In this case the model is focused on specific LPSD POS conditions. The conditional core damage probability (CCDP) and CDF models are the same. To obtain the CCDP, the model is quantified using 1.0 for the initiating event frequency. Step 1 is divided into three sub-steps as follows:

  - Step 1.1: Select Appropriate Fire-Induced Initiating Events and Sequences and Verify Against the Component List and Failure Modes: The initiating events identified in Step 3 of Task 2 are reviewed and verified in this step. It should be noted that new initiating events (i.e., other than those adopted from the at-power fire PRA and internal events LPSD analyses) may be identified here based on the special conditions created by a specific POS.

  - Step 1.2: Incorporate Fire-Induced Equipment Failures: Equipment failure due to fire impact is carefully studied in the at-power fire PRA. The same information should apply to LPSD conditions. The LPSD analysis will need to (1) capture fire-induced failure of new plant equipment and cables identified as important to the LPSD POSs that were not included in the at-power fire PRA, and (2) identify and capture potential new failure modes for previously modeled equipment and cables that may present unique challenges for LPSD operations. As an example of the second element, for a particular valve the at-power fire PRA may have modeled loss of function failure modes but might not have included spurious operation if that failure mode did not impact the at-power analysis. If that same valve has a unique LPSD role where spurious operation is a factor, then the spurious operation failure mode would need to be added to the LPSD plant response model. The converse could also apply; that is, a valve included in the at-power fire PRA might only have been a concern given spurious opening (i.e., a potential diversion path) whereas in the LPSD analysis, the ability to operate the valve may be a factor. Step1.3: Incorporate Fire-Induced Human Failures: The manual actions credited in the at-power fire PRA model should be reviewed and modified to reflect the special conditions that may exist during the postulated POS. If POS specific FEPs are developed, the manual actions credited in those procedures should also be reviewed carefully and incorporated in the model.

- Step 2–Develop the Fire PRA LERF/CLERP Model:

  The same discussions apply to the LERF and conditional large early release probability (CLERP) model as in Step 1 above. Under certain POS conditions, the containment may be open to the atmosphere. In that case, the LERF model could be very simple compared to the at-power containment failure models. The model complexity would depend mainly on the extent to which potential recovery actions are modeled. If, for example, the analysis includes the potential for isolating containment then the time available, required support systems, environment inside containment, evacuation times for plant personnel, and other factors would need to be considered and many of these may be POS-specific. This would, of course, provide a more realistic analysis result, but would also represent a higher analysis burden. The expectation of this framework is that the decision to pursue higher levels of detail would be left to the analyst and would be based on the goals of the analysis and, at least in part, on the risk results given a more simplistic model (e.g., the burden might not be warranted for very low risk POSs). If the containment is closed, the analyst should develop a LERF model based on the internal events LPSD model and review and verify the applicability of equipment failures and operator actions as in the case of the CDF model.

4.6 Task 6: Fire Ignition Frequencies

4.6.1 Background Information

Similar to Task 6 of reference [1], the LPSD fire PRA should estimate fire-ignition frequencies and their respective uncertainties for ignition sources and compartments. The ignition frequency task represents the first step in quantifying fire scenarios as they are defined and analyzed in later tasks. A generic set of fire-ignition frequencies for various generic equipment types (ignition sources) typically found in certain plant locations was developed as a starting point for the at-power analysis. The same analysis approach described in Task 6 of reference [1] applies to LPSD conditions with a few exceptions as discussed below.

The frequencies provided in reference [1] were based on events that either occurred during all operating modes or just during power operation including startup. That is, as a part of the at-power methodology development, each of the identified fire ignition source bins was reviewed. Judgment was applied to assess whether or not the frequency of fire events would be substantially dependent on the plant operating mode. Two fire frequency cases resulted as follows:

- Case 1: If the fire ignition frequency of an ignition source bin was judged to be independent of the operating mode, then the fire frequency analysis considered all fire events occurring over all plant operating states and the corresponding years of reactor experience. For these fire frequency bins, no changes are needed and the at-power fire frequency values apply to the LPSD fire PRA unchanged.
- Case 2: If the fire ignition frequency for a fire ignition source bin was judged to be dependent on the plant operating mode, then only those fire events occurring during plant power operations, *including startup operations (mode 2)*, were considered along with the corresponding at-power reactor experience (i.e., excluding the fraction of the time that the plants were not in power mode) in developing the at-power fire frequency estimates.

Ignition source bins falling into Case 2 require re-analysis to estimate fire frequency for plant shutdown modes only. These results are provided in Table 2 and include both the shutdown fire frequencies and, as applicable, split fractions by fire type.

Details relating to the decision as to which case the various fire ignition source bins were assigned are provided in reference [1] and have not been repeated here. In general terms those decisions were based on several factors summarized as follows:

- Location: Some locations were expected to have higher fire frequencies given LPSD conditions so frequency bins associated with those locations were assigned to case 2. The most obvious example here is containment.
- Activity-related fires: Both transient fires and hot work related fires are associated with maintenance activities and, given an increase in the level of related activities during LPSD conditions as compared to at-power, all related fire frequency bins were assigned to case 2.

- Equipment operating state: Some equipment is operated only during start-up or at-power conditions and would not be expected to see fires during other LPSD modes (e.g., the main generator set). Frequency bins associated with these items were assigned to Case 2. In contrast, some equipment such as electrical cabinets were assumed to be either energized at essentially all times or rotated in and out of service at various times independent of the operating mode. Frequency bins associated with these items were assigned to Case 1.

Table 1 provides the list of bins that fell into the second case. For these bins, a reanalysis of the fire frequency has been performed and shutdown-specific fire frequency values and, as applicable, fire type split fractions determined. Note the following:

- The analysis presented here is based on the same fire event database and the same fire event set as was used in the original development work for the at-power methodology [1]. A collaborative effort is currently underway involving both RES and EPRI to develop a more comprehensive and current fire event database that will include fire events during shutdown. It is expected that a re-analysis of all of the shutdown fire frequency bins will be undertaken once the database has been completed. Hence, the fire frequencies presented here should be considered illustrative interim values.

- One event involving a gas-turbine was observed during LPSD operation that was not considered in the at-power analysis. Since the number of gas-turbines and corresponding experience base (i.e., total number of operating years) is not readily available, an ignition frequency for this bin is not estimated.

- Fires are not considered plausible inside inerted BWR containments in the at-power fire PRA. In contrast, several transient and hot work events have taken place inside BWR containments during shutdown, events not considered in the at-power analysis. Since BWR and pressurized water reactor (PWR) containments are quite different, a new bin is defined specifically for transient and hot-work fires in BWR containments (bin 3B) and the PWR containment transient and hot-work fire bin has been renamed (bin 3P rather than simply bin 3 as in the at-power set).

- Note that there is a short period of time during which BWRs, while still at-power, will typically begin containment de-inerting in advance of a planned outage.[10] The corresponding time window is short (on the order of 24 hours) over which time the plant remains in mode 1 and the level of inerting (i.e., nitrogen concentration) is slowly reduced. There was no intent in the at-power fire PRA methodology to treat this unique transitional time period and no fire frequencies were calculated to support such analysis. However, it would be appropriate for BWRs to consider this transitional state as a part of a LPSD analysis. It is expected that insights from the shutdown mode containment fire analysis could be extrapolated to this transitional period just as at-power fire analysis results (e.g., fire growth, damage and suppression results) are extrapolated to LPSD conditions. Because entry into containment is still prohibited, any such anlaysis should consider the potential for fires involving cables, oil, and electrical equipment only (e.g., not hot work or transient fires).

- The shutdown frequencies are considered applicable to operation in modes 3-5. The power operation values are applicable to modes 1 and 2 (i.e., to start up, intermediate transitional power levels, operation at 100% power transitions, and the transition from at-power to shutdown prior to entering mode 3).

[10] Based on insights from the tabletop exercise, typical BWR outage schedules call for initiation of containment de-inerting efforts prior to the plant being taken off-line so that the inerted atmosphere does not become an obstacle to containment entry once the other environmental factors (e.g., temperature and radiation conditions) become amenable for entry. A 24 hour transition window was cited as typical.

Table 1: Fire Ignition Frequency Bins Specific to LPSD Conditions.

Bin #	Location	Ignition Source (Equipment Type)
2	Containment (PWR)	Reactor Coolant Pump (RCP)
3P	Containment (PWR)	Transients and Hotwork
3B	Containment (BWR)	Transients and Hotwork
5	Control/Aux/Reactor Building	Cable fires caused by welding and cutting
6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting
7	Control/Aux/Reactor Building	Transients
11	Plant-Wide Components	Cable fires caused by welding and cutting
20	Plant-Wide Components	Off-gas/Hydrogen Recombiner (BWR)
22	Plant-Wide Components	Reactor protection system (RPS) motor-generator (MG) Sets
24	Plant-Wide Components	Transient fires caused by welding and cutting
25	Plant-Wide Components	Transients
27	Transformer Yard	Transformer – Catastrophic
28	Transformer Yard	Transformer - Non Catastrophic
29	Transformer Yard	Yard transformers (Others)
31	Turbine Building	Cable fires caused by welding and cutting
32	Turbine Building	Main Feedwater Pumps
33*	Turbine Building	Turbine Generator (T/G) Exciter*
34	Turbine Building	T/G Hydrogen
35	Turbine Building	T/G Oil
36	Turbine Building	Transient fires caused by welding and cutting
37	Turbine Building	Transients

* Bin #33 frequency was not quantified assuming that under all POS conditions, the main generator would not be generating power.

As in reference [1], the combination of locations and equipment types (ignition source) are referred to here as ignition frequency bins. Table 2 provides the list of these bins and their respective generic mean frequencies (i.e., the mean value of the uncertainty distribution) in terms of the number of events per year assuming that the plant is in the specific operating mode the entire year. Table 2 is the LPSD version of the original study (i.e., Table 6-1 of reference [1]). Most of the values presented in Table 2 are identical to those presented in reference [1]. New shutdown frequencies have been calculated here but only for those ignition frequency bins identified in Table 1. All of the other ignition source bins (i.e., those not in

Table 1) have simply been reproduced here directly from Table 6-1 of reference [1] with no change in value.

Appendix A describes the frequency analysis approach, assumptions and derivation method. The general approach is the same as that applied to the at-power fire frequency analysis. It should be noted that proposed modifications to various ignition source bins for at-power conditions have been put forth via the NFPA-805 Frequently Asked Questions (FAQ) process (see FAQ08-0048 in the NRC Agency-wide Documents Access and Management System (ADAMS) accession number ML092190457). The FAQ proposes that a change (reduction) in fire frequencies was observed after 1990 and recalculates fire frequencies on that basis. The analysis presented in this document (i.e., in Appendix A) uses the complete set of fire event data consistent with the original treatment in NUREG/CR-6850. That is, the analysis performed here does assume that general fire frequencies dropped beginning in 1990. This approach preserves a larger event set for the LPSD-specific fire frequency bins.

There is an ongoing effort between NRC/RES and EPRI to develop an enhanced fire event database that should resolve this frequency trend issue. The analyst should be aware that a new set of fire frequencies for both at-power and LPSD conditions will likely be developed in the near future.

As with the at-power analysis, a two-stage Bayesian update method [6] was used to account for plant-to-plant variability. The 5^{th}, 50^{th} and 95^{th} percentiles of the uncertainty distributions are also provided in Appendix A. As in at-power fire PRA, single stage Bayesian update methods can be used to modify the generic frequencies to reflect the influence of plant specific fire event experience.

As in reference [1], different fire types can be postulated for some of the ignition sources. For example, the bin "plant-wide components/pumps" can refer to both electric and oil fires. In those cases, Table 2 provides a split fraction for each fire type. The split fraction was determined according to fire events in the FEDB. Continuing with the plant-wide-components/pumps example, the pump fire events in the database were reviewed and classified as oil or electrical fires. This classification serves as the basis for the split fraction.

If the quantification process needs the fire frequency associated with a compartment, the following equation remains valid for the LPSD operating modes:

$$\boldsymbol{\lambda_{J,L} = \Sigma\, \lambda_{IS}\, W_L\, W_{IS,J,L}}$$

where the right-hand side is summed over all ignition sources (IS) in compartment J of location L and where:

$\lambda_{J,L}$ = Compartment (J) level fire frequency

λ_{IS} = Plant-level fire frequency associated with ignition source IS

W_L = Location weighting factor associated with the ignition source

$W_{IS,J,L}$ = Ignition source weighting factor reflecting the quantity of the ignition source type present in compartment J of location L.

Note that the frequencies presented in Table 2 are instantaneous values that are assumed to remain constant over the POS. As presented in Section 3.0 above, the CDF calculated based on these frequencies should be adjusted for the fraction of the time that the plant is in the specific operating mode.

Plant-level fire frequencies (i.e., λ_{IS}) are either taken directly from Table 2 or can be updated using plant-specific fire experience. The location weighting factor, W_L, adjusts the frequencies for those situations where a common location (e.g. turbine building) or set of equipment types are shared between multiple units. The ignition source weighting factor, in general terms, is the fraction of an ignition source type found in a specific compartment. The discussions provided in reference [1] for these parameters apply to LPSD conditions as well.

4.6.2 Assumptions

The same set of assumptions as in reference [1] applies to LPSD fire ignition frequencies. Because of their importance, they are repeated below with specific comments relative to the LPSD fire PRA:

- Fire ignition frequencies remain constant over time.
- Among the plants, total ignition frequency is the same for the same equipment type, regardless of differences in the quantity and characteristics of the equipment type that may exist among the plants.
- Within each plant, the likelihood of fire ignition is the same across an equipment type. For example, pumps are assumed to have the same fire ignition frequency regardless of size, usage level, working environment, etc.
- The ignition frequency is the same among all POSs covered by a specific frequency value.
- The POSs covered by a frequency value are indicated in Table 2 under the column labeled "mode basis." For some fire ignition source bins, the fire frequencies are assumed to be the same for all modes of operation (modes 1-5) and in the table this is indicated as "Mode basis: All." For other cases, the frequencies are split between power operation POSs including low-power (i.e., modes 1 and 2) and shutdown POSs (modes 3-5) as indicated in Table 2 by "Mode Basis : Split."
- Clearly there are marked differences among the POSs that might influence the ignition frequencies. The level of detail provided in FEDB could not support a meaningful resolution among POSs. Therefore, one set of frequencies were estimated for all the SD POSs and, as noted above, in some cases these values are also the same for at-power conditions.

With respect to the last two assumptions in particular, these are based largely on (1) the manner in which fire events were binned for the at-power methodology (i.e., having included fire events occurring during plant start-up in particular) and (2) limitations to the current FEDB which contains insufficient detail to allow for a division of fire frequencies among various LPSD POSs. It may be possible to relax these assumptions in the future and the authors are aware of current efforts to update the EPRI FEDB. However, pending the outcome of the update effort, these assumptions are considered undesirable but necessary.

4.6.3 Procedure

The same procedure as in reference [1] applies to LPSD conditions. The following general conditions apply as in the at-power case:

- This task needs the list of unscreened PAUs generated in Task 4, Qualitative Screening, to establish fire frequencies by compartment. There is one aspect of this effort that is unique for the LPSD context as compared to the at-power context, and that has to do with where fires are assumed to occur. The general intent of the approach is to maintain a consistent set of potentially risk-relevant plant fire locations across all modes of plant operation.
- For the at-power analysis, fixed fire ignition sources are not counted in plant locations that fall within the global analysis boundary but are screened out qualitatively. This reflects the fact that fire events occurring in such areas (e.g., office buildings, security access areas, parking lots) are screened out of the fire frequency calculation. Similarly, transient and hot work fire frequencies are not allocated to these locations during the at-power analysis.
- For the LPSD analysis the decision to count or not count a location will not be made *on a POS basis*. As a result, in the LPSD analysis locations where fixed ignition sources *are* counted *may screen out qualitatively* for one or more LPSD POSs. The general expectation is that, unless new unscreened locations have been added during Task 1, the locations where fixed ignition sources are counted for the at-power fire PRA should match those counted for the LPSD fire PRA; that is, the

location set should be the same for all POSs. This approach will also maintain consistent fixed fire ignition source counts for all POSs.

- The numerical values assigned to location specific transients and hot work weighting factors will likely change depending on POS conditions (as discussed further below) but, in the same context, transient and hot work fires are apportioned plant-wide to the same set of fire locations for which fixed ignition source counts are obtained. Again, some of these locations may not contribute to risk for a given POS and may be screened out qualitatively.

- Fire event records available at the plant applicable to the bins defined in Table 1 may be used to update ignition frequencies of those bins using plant-specific data. (Note that it is assumed that the frequencies of the bins not included in Table 1 are already examined for plant specific fire experience and other conditions as part of the at-power fire PRA.)

- For consistency, all fire frequencies are reported on, in effect, a per-mode-year basis (i.e., as if the plant would operate in the given mode for a full year). No adjustments have been made for the *fraction* of time spent in any given operating mode. Rather, the frequencies use the total number of years logged by the U.S. reactor fleet either in all modes of plant operation (i.e., for bins that are assumed to be the same for at-power and SD conditions) or total years spent in SD operating modes (for bins where a unique SD value is given) as the basis for calculation.

- At least one plant or unit walkdown is recommended to identify ignition sources. The impact of the insights gained would be enhanced if multiple walkdowns are performed over the course of different outages and encompassing different POSs with those insights incorporated over time as a part of PRA maintenance efforts. In the case of LPSD, it is expected that transient and hot work related fire frequencies would be different from at-power conditions. Those parts of the plant where maintenance activities are planned may need to be examined carefully. Plant personnel involved in planning the outage may need to be consulted to establish the type and range of transient activities to establish the types of ignition sources that may be introduced in certain compartments. It is recommended that the analyst consult with outage planes and maintenance supervisors as a part of this effort. Consulting records from previous outages may also provide insights relative to both hot work activities and the introduction of transient combustibles.

Table 2: Fire frequency bins, generic frequencies and fire type split fractions for use in the analysis of shutdown modes of plant operation (for at-power and low-power operation modes 1 and 2 see reference [1])

Bin #	Location	Ignition Source (Equipment Type)	Mode Basis for Frequency Calculations (All Modes or Split – see text)	Generic Freq (per yr)	Split Fraction for Fire Type					
					Electrical	Oil	Transient	Hotwork	Hydrogen	High energy arc fault (HEAF)
1	Battery Room	Batteries	All	7.5E-04	1	0	0	0	0	0
2	Containment (PWR)	Reactor Coolant Pump	Split	6.6E-03	0.25	0.75	0	0	0	0
3P	Containment (PWR)	Transients and Hotwork	Split	3.1E-02	0	0	0.39	0.61	0	0
3B	Containment (BWR)	Transients and Hotwork	Split / Shutdown modes only	3.5E-02	0	0	0.29	0.71	0	0
4	MCR	Main Control Board (MCB)	All	2.5E-03	1	0	0	0	0	0
5	Control/Auxiliary/Reactor Building	Cable fires caused by welding and cutting	Split	1.2E-03	0	0	0	1	0	0
6	Control/Auxiliary/Reactor Building	Transient fires caused by welding and cutting	Split	9.3E-03	0	0	1	0	0	0
7	Control/Auxiliary/Reactor Building	Transients	Split	4.7E-03	0	0	1	0	0	0
8	Diesel Generator Room	Diesel Generators	All	2.1E-02	0.16	0.84	0	0	0	0
9	Plant-Wide Components	Air Compressor	All	2.4E-03	0.83	0.17	0	0	0	0
10	Plant-Wide Components	Battery Chargers	All	1.8E-03	1	0	0	0	0	0
11	Plant-Wide Components	Cable fires caused by welding and cutting	Split	8.8E-04	0	0	0	1	0	0
12	Plant-Wide Components	Cable Run (Self-ignited cable fires)	All	4.4E-03	1	0	0	0	0	0
13	Plant-Wide Components	Dryers	All	2.6E-03	0	0	1	0	0	0
14	Plant-Wide Components	Electric Motors	All	4.6E-03	1	0	0	0	0	0
15	Plant-Wide Components	Electrical Cabinets	All	4.5E-02	1	0	0	0	0	0

Table 2: Fire frequency bins, generic frequencies and fire type split fractions for use in the analysis of shutdown modes of plant operation (for at-power and low-power operation modes 1 and 2 see reference [1]) (continued)

Bin #	Location	Ignition Source (Equipment Type)	Mode Basis for Frequency Calculations (All Modes or Split – see text)	Generic Freq (per yr)	Split Fraction for Fire Type					
					Electrical	Oil	Transient	Hotwork	Hydrogen	High energy arc fault (HEAF)
16	Plant-Wide Components	High Energy Arcing Faults[1]	All	1.5E-03	0	0	0	0	0	1
17	Plant-Wide Components	Hydrogen Tanks	All	1.7E-03	0	0	0	0	1	0
18	Plant-Wide Components	Junction Boxes	All	1.9E-03	1	0	0	0	0	0
19	Plant-Wide Components	Misc. Hydrogen Fires	All	2.5E-03	0	0	0	0	1	0
20	Plant-Wide Components	Off-gas/Hydrogen recombiner (BWR)	Split	2.0E-02	0	0	0	0	1	0
21	Plant-Wide Components	Pumps	All	2.1E-02	0.54	0.46	0	0	0	0
22	Plant-Wide Components	RPS MG sets	Split	3.2E-03	1	0	0	0	0	0
23a	Plant-Wide Components	Transformers (Oil filled)	All	9.9E-03	0	1	0	0	0	0
23b	Plant-Wide Components	Transformers (Dry)			1	0	0	0	0	0
24	Plant-Wide Components	Transient fires caused by welding and cutting	Split	1.1E-02	0	0	0	1	0	0
25	Plant-Wide Components	Transients	Split	5.8E-03	0	0	1	0	0	0
26	Plant-Wide Components	Ventilation Subsystems	All	7.4E-03	0.95	0.05	0	0	0	0
27	Transformer Yard	Transformer - catastrophic	Split	7.2E-03	0	1	0	0	0	0
28	Transformer Yard	Transformer - noncatastrophic	Split	3.8E-03	1	0	0	0	0	0
29	Transformer Yard	Yard Transformers (others)	Split	2.0E-03	1	0	0	0	0	0
30	Turbine Building	Boiler	All	1.1E-03	0	1	0	0	0	0

Table 2: Fire frequency bins, generic frequencies and fire type split fractions for use in the analysis of shutdown modes of plant operation (for at-power and low-power operation modes 1 and 2 see reference [1]) (continued)

Bin #	Location	Ignition Source (Equipment Type)	Mode Basis for Frequency Calculations (All Modes or Split – see text)	Generic Freq (per yr)	Split Fraction for Fire Type					
					Electrical	Oil	Transient	Hotwork	Hydrogen	High energy arc fault (HEAF)
31	Turbine Building	Cable fires caused by welding and cutting	Split	1.3E-03	0	0	0	1	0	0
32	Turbine Building	Main feedwater pumps	Split	1.9E-03	0	1	0	0	0	0
33	Turbine Building	T/G exciter	Power modes only	6.2E-04	1	0	0	0	0	0
34	Turbine Building	T/G hydrogen	Split	3.0E-03	0	0	0	0	1	0
35	Turbine Building	T/G oil	Split	2.5E-03	0	1	0	0	0	0
36	Turbine Building	Transient fires caused by welding and cutting	Split	2.2E-02	0	0	1	0	0	0
37	Turbine Building	Transients	Split	1.0E-02	0	0	1	0	0	0

As in reference [1], this task is organized around the following eight steps:

- Step 1 Mapping plant ignition sources to generic sources,
- Step 2 Plant fire event data collection and review,
- Step 3 Plant specific updates of generic ignition frequencies,
- Step 4 Mapping plant-specific locations to generic locations,
- Step 5 Location weighting factors,
- Step 6 Fixed fire ignition source counts,
- Step 7 Ignition source weighting factors, and
- Step 8 Ignition source and compartment fire frequency evaluation.

These steps are further discussed below:

- Step 1: Mapping Plant Ignition Sources to Generic Sources

This step should already be completed as part of the at-power fire PRA. That is, the characteristics of fixed ignition sources in the plant should not change based on POS in the context of this step. If any new plant locations have been added to the LPSD study, then some additional mapping may be required.

Note that some consideration will be needed for temporary equipment brought in to support a planned outage (e.g., compressors, generators, welding sets, pumps, etc.). It is possible, but not recommended, to establish a revised ignition source count for each such class of equipment whenever substantial temporary equipment is brought into the plant. This would reduce the individual fire source frequency values by a very modest amount in most cases (i.e., the population of temporary equipment will likely be small compared to the normal population of equivalent items). There is a substantial advantage to maintaining consistent fixed ignition source counts across all POSs and from outage to outage. As an alternative to updating the fixed source counts to include temporary equipment, it is recommended that temporary equipment be assigned a fire frequency equal to that applied to any single item of a similar type that is fixed in the plant without altering the based equipment count. This approach will result in a very modest conservatism relative to fire frequency.

Also note that some smaller items that may be introduced into the plant would fall under the umbrella of potential transient ignition sources rather than fixed equipment items. This would include items such as a small hand-portable compressor. It is recommended that only larger equipment items (e.g., skid-mounted equipment or equipment that requires mechanized handling equipment such as a fork-lift, crane or pallet jack) be treated as if they were fixed ignition sources. The smaller hand-portable equipment items should be classified as potential transient ignition sources.

- Step 2: Plant Fire Event Data Collection and Review

For fire event data collection and review, the same approach as that presented in reference [1] can be followed for LPSD operating modes. In this case the fire events that had occurred during LPSD operating modes are collected and analyzed. The same two questions, as in at-power case apply here:

(1) Are there any unusual fire occurrence patterns in the plant?

(2) Is plant-specific fire frequency evaluation warranted?

Guidance provided in reference [1] on determining the response to these two questions applies to LPSD operating modes as well. Recall that in performing the event review, the POS at the time of the fire is of interest and currently would be either power operations (modes 1 and 2) or shutdown operations (all other modes).

- Step 3: Plant Specific Updates of Generic Ignition Frequencies

As in reference [1], this step should be followed for those frequencies that will be updated based on plant-specific fire event data. The approach described in reference [1] applies here with the exception of one minor difference. The generic bin frequencies can be updated using a Bayesian approach [6] that includes Poisson distribution for the likelihood function of plant specific fire events. The Poisson distribution requires number of reactor years (T). In the case of LPSD operating modes, this should be the total time that the affected unit has been in LPSD operating modes since commercial operation (i.e., "reactor-in-LPSD-years" rather than "reactor-at-at-power-years.").

- Step 4: Mapping Plant-Specific Locations to Generic Locations

The location mapping of the at-power fire PRA should be validated for LPSD specific conditions. For example, in the case of the BWRs, the containment may need to be added to the list because maintenance work may be scheduled inside the containment.

- Step 5: Location Weighting Factor

Plant configuration may be reviewed to verify that changes planned for LPSD conditions do not affect W_L. For example, if Unit 1 is shutdown with several systems under maintenance and part of Unit 2 systems are used to provide the necessary functions, the fire PRA analyst may need to include parts of Unit 2 in the Unit 1 analysis. In such a case, the analyst should define the method for counting ignition sources carefully so that relevant compartments and ignition sources from Unit 2 can be correctly included in the Unit 1 LPSD fire PRA. To further expand this example, consider 10 pumps in Units 1 and 2 each and two of the Unit 2 pumps are being used for Unit 1 service during a specific LPSD operating mode. Also, consider that those two pumps are located in the same compartment, J, with 3 other Unit 2 pumps (total of 5 pumps). The fire ignition frequency in that compartment associated with pump operation would then be calculated by the following equation:

$$\lambda_{J,\,pump} = \lambda_{bin\,21} \times W_{IS,\,J,\,L} \times W_L$$

where:

$\lambda_{bin\,21} = 2.1 \times 10^{-2}$ per reactor year, frequency of a fire from any one of the pumps in one of the two units.

$W_{IS,\,J,\,L} = 5/20$ Fraction of the pumps present in this room with respect to all the pumps in the two units

$W_L = 2$ The correction factor for counting both units in the total pump count

- Step 6: Fixed Fire Ignition Source Counts:

To estimate the frequency of fire occurrence per ignition source or per compartment, it is necessary to obtain the total number of items within a unit that belong to each bin. The counting approaches recommended in reference [1] augmented by responses to the FAQs generated after the publication of reference [1] should apply to LPSD operating modes. Generally, the number of countable items (e.g. pumps and electrical cabinets) should remain the same between at-power and LPSD conditions. However, for those bins for which LPSD specific ignition frequencies are established, the analyst should review the equipment configurations during LPSD conditions to verify that at-power counts remain valid. Transients and hot work related ignition source weighting factors could be different during LPSD operating modes, which is discussed as part of Step 7 below.

It is expected that various temporary components may be introduce in the plant site. This would typically include air compressors, ventilation fans, electric generators, and other similar equipment that would normally fall under the umbrella of various fixed ignition source bins. The treatment of these items for fire frequency needs some consideration. It is expected that relatively few such items will be introduced so that revising the plant-wide component counts would yield minimal changes. As an alternative, it is recommended that temporary items of this type simply be assigned a frequency consistent with one such item based on the nominal population count obtained for the at-power analysis. This would result in a very modestly conservative frequency value for such items, but would substantially reduce the work burden.

- Step 7: Ignition Source Weighting Factors:

The Ignition source weighting factor, $W_{IS,J,L}$, is the fraction of ignition source (IS) that is present in compartment J. The $W_{IS,J,L}$ are evaluated for all the ignition sources identified in Step 1 of this task and all the compartments identified in Task 1. The bins listed in the preceding section can be classified in three categories: countable items, transients, and large systems. The procedure presented in reference [1] for all three types of items should apply to LPSD operating modes.

It is anticipated that the relative likelihood of transient and hot-work related fires in various plant locations will shift during LPSD operations as compared to at-power operation and the analysis should account for these differences. Transient combustible controls programs are expected to be maintained during shutdown much as they are during power operations, although the restrictions (e.g., combustible material limits) may be relaxed in specific locations and a larger number of combustible material permits are likely to be issued. Transient materials not expected to be found during at-power operations (e.g., larger quantities of grease or oil and various equipment packing materials) may be introduced into the plant given that a range of longer-term maintenance activities will be undertaken. Hot work (e.g., welding and cutting) may be allowed in locations where that type of work would normally be disallowed during power operations. Plant traffic and occupancy factors would also be different.

It is in practice possible that plant practices relative to allowing hot work and transients in specific locations may shift from outage to outage or even within an outage. For example, the practices may be different for locations associated with the available or operating equipment train(s) as compared to locations associated with an out-of-service train. Given that the status of equipment trains may change from outage to outage or within an outage, the potential for hot work and transient fires might also change. One suggestion arising from the tabletop exercise was to allow for a matrix approach to transient and hot work ranking that would equate the ranking factors to POSs or to train availability/outage status. This would substantially complicate the weighting factor approach, but may be appropriate especially given plant practices that would tie the hot work and transient permitting system to equipment status (e.g., protected train type approaches). No development work on this concept has yet been undertaken.

As a result, for the ignition source bins related to “general transients” (i.e., bins 3A, 3B, 7, 25 and 37), “transient fires caused by welding and cutting” (i.e., bins 6, 24, and 36) and “cable fires caused by welding and cutting” (i.e., bins 5, 11 and 31) the influencing factors assigned to each compartment should be adjusted to reflect the specific LPSD conditions. This will require updating of the location-specific frequencies accordingly. For example, for those compartments where maintenance work is planned, “very high” may be assigned to the maintenance factor. For the passageways that lead to that compartment, the occupancy factor could be “high” as well.

The recommended approach to assigning activity-related weighting factors is to begin with the at-power designations for each location and to adjust those factors to reflect the outage conditions. If the general trend is towards a greater level of such activities, this would imply that the “typical” ranking value, which for at-power conditions was expected to be “3”, might be higher when analyzing shutdown conditions (e.g., an assigned value of 10 or 50 would likely be more common). The weighting factor approach self-corrects to maintain the overall plant-wide fire frequency, but the assigned ranking factors would also reflect activity levels for specific locations under at-power versus shutdown conditions.

One final correction factor should be applied for activity-related fires that may be plausible only during a specific fraction of an outage. There is no intent to force an analysis of activity related fires for POSs where the corresponding activities are precluded by the plant conditions. In particular, transient and hot work fires inside containment should only be postulated during POSs where the containment is accessible to plant personnel doing maintenance work (i.e., hot work or work involving introduction of transient combustibles). However, if this approach is taken, then the fire frequencies would need correction in order to preserve the total fire frequency. This correction would be a simple multiplier based on the fraction of the total outage duration that the fire source is considered plausible. To illustrate, if transient and hot work fires inside containment are only postulated when the containment is open and accessible, and that condition is active for 90% of an outage, then the corresponding hot work and transient fire frequencies would be multiplied by (1.0/0.9 = 1.1) to correct for the shortened time window.

- Step 8: Ignition Source and Compartment Fire Frequency

Fire frequencies (generic or plant-specific) for a single fire ignition source, $\lambda_{IS\text{-}J}$, and fire frequencies for an entire PAU (i.e., considering the combined frequency for all ignition sources in the PAU) are calculated using the same process as was described in reference [1].

4.7 Task 7: Quantitative Screening

The objective of this task is to apply quantitative screening criteria to reduce the list of PAUs and fire scenarios carried forward for detailed analysis. This is an important task used commonly in fire PRA to limit the level of effort and yet maintain the integrity of the analysis. Screening does not imply *removing* a PAU or fire scenario from the analysis. Rather screening simply implies that no further analysis effort (e.g., to increase the level of analysis detail) will be expended on that scenario or PAU. The CDF and LERF of the screened PAU or scenario would be based on the existing level of detail (a screening result) and the risk contribution would be ranked among all other PAUs and fire scenarios on that basis.

For at-power PRA, screening criteria are defined in reference [1] for CDF, LERF, incremental core damage probability (ICDP) and incremental large early release probability (ILERP). The same criteria may be used for LPSD fire PRA. For ease of reference, the criteria presented in reference [1] are repeated here in Tables 3 and 4. Note that the quantitative measures (e.g., CDF) are expressed in reactor years, which means that they *include the fraction of time that the plant is in the postulated POS*.

Also note that screening based on ICDP and ILERP are considered *optional* in the at-power methodology and are also considered optional for the LPSD fire PRA. These concepts generally derive from certain risk applications, such as an on-line risk monitor, and involve screening that is based on the sensitivity of the risk results (CDF and LERF) to the availability of credited mitigating equipment on a train or system level.[11] For such applications, there may be unique perceptions of risk importance for a PAU that would be captured by the optional screening criteria.

The criteria presented in Tables 3 and 4 may be met by reducing the duration of a POS. One then may argue that defense in depth can be reduced significantly while meeting the screening criteria. Defense in depth related and all other regulatory requirements remain in effect during a POS. The PRA provides a measure to establish the overall risk and relative ranking of various contributors that can be used to determine if added risk reduction measures are necessary and where those measures can be most effective.

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[11] The ICDP and ILERP screening approaches are explained more fully in NUREG/CR-5593, *Risk Comparisons of Scheduling Preventive Maintenance for Boiling Water Reactors During Shutdown and Power Operations*, U.S. NRC, April 1999.

Table 3: Quantitative Screening Criteria for Single PAU Analysis.

Quantification Type	CDF and LERF Compartment Screening Criteria	ICDP and ILERP Compartment Screening Criteria (Optional)
PAU CDF	CDF < 1.0E-07/year* *Note: This criterion should be reduced, as necessary, to ensure that the CDF criterion in Table 4 is met*.	
PAU CDF with Intact Trains/Systems Unavailable		ICDP < 1.0E-7 *Note: This criterion should be reduced, as necessary, to ensure that the ICDP criterion in Table 4 is met*
PAU LERF	LERF < 1.0E-08/year* *Note: This criterion should be reduced, as necessary, to ensure that the LERF criterion in Table 4 is met*	
PAU LERF with Intact Trains/Systems Unavailable		ILERP < 1.0E-8 *Note: This criterion should be reduced, as necessary, to ensure that the ILERP criterion in Table 4 is met*

* All quantitative measures include the fraction of time that the plant is in the postulated POS.

Table 4: Quantitative Screening Criteria for All Screened PAUs (cumulative).

Quantification Type	Screening Criteria
Sum of CDFs for all screened out PAUs for each POS (or POS group) analyzed	< 0.1 * [Internal Event CDF for the same POS (or POS group)]
Sum of LERFs for all screened out PAUs for each POS (or POS group) analyzed	< 0.1 * [Internal Event LERF for the same POS (or POS group)]
Sum of ICDPs for all screened out PAUs for each POS (or POS group) analyzed	< 1.0E-06
Sum of ILERPs for all screened out PAUs for each POS (or POS group) analyzed	< 1.0E-07

It should be noted that these are suggested screening criteria. The question of LPSD quantitative screening criteria is expected to evolve as the analysis methods mature. Hence, the recommended screening criteria presented here are largely illustrative in nature but parallel those commonly uses in at-power analyses. Also note that the cumulative screening criteria presented in Table 4 compare the LPSD fire PRA to the corresponding internal events LPSD analysis results on a POS by POS basis. The intent of the criteria in Table 4 is to ensure that the total risk contribution for PAUs screened out from the fire PRA analysis (i.e., for all screened PAUs combined) does not exceed certain limits that are set based on the internal events LPSD risk results. This approach is intended, in part, to maintain consistency with this document's neutrality relative to how the POSs to be analyzed are defined, and in particular, with how complete the POS set is. This screening approach works equally well whether the analysis quantifies a complete set of very specific POSs, quantifies a smaller set of grouped POSs, quantifies a generally defined set of average outage conditions, or quantifies just one POS. Moreover, if a large number of PAUs meet the criteria in Table 3, it may not be possible to meet the criteria presented in Table 4. The analyst may encounter this situation after a few screening phases. To meet Table 4 criteria, the analyst may need to adjust Table 3 criteria downward (make the criteria more stringent).

As in reference [1], it should be emphasized that the screening criteria are meant to be applied as part of the fire PRA Model building and quantifying process. The screening criteria are not the same, nor should they be confused with the acceptance criteria for applications of PRA. For example, the screening criteria herein are not directly correlated to the delta-CDF and delta-LERF criteria used in Regulatory Guide 1.174 [7] for the acceptability of making permanent changes to the plant. The screening criteria are intended to complement the Regulatory Guide (RG) 1.174 criteria and to allow for the use of fire PRA results in a RG 1.174 application, but they are also intended to serve the broader objectives of a typical fire PRA.

The overall approach described in reference [1] is applicable to LPSD conditions. The same assumptions and input and output discussions apply here as well. Several stages of quantitative screening are expected to be necessary to identify plant areas that need detailed analysis and establish risk ranking of PAUs and fire scenarios. Four phases of quantitative screening are identified in reference [1] (Tasks 7A through 7D) based on implementation of Tasks 8 through 10 of the methodology. The same phases may be used in LPSD fire PRA. Clearly, conducting a screening phase would depend on the analyst's preferences and the results of each task (i.e., Tasks 8 through 10).

- Step 1–Quantify CDF Model:

The model developed in Task 5 is quantified in this step. The CCDP is quantified first followed by CDF. This step involves 3 sub-steps as follows.

- Step 1.1: Quantify CCDP Model: The CCDP is calculated by setting the fire scenario frequency as 1.0 per reactor year. Event trees and fault trees are quantified using internal events failure probabilities and human error probabilities (HEPs) estimated in Task 12. In the initial stages of screening, the circuit failure probabilities may be set at 1.0 and screening HEPs may be used (see Task 12). In later stages of screening, more refined values may be used. The outcome of this step is a list of PAUs and fire scenarios organized by CCDP. This result provides an important insight into fire risk significance of a PAU or scenario.

- Step 1.2: Quantify CDFs: CDF results can be calculated for a single fire scenario, for a group of fire scenarios (e.g., a group of electrical cabinets), for a PAU, or for the entire plant. Quantitative screening is generally based at the fire scenarios and/or PAU level. For quantification, the fire frequency is matched to the screening level applied (e.g., fire frequency might reflect a single fire source, a group of fire sources, or an entire PAU). The CDF of a specific POS is calculated using the following equation (from Section 3.0 above):

$$CDF_{POS(i)} = CDFPOS(i) \times ft_{POS(i)}$$

Where:

$$CDF_{POS(i)} = \lambda_{fire} \times CCDP_{POS(i)}$$

λ_{fire} = The fire frequency of the PAU or fire scenario (depending on screening level being applied) from Task 6 or Task 11 per reactor year.

$CCDP_{POS(i)}$ = The CCDP of POS(i) calculated in Step 1.1 above.

The fraction of time that POS(i) is in effect (i.e., $ft_{POS(i)}$) is estimated in this step and used in CDF calculation.

In the first quantitative screening stage, the frequency (i.e., λ_{fire}) would be gleaned from Task 6 where fire frequencies are estimated at the PAU level. At later stages of analysis, the refined fire frequency calculated in Task 11 is used. By applying the screening criteria discussed above, PAUs or fire scenarios are set aside from further analysis.

- Step 1.3: Quantify ICDP Values (Optional): This is an optional task that may not be applicable to LPSD conditions since Limiting Conditions of Operation (LCOs) may not be applicable. The same approach may be used as in reference [1] to define and calculate ICDP values.

- Step 2–Quantify LERF Model:

The same formulations and process as for CDF can be used to establish the LERF for each PAU or fire scenario. Similar to Step 1, this step is defined in three substeps where CLERP is calculated first. Similar to CDF, LERF is calculated as the product of CLERP, fire frequency (i.e., λ_{fire}) and fraction of time POS is in effect (i.e., $ft_{POS(i)}$).

- Step 3–Quantitative Screening:

In this step, the CDF, LERF, ICDP (optional), and ILERP (optional) values are compared against the quantitative screening criteria provided in Tables 3 and 4. PAUs and fire scenarios that fall below the screening criteria are screened out from further analysis but retained for overall risk quantification and risk ranking of significant contributors. As this screening task progresses, the analyst may have to reduce the criteria presented in Table 3 to allow the results to meet Table 4 criteria.

4.8 Task 8: Scoping Fire Modeling

4.8.1 General Discussion

Scoping fire modeling is the first task where computational fire modeling tools are used to identify those fixed ignition sources that may impact the fire risk of the plant. Note that transient related ignition sources are not examined in this task. Screening some of the fixed ignition sources, along with the application of severity factors to the unscreened ones, may reduce the compartment fire frequency previously calculated in Task 6.

The process for completing the LPSD fire PRA Scoping Fire Modeling Task is fundamentally the same as the at-power analysis described in reference [1]. The analysis considers the potential for each fire ignition source to induce either fire spread to secondary combustibles or damage to PRA targets (equipment and cables) without fire spread.

For this task, the analyst may, in fact, be able to draw upon results obtained in the at-power fire PRA to a large extent. The nature of the fires associated with fixed fire sources may be independent of the plant operating mode. The nature and proximity of fixed secondary combustibles are also unlikely to change. The primary challenge may lie in two areas; namely, changes to the nature or location of PRA targets and potential changes to the configuration or characteristics of certain types of fixed fire ignition sources.

In the case of PRA targets, several factors could change the relationship between ignition source and target. LPSD fire PRA targets may exist in locations that do not contain at-power fire PRA targets. The damage targets of concern may also change depending on the POS being analyzed, so the analysis needs to either bound all POSs or consider each POS separately. Damage targets may also be of a different type than were considered in the at-power analysis (e.g., a different type of cable or presence of electronic equipment rather than cables as the most easily damaged target).

The second factor that should be considered is the possibility of altered conditions of a fixed ignition source. Altered conditions may lead to a fire more severe than the most severe conditions postulated in at-power analysis for a given ignition source. For example, an electrical cabinet that is normally fully enclosed during at-power operations may be operated with the doors open during a specific POS (e.g., to allow for maintenance or monitoring activities). Opening the cabinet door increases the potential fire intensity and the potential for fire spread outside the cabinet. This could, in turn, affect other aspects of the fire scenario including time to detection and time to fire damage.

4.8.2 Crediting Equipment Operational Status

Altered equipment conditions might also effectively preclude specific types of fires with certain types of ignition sources. For example, a bus duct that has been de-energized during a particular POS cannot act as a source of a high energy arc fault (HEAF) and fire. Other types of equipment that are fully shut down during specific POSs might also preclude, or sharply limit, certain types of fires. For example, an electrical motor fire would not be considered plausible for a motor that is never energized during a particular POS because it is the electric potential that creates the fire hazard.

Whether or not special treatment is warranted for de-energized or non-operating equipment should be determined on a case-specific basis. That is, the analyst should make the argument for elimination or modification of a specific fire ignition source (or a specific type of fire for a given fire ignition source; e.g., electrical fires for a pump) based on the plant configuration and equipment status. The results could then be factored into the scoping fire modeling analysis by incorporating the modified fire characteristics or by screening out the fire source.

There is a substantive difference between at-power and LPSD conditions that impacts the viability of this approach. For the at-power fire PRA, de-energizing plant equipment is not considered as a mitigating factor in the potential for fires to occur [1] largely because the analysis should span all potential operating configurations which could include swapping of active and standby equipment trains. Demonstrating that a specific set of equipment would never be operated or energized during power operations is quite difficult for most of the equipment of interest. The approach is more viable for LPSD plant operations because a broader range of plant equipment will be deenergized and non-operational during certain POSs. For example, unless the plant is actively generating electric power, the turbine generator exciter will not be active, the turbine lube oil system will not be pressurized, and the iso-phase bus duct will be deenergized. For various LPSD POSs, a broad range of reactor systems will be shut down and non-operational (e.g., high pressure flow and inventory control systems during refueling).

As a result, LPSD conditions present a greater opportunity to credit equipment status as a factor in fire likelihood because it will be easier to demonstrate that certain equipment will, in fact, be non-operational and/or deenergized. This is especially true and potentially advantageous for analyses built on a foundation of specific POSs able to deal with specific equipment line-ups. For a detailed outage-specific approach, the analysis could include consideration of the fire potential of equipment based on whether or not that equipment is energized and/or operating (e.g., whether or not electrical potentials are present or whether or not oil systems are pressurized). If the analysis is based on an *average POS* approach, it will be more difficult to argue that certain types of equipment will never be energized. In particular, the analysis would likely not be able to take advantage of train outages for LPSD equipment, but might still take advantage of the shutdown of other equipment exclusively associated with power operations (e.g., BOP equipment).

This concept does, however, introduce complications that cannot currently be fully treated. For example, the approach described above is <u>not</u> equivalent to simply not counting a particular component when developing fire frequencies. Instead, the recommended approach is to count the equipment but to make case- and POS-specific arguments to reduce fire frequencies or to eliminate fire scenarios for specific items under certain conditions. This does introduce an inconsistency in the analysis in that the total plant wide fire frequency for a given class of equipment may not be preserved. The alternative would be to develop unique equipment counts for each POS or even for each phase of a given POS (e.g., with phases associated with periods of specific equipment outages within a POS). This type of approach is not considered practical. In contrast, to ignore equipment operational status entirely would likely mean that unrealistic fire scenarios are carried forward as contributors to fire risk. The recommended approach is a compromise that allows for equipment operating mode to be incorporated into the analysis on a case-specific basis without over-complicating the problem. The results are expected to more accurately reflect real-world plant conditions and risk, albeit at the cost of minor fire frequency accounting errors.

Specific potential considerations in this regard are as follows:

- Portions of a circuit that are isolated from electric power during a particular POS would not be subject to electrical fires. Note that consideration should be given to both power circuits and control circuits. As an example, even if a switchgear breaker is "racked out," if control power remains available, a potential for electrical fires also remains.[12] However, a switchgear breaker that is "racked out" would deenergize the power circuits and cables fed by that breaker eliminating the potential for electrical fires in the downstream power circuits.

- Some lubrication systems may be depressurized during various LPSD POSs. No specific analysis of oil fires in pressurized versus non-pressurized systems has been conducted so it is not possible to speculate on the impact of system pressurization on fire frequencies. Note that for some specific cases LPSD specific fire frequencies have been calculated (i.e., main feedwater pump oil fires and turbine generator lube oil fires) while other cases assume the same fire frequency for all modes of plant operation. In general, two types of oil fires are possible; namely, oil spills burning as a pool fire and pressure-driven oil spray fires. For a normally pressurized oil system that is de-pressurized during LPSD conditions, the potential for an oil spray fire becomes localized to system elements subject to a static pressure head (e.g., leaks at a low-elevation outlet valve on a storage tank). For locations not subject to a static pressure head, a spill consistent with leakage from a non-pressurized system should be assumed. It is common practice to locate oil reservoirs at a relatively low point in the system so much of the system piping for a normally pressurized system will likely be at or near atmospheric conditions when the system is de-pressurized. Some system elements may also be drained of oil. For locations that retain oil, a reduced pressure would also impact potential leak rates. A review of any oil fire scenarios postulated in the at-power fire PRA is recommended to ensure that the assumed fire conditions and characteristics are consistent with the actual status of the lubricating system.

In general, most aspects of the ignition frequency analysis need not be revisited. In particular, de-energized equipment would not need to be removed from the equipment type counts in Task 6 in order to take advantage of these approaches. This recommendation is based on the notion that the Task 6 approach to estimating ignition frequencies inherently reflects the fact that any given piece of equipment will cycle through periods of both in and out of service times. The method does not attempt to estimate, for example, pump operating years but rather uses reactor years as the frequency basis. In the specific case of the LPSD analysis, specific equipment line-ups are likely based on the POS definition, and it would be appropriate to reflect a known line-up to the extent feasible in the risk evaluation.

Beyond these possible modifications, the general task objectives and approach for Task 8 remain the same for LPSD fire PRA**.** The only differences are that in the application of Table 8-1 of reference [1] where one new bin is introduced; namely, Bin 3B, Containment BWR - transients and hot work. Like other transient and hot work fire frequency bins, these ignition sources cannot be screened out in this task. Note again that this task focuses only on fixed ignition sources.

[12] Note that non-operational equipment might still be vulnerable to fire-induced spurious actuation, but this would be a potential consequence of a fire involving some other fire ignition source and not a factor that would contribute to the potential for fire ignition.

4.9 Task 9: Detailed Circuit Failure Analysis

This is the second phase of circuit analysis where circuit operation and functionality are examined to determine equipment responses to specific cable failure modes. These relationships are then used to further refine the original cable selection by screening out cables that cannot prevent a component from completing its credited function. The approach presented in reference [1] should also apply to LPSD conditions. Since control circuits are not generally altered during any LPSD POS, it is anticipated that the analysis done and information generated as part of at-power fire PRA would also be applicable to LPSD conditions. However, it is recommended that as in Task 3, the information obtained from at-power fire PRA be reviewed carefully to verify that it is applicable to the specific conditions imposed by the postulated LPSD POS(s).

In a LPSD fire PRA additional circuits may be identified needing a detailed analysis. The same methodology as that described in Chapter 9 of reference [1] can be applied here to conduct that analysis. This includes adding the new information to the circuit failure data base created as part of at-power fire PRA.

As in at-power fire PRA, the output of this task supports the quantitative screening process under Task 7.

4.10 Task 10: Circuit Failure Mode Likelihood Analysis

The purpose of this task is to estimate the failure mode probabilities of circuits that are identified in the previous tasks for further analysis. As noted in reference [1], the methods and data for deriving circuit failure probabilities are based on limited information and the field continues to evolve. The analyst is encouraged to use the latest information, if this task is included in a LPSD fire PRA.

There is no reason to conclude that the methods and underlying test data used for estimating circuit failure probabilities should be different between at-power and LPSD POS conditions. Therefore, the discussions provided in Chapter 10 of reference [1] should apply to LPSD conditions as well. The assumptions provided in Section 10.3.2 of reference [1] are also applicable to LPSD conditions, except that some of the circuits may be de-energized during a specific POS.

It is anticipated that the majority of circuits that would be identified in Task 9 of LPSD fire PRA for further analysis would have already been addressed in the at-power fire PRA. It is recommended that the existing analyses be reviewed to ensure that all underlying assumptions remain valid under the specific conditions of the LPSD POS. For example, if the analyst adjusted a probability value because of special conditions affecting a cable, the LPSD analysis should confirm that those special conditions remain valid during the postulated POS.

4.11 Task 11: Detailed Fire Modeling

4.11.1 Purpose and Scope

Detailed fire modeling provides the final estimates for the frequency of occurrence of fire scenarios involving a specific fire ignition source failing a predefined target set before fire protection succeeds in protecting this target set. This result is combined in the final quantification steps that follow this task, with the CCDP/CLERP given failure of the target set to estimate the CDF/LERF contribution for each fire scenario. The CCDP/CLERP may include modified human error probabilities based on fire scenario specifics.

The detailed fire modeling process generally follows a common structure, but the details of the analyses often vary depending on the specifics of the postulated fire scenario. This chapter addresses three general categories of fire scenarios: fires affecting target sets located inside one compartment; fires affecting the main control room (MCR); and fires affecting target sets located in more than one PAU (multi-compartment fire analysis).

For LPSD fire PRA, the detailed fire modeling process is generally the same as the RES/EPRI at-power fire PRA methodology in reference [1]. The same input and output information applies. Focused walkdowns are an important part of this task. The supporting information provided in the Appendices of reference [1] is also applicable[13]. Clearly, the analyst should use the latest information applicable to each scenario analysis. Though the general fire modeling approach and process is essentially unchanged between LPSD and at-power, the plant configuration will impact the choice of fire scenario damage targets, and may alter the relationship between fire source and damage targets (e.g., relative locations, damage thresholds, and intervening combustibles). These changes could in turn alter the objectives and results of the detailed fire modeling task. Therefore, to the extent that fire source and target relationships change, fire modeling analyses may need to be repeated for different POSs to ensure that all POS specific factors are incorporated and evaluated.

The ultimate output of Task 11 is a set of fire scenarios, each including:

- a defined fire ignition source;
- a defined target set consisting of those LPSD fire PRA components and cables that are subject to fire-induced damage given ignition of the fire ignition source;
- an estimate of the frequency of fires involving the defined fire ignition source leading to loss of the defined target set (including the fire ignition frequency, applicable severity factors, and corresponding non-suppression probability values); and
- an examination of forced abandonment scenarios involving fire in the MCR or in other plant areas that could lead to MCR abandonment (i.e., due to loss of MCR functions).

4.11.2 General Approach.

The general approach to fire scenario modeling remains the same for the LPSD fire PRA as in the at-power fire PRA [1]. Figure 2 provides a block diagram of the overall process. Note that the step definitions are the same as those cited in reference [1]. Clearly, the special conditions of each POS should be taken into account when conducting each step, but the nature and objectives of each step remain unchanged.

One approach that might work for plant fire protection posture/status changes would be to adopt a binary state analysis approach to specific posture changes. For example, plant practice may require that a fire barrier be breached during certain POSs (e.g., a fire door is opened to allow for routing of temporary cables). For this case, the analysis could consider fire behavior given an intact barrier and given the breached barrier (open doorway) as a binary set. The intact barrier case is essentially the at-power condition and should generally require only limited updating to reflect outage conditions. The second analysis state (e.g., the door has been blocked open) also mirrors the at-power fire PRA to the extent that the multi-compartment scenarios should have included random failure of the same barrier element. The LPSD analysis would likely seek a more detailed analysis of this multi-compartment scenario than was required to meet at-power analysis objectives given, in effect, a barrier failure probability of 1.0. Additional factors specific to the outage conditions might also come into play such as posting of a fire watch and whether or not the barrier can be quickly restored (e.g., the cables removed and the door closed). In the end, the two possible fire barrier states (intact versus breached) could each be addressed

[13] Note that some aspects of various fire modeling approaches have been modified or amended based on feedback from the NFPA-805 pilot plant applications. Modifications documented via the NFPA implementation FAQ process are considered equally applicable to the LPSD fire PRA.

analytically and the results then treated as a binary "pick-list" from which either a generic or outage specific plant status model is developed. This mirrors the approach to POS definition used by one of the two tabletop plants where outage-specific risk profiles were developed by picking POSs from their pre-defined list of 30 POSs. The approach has not yet been fully explored in the fire context.

As in the at-power fire PRA, a detailed fire modeling analysis may be performed for each fire scenario in each unscreened PAU. For the LPSD fire PRA, the focus would be placed on those fire scenarios with the highest contribution to the CDF/LERF and on those fire scenarios where conditions have substantially changed given the LPSD plant conditions. As with the at-power fire PRA, it may be appropriate to develop several fire scenarios for a single PAU in order to appropriately represent the range of unscreened fire ignition sources (i.e., ignition sources that were not screened in Task 8). Here again, most of the likely fire sources, including both fixed and transient ignition sources, will already have been identified and analyzed in the at-power fire PRA. The expectation is that the LPSD fire PRA would focus on scenario changes that are tied to the POS and that substantively impact scenario analysis. Scenario changes of interest could be relatively simple such as the application of LPSD-specific fire frequencies or suppression curves (see discussion below). Other changes could be more complex such as changes in transient fire characteristics (e.g., if larger fuel packages are allowed during an outage than would be allowed at-power) and fire damage target locations relative to the fire source (e.g., given POS specific cable and equipment). The tools available to support the analysis include all those available to the at-power fire PRA such as computational fire models, statistical models, and empirical models.

The factors that may require special consideration for the LPSD fire PRA include the following:

- For certain POSs, the status of compartment boundaries could be significantly different from at-power conditions. For example, during a maintenance outage certain doors that are normally closed may be propped open by temporary piping and cables passing through the doorway, penetrations may be un-sealed to allow for cable or piping work, equipment hatches may be removed, and/or the containment structure may be open. In such cases, the potential for recovery of barrier integrity would also vary widely but should be considered. For example, an open doorway might be easily closed if the obstructions are readily removed, but an open floor-hatch likely could not be replaced quickly.

- As noted with regard to scoping fire modeling (Task 8), the characteristics of an ignition source may be altered. For example, cabinet doors may be opened whereas they are normally closed. (Note that based on Table G-1 of reference [1], open versus closed doors only impacts cabinets containing more than one bundle of un-qualified cables).

- The status of fire detection and suppression systems could be altered. For example, fire protection systems may be unavailable due to maintenance or may be intentionally disabled due to other maintenance activities under way in the protected space (e.g., to prevent spurious actuation).

- Note that both of the plants participating in the tabletop exercise cited that their practice was to maintain fire protection systems in active/available status during planned outages. Both plants recognized a greater potential for fire ignition events during an outage due to the heightened levels of activity and maintenance. Hence, primary fire protection systems (e.g., fire pumps and the fire water system) are maintained fully available and local systems (e.g., local detection or an automatic suppression capability) are only disabled on a case-specific basis and under a strict permitting system with time windows limited as tightly as possible. Both plants cited that routine fire protection system maintenance was scheduled during normal plant operations given the desire to maintain system availability and potential conflicts with other maintenance activities during an outage. This was cited as common industry practice as understood by tabletop participants.

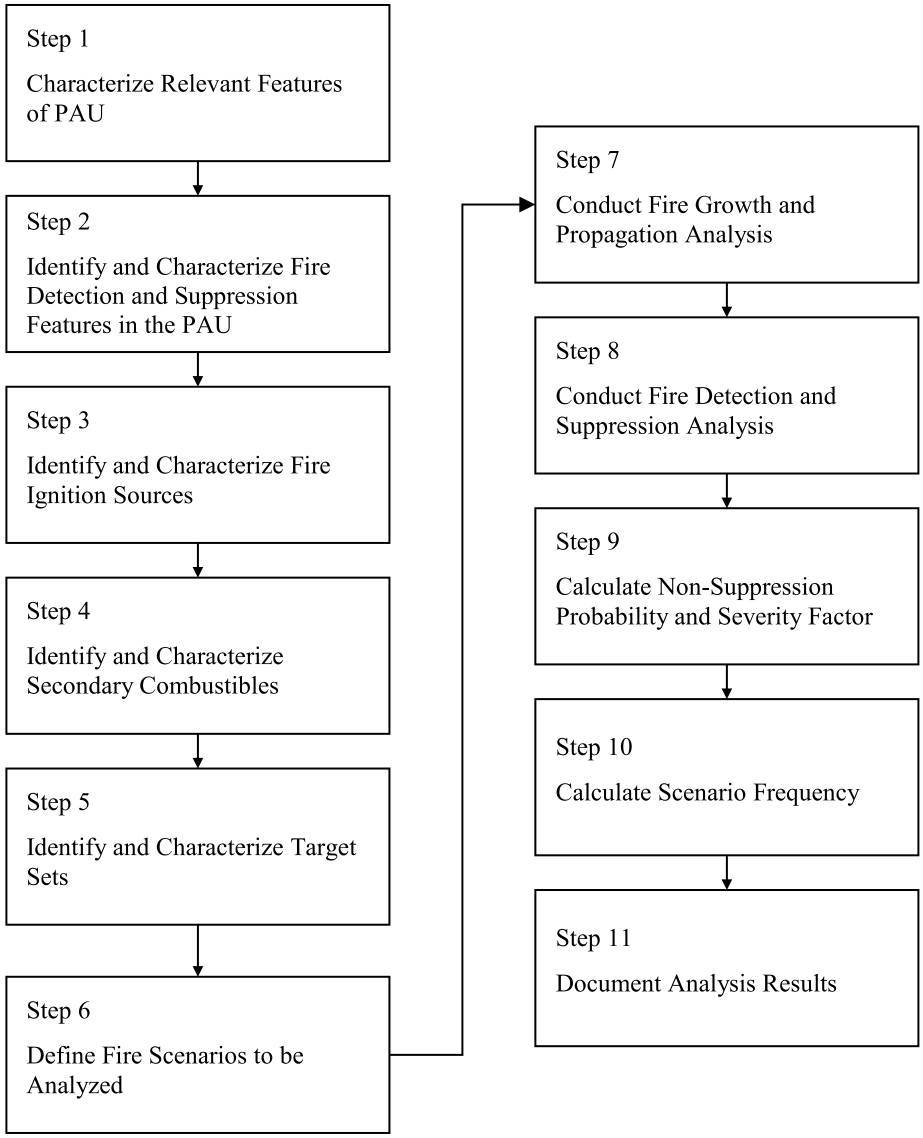

Figure 2: General Analysis Flow Chart for Task 11 – Detailed Fire Modeling.

- Fire brigade access paths may be altered because of maintenance or plant upgrade activities. Fire brigade staffing may, however, increase during an outage given that plants typically shift from three-shifts to two-shifts per day (e.g., splitting the swing shift) so that more staff are on site at any given time including a larger compliment of fire brigade trained staff and operators.
- New transient combustibles may be present in a compartment. For example, packing materials for new or replacement equipment may be introduced, combustible controls restrictions for specific areas may be relaxed, pump oils may be changed out so that a larger quantity of oil than might normally be present is introduced into an area (e.g., both the old oil and new replacement oil loads may be present and exposed), and/or combustible cutting oil may be brought into a compartment for certain repair or modification work.

- Welding and cutting operations may be undertaken in areas where such activities would be either prohibited or very unlikely during at-power operations (e.g., the MCR, cable spreading room, cable vault and tunnel areas, emergency switchgear rooms, etc.).
- Staffing changes could alter fire watches and other general personnel traffic and occupancy patterns. For example, compensatory measure fire watches may be suspended or a space that is not routinely manned during power operations may be manned during a specific POS.
- The containment structure may be open with substantive work activities underway. In particular, for BWRs with inerted containment, de-inerting of the containment introduces a potential for fires in areas never considered in the at-power fire PRA.

The approach for addressing these issues is exactly the same as that described in Table 11-1 of reference [1]. The analyst should simply gather and apply the appropriate data to support the analysis for the POS of interest. There are only two clarifications relative to the application of Table 11-1in the LPSD context as follows:

- Bin 3 has been split into two bins (3P and 3B) for BWR and PRW containments respectively. Note that in reference [1] Bin 3 applies to PWRs only (given that nearly all BWRs have inerted containments during power operations). Bin 3B is added to deal with BWR containment fires during shutdown and the treatment for both 3P and 3B is consistent with that shown for Bin 3 in Table 11-1.
- Bin 33, turbine generator exciter fires, are cited as not considered for non-power operating modes. That is, potentially consequential exciter fires are only postulated for modes where the exciter is in operation.

Note that certain types of fires inherent in the various frequency bins would be adjusted or even eliminated for LPSD conditions although they are not explicitly called out here. For example, catastrophic turbine generator set failure (covered in reference [1] appendix O) would not be considered for POSs where the generator is not spinning. It is expected that common-sense arguments for these cases will be readily made by the analyst and no attempt has been made to call out all such cases here.

It should be noted that, as discussed below, the manual suppression curves may need to be adjusted to reflect either general shutdown conditions and/or the specific conditions of a POS. The available LPSD suppression data were not sufficient to support a statistical analysis of the LPSD versus at-power suppression timing. Hence, it is recommended that a judgment-based adjustment be applied to address the specific plant conditions and changes as compared to at-power conditions pending completion of ongoing fire event database update and analysis efforts. Even given shutdown-specific fire suppression curves, it may not be possible to fully characterize those aspects of the fire scenarios that would impact manual firefighting and suppression reliability. The characteristics of interest (e.g., fire watches, location accessibility, firefighting system outages, staffing levels, etc.) might vary over the course of a given POS, from POS to POS, or from outage to outage. Hence, the recommended approach would be to apply judgment based adjustments to, for example, reflect the possibility that an area might be manned at the time of the fire increasing the likelihood of rapid detection and suppression or, conversely, that ongoing work may interfere with fire fighters reaching the scene and thereby delay the response.

4.11.3 Assumptions

The same assumptions apply to LPSD fire scenario analyses as in the at-power fire PRA [1]. The key assumptions are repeated below:

- The analysis is limited to considering a single fire occurring at any given time.

- If a fixed, water-based fire suppression system is available, actuation of that system is assumed to disrupt the process of fire growth and spread sufficient to achieve and maintain effective control of the fire so that additional damage to potential fire PRA targets will not occur.
- If a fixed, gaseous fire suppression system is available, actuation of that system is assumed to disrupt the process of fire growth and spread sufficient to achieve effective control of the fire. However, the duration of control is assumed to be the time period over which it has been demonstrated, by test or analysis, that a sufficient suppressant concentration, per applicable standards, can be maintained. The potential for a breached fire barrier (e.g., an open doorway) to compromise the ability to maintain suppressant concentration should also be considered.
- Core damage would occur if the MCR operators are unable to use the main control board (MCB) and no actions are taken from outside the MCR.

4.11.4 Single Compartment Fire Scenarios

The overall process for analyzing single compartment fire scenarios for LPSD fire PRA, regardless of the POS, remains the same as what is presented in reference [1] for at-power fire PRA. For LPSD fire PRA, the analyst should ensure that the following issues are addressed:

- The heat release rate (HRR) of the ignition sources and other combustibles reflect the conditions of the POS. For example, if the doors of an electrical cabinet with multiple bundles of unqualified cable are opened during a specific POS, the heat release rate of that cabinet should be modified to reflect the POS-specific condition as applicable. (Note that most cases do not distinguish between open and closed cabinets.)
- Status of protective barriers should be verified. For example, heat shields may be removed temporarily for maintenance work while the ignition sources remain operational.
- Status of detection and suppression systems should be verified. For example, parts of an automatic suppression system may be valved off for repair or modification work.
- As noted above, common practice appears to be to maintain fire protection systems in an active/available status as much as possible during outages. The plant-specific practice in this regard should be defined and reflected in the analysis. Localized system outages (e.g., isolation of an automatic suppression system to allow for hot work) may still occur and should also be considered.
- If the fire brigade is credited, the path between fire brigade equipment and the PAU should be reviewed and the response time adjusted. Longer response times should be used if there is a possibility of maintenance or other activities in the PAUs along the fire brigade's path.
- Transient ignition sources should be characterized carefully to reflect the additional items that may be brought into the PAU. Under certain POS that include maintenance activity or plant modification, the quantity and type of transient materials may be different.
- Secondary combustibles should be specifically characterized in case of POS that include maintenance activities and plant upgrade. Quantity, type and position of potential combustible materials should be identified.
- If there is a potential for erecting scaffolding or other structures to be used as a temporary platform for staging maintenance work, the analyst should postulate secondary combustibles accordingly using conservative assumptions where the specifics of the activity may not be completely defined.

4.11.5 Analysis of Fire Scenarios in the MCR

The MCR analysis framework remains the same as in reference [1]. The conditions within the MCR, and especially the alternate shutdown system, may be markedly different under certain POS. However, the same key concerns apply to LPSD conditions. The MCB should be examined for specific areas where fire damage can lead to a significant CCDP. All other control boards and electrical cabinets should be examined for potential risk impact. Finally, the possibility and likelihood of MCR abandonment should be examined.

For LPSD fire PRA, the analyst should ensure that the following issues are addressed:

- Activities within the MCR should be characterized and changes that can impact the fire risk profile identified. For example, the number of personnel within the MCR may increase. Multiple parallel activities may be taking place. Electricians could be working inside the MCB.
- When analyzing the MCB, the analyst should understand which controls will be tagged and the position of the control device while tagged.
- The MCB fire propagation and suppression curve presented in Appendix S of reference [1] can be used for all POS cases except those that include a maintenance activity behind the main face of the board. If such an activity is planned, the specifics of those tasks should be identified and evaluated. A set of fire scenarios may need to be identified to address those specific activities. Those scenarios should cover new ignition sources introduced inside the MCB and fire growth starting with that source and propagating to secondary combustibles (i.e., vertical and horizontal wire bundles and electrical and electronic devices). The target sets should be identified carefully in terms of the circuits present in the affected wire bundles and controls on the control board. The detection and suppression curves for MCR fires may still be used for these cases.
- Operating procedures for LPSD conditions will need to be reviewed and assessed. Substantial changes to fire-related operator manual actions may occur when the plant transitions to LPSD operations.
- Both remote and alternate shutdown capabilities should be re-examined using the specific condition imposed by the POS to assess their role in, and relevance to, LPSD operations. Access to the remote/alternate shutdown location(s) could be different during LPSD. The alternate shutdown circuits could also be altered or may be out of service and unavailable (without repair/restoration work) if the alternate shutdown train has been designated for service during part or all of a planned outage. These issues should be identified and taken into account when analyzing operator error using the alternate shutdown capability.
- MCR abandonment calculations (i.e., the fire environment modeling analysis) may need to be reviewed and verified for applicability to the specific POS conditions. If the transient combustibles profile or electrical cabinet characteristics are altered, the calculations for MCR abandonment should be verified. Also note that MCR abandonment scenarios will present HRA challenges given that plant procedures may provide little guidance relative to operator actions for a forced abandonment during shutdown (see 4.12 for further discussion).

4.11.6 Analysis of Fire Scenarios Initiated Outside the MCR that May Impact MCR Functions or Habitability

The possibility of adversely impacting the MCR function by a fire outside the room, as in at-power fire PRA, should also be examined. As discussed in reference [1], there could be other compartments where a fire may damage sufficient control circuits rendering a part of the MCR function inoperable or affect the information displayed for the operators. For example, a fire may cause a loss of RHR or a reactor cavity drain-down event that also renders MCR controls or indications inoperable. Also, there could be locations where a fire may adversely impact the MCR environment forcing abandonment. It is very possible that these compartments are the same as those identified in the at-power fire PRA. However, it is recommended that the analyst revisit this task and re-examine the underlying assumptions and information. Conditions associated with a specific POS may lead to areas within the plant or fire scenarios other than those identified in the at-power analysis that can adversely affect the MCR. Two specific areas of consideration should be included as follows:

- The locations that might lead to functional degradation of the MCR control and indication systems could change based on the POS and plant status. This is because the systems and indications which are most important to maintaining core integrity will change depending on the POS, which means the location of equipment and cables of potential concern could also change.
- The status of fire barrier elements (e.g., opened doors or breached barriers) could create smoke, heat, and fire spread paths that were not considered plausible in the at-power fire PRA.

4.11.7 Analysis of Fire Scenarios Impacting Multiple Compartments

Multi-compartment fire propagation and damage analysis as presented in reference [1] uses four screening steps to arrive at fire scenarios that could be risk significant and that thereby may warrant a more detailed analysis. The detailed analysis uses the same general approach as does the single-compartment fire analysis. The same screening steps can be used for LPSD conditions as those described in reference [1]; however, the conditions relevant to screening could be markedly different under certain POSs.

For LPSD fire PRA, the analyst should ensure that the following issues are addressed:

- The exposing and exposed compartment matrix should be reviewed and updated to reflect the POS-specific status of PAU partitioning elements (e.g., breached barriers or open hatches and doorways). The at-power multi-compartment analysis limits scenarios to the fire location plus one adjacent compartment. LPSD conditions may allow smoke and heat to spread to more than one adjacent compartment if multiple fire barrier elements are breached. For example, removal of a series of floor/ceiling hatches would allow smoke to rise beyond the first level above. Multiple open doorways may also allow additional smoke spread horizontally. A second difference is that the at-power analysis generally assumes that a non-recoverable random failure of a barrier element is the cause of multi-compartment effects. In contrast, the LPSD analysis will face purposeful barrier breaches that may be recoverable. For example, the analysis may be able to credit compensatory measures (e.g., if a fire watch is posted at an open doorway and has the ability to close that door in the event of a fire) or other mitigating actions (e.g., plant responders may be able to close an open doorway so long as no cables are routed through the door that cannot be easily and quickly removed). The exact means for quantifying compensatory measures in the at-power analysis remain an area of HRA challenge and the same will be true for LPSD.
- Multi-compartment fire damage target sets will need to be re-defined to reflect the equipment and cables important to maintaining core integrity for each identified POS.
- Once the compartment relationships have been re-defined, the same screening assumptions and criteria can be used to identify compartment combinations that warrant more detailed analysis. However, depending on plant practices relative to maintaining fire protection system availability, the screening analysis may need to consider that fire protection features and systems that were credited in the at-power fire PRA may be unavailable or degraded under LPSD conditions. Screening should be performed accordingly.
- For barriers whose status and integrity are not changed, the failure probabilities and guidance provided in reference [1] can be used.

- If a particular barrier element will be breached during a specific POS (e.g., hatch removal or a specific outage plan that involves breaching of fire barrier elements) it is recommended that the analysis should treat the breached barrier as a non-confining partitioning element relative to the spread of fire or fire products (e.g., smoke, heat and toxic gas). The importance of breaching such barriers can be assessed in a sensitivity study if necessary. In some cases, the consideration of barrier restoration may be appropriate if the actions required are simple and easily implements (e.g., closing a door given a posted fire watch and provisions for removal of temporary obstructions).

4.12 Task 12: Post-Fire Human Reliability Analysis

4.12.1 Background

One insight made clear during the tabletop exercise is that LPSD PRA in general will face a significant challenge when it comes to crediting operator actions. For most plants the available operating procedures focus mainly on at-power operations with a more limited set of operating procedures available to support, in particular, shutdown operating modes (e.g., loss of shutdown cooling procedures). This is especially true in the area of fire safety where the regulations focus on the ability to achieve safe shutdown given a fire that starts while the plant is operating at nominal full power. The LPSD fire PRA will instead be considering fires that occur while the plant is in a transitional state or a relatively stable shutdown mode. Both of the tabletop plants emphasized that including consideration of operator recovery actions beyond the plant procedures will be important to gaining an accurate representation of plant risk especially for POSs where a much longer time frame for action may be available (e.g., many hours).

While considerable effort has been directed toward the development of human reliability analysis (HRA) methods and approaches, historically, most of these efforts have resulted in methods and approaches that are intended to apply to at-power internal events PRA applications.

One exception is the recent joint development of fire HRA guidance by EPRI and NRC-RES [8] which supersedes that given in NUREG/CR-6850, EPRI TR-1011989. Consequently, it is recommended that for the purposes of LPSD fire PRA, the updated joint RES-EPRI fire HRA guidance be used, in combination with the special considerations for LPSD conditions given below. As with other elements of the LPSD fire PRA framework, Task 12 also assumes the existence of a LPSD, internal events PRA that includes corresponding HRA elements.

It is also recommended that only the detailed HRA analysis approaches as described in the joint RES-EPRI fire HRA guidance be used. No specific development effort for LPSD Fire HRA guidance has been undertaken so it is not known how relevant the screening and scoping HRA approaches from the joint guidance document would be to LPSD conditions. Finally, consistent with overall fire PRA guidance and standards, the fire HRA guidance does not address pre-initiator human failure events (HFEs) (or latent human failures). Pre-initiator HFEs will need to be addressed using typical at-power, PRA approaches, supplemented by any special considerations for LPSD conditions.

At present, no specific HRA guidance has been developed for LPSD PRA, paralleling that for at-power fire HRA/PRA. However, a variety of applications of HRA for LPSD internal events PRA have been performed, including two PRAs sponsored by the NRC [9,10]. Also, preliminary development work to support a LPSD HRA method was performed in the early 1990s [11,12]. Consequently, there is some basis for performing LPDS HRA/PRA even in absence of a comprehensive LPSD-specific approach.

4.12.2 Special Considerations Related to LPSD

Since, as discussed above, no comprehensive LPSD-specific HRA method has been developed, the recommended approach, at present, is to combine some known, LPSD-specific considerations with the joint RES-EPRI guidance developed for at-power fire HRA.

The following are examples of such considerations (but should not be considered a complete list):

- Plant conditions or configurations typically are different for LPSD than for at-power (potentially resulting in function, system, equipment, instrumentation and control, as well as indication and alarm, unavailability). HRA analysts should be aware that some of these condition or configuration differences may matter only to the operators (i.e., there may be no impact on plant equipment as in the case, for example, of control room indication unavailability). For fires during LPSD, indications needed to identify the fire location may be effected. Also, the HRA analyst should collect information on how control room operators maintain an awareness of plant conditions and configurations (e.g., log books, shift turnover briefings, schematics, risk monitors).

- Success criteria for plant functions are likely to be different during LPSD conditions, changing operator actions (e.g., number of pumps that need to be started, manual action required for initial response rather than backup/recovery of automatic actuation) and changing the required timing for response.

- Different and additional human failure events should be addressed in LPSD HRA, largely because of the two preceding items. In particular:

    - A general issue related to LPSD HRA is the question of human-induced initiating events (e.g., human initiated drain-down events). As noted in NRC's Good Practices Guidance [13], if there are important dependencies between operator actions that cause an initiating event and the actions required for accident response, then the human-induced initiator should be addressed explicitly. In the fire context, this would not mean human caused fires. The fire PRA analyzes fires that may cause of an initiating event, but the fire is not in and of itself the initiating event. Further, human caused fires are already inherently captured by the fire event data used to estimate fire frequencies (e.g., hot work fires and fires associated with tests and maintenance activities). For the LPSD fire PRA these types of human action dependencies are considered unlikely. However, the possibility cannot be ruled out entirely so that some consideration would be appropriate.

    - Because of the increased number of maintenance, testing, and other outage activities during shutdown, the number of potential pre-initiator HFEs or latent failures also increases. The HRA analyst should review relevant information to identify such opportunities and realistically provide credit for recovery of such failures (i.e., do not credit multiple, independent verifications).

- Which procedures are used for accident mitigation, how they are used, and how they are entered can be different for LPSD than for at-power (e.g., there is no equivalent of "E-O" in EOPs for LPSD, operators may be required to do more diagnosis when using AOPs for LPSD than when using EOPs in at-power events). The HRA analyst should review all of these aspects with respect to procedure usage.

- Operator training for response to LPDS accidents is likely to be different, in frequency and depth, from that for at-power. Similarly, training for LPDS fire events may be even less than that for general LPSD plant operations.

- Staffing of the control room during LPSD is likely to be different than that for at-power and should be reviewed by the HRA analyst. In addition, as in the at-power fire HRA guidance, the HRA analyst should determine if some control room staff will be required to serve roles on the fire brigade, making them unavailable for control room actions.

- There can be concerns related to staffing, procedures, and training in combination for fire HRA/PRA for both at-power and LPSD. In particular, the HRA analyst should identify situations in which the following occurs:

    - Fewer operators are in the control room for a fire event than for an internal events accident, and/or

- multiple procedures (e.g., emergency operating procedures and fire response procedures) are being used with individual operators assigned to independently implement one of the two or more procedures (i.e., the control room operators are no longer operating as a normal crew), and

- use of multiple procedures (especially, use of fire response procedures) is not normal operating practice and there is infrequent training on the use of multiple procedures that require coordination.

There are other considerations that can be important in performing LPSD HRA such as:

- ex-control room or local actions (with, for example, different human-machine interface issues than the control room),
- accessibility of equipment,
- environmental factors (such as habitability),
- special fitness needs, and
- needs for special equipment or tools.

These issues (and others) are explicitly addressed in the joint RES-EPRI fire HRA guidance and, therefore, are not discussed here. The same approaches for dealing with such factors as are outlined for at-power conditions are expected to apply to LPSD conditions.

4.13 Task 13: Seismic-Fire Interactions Assessment

A qualitative approach is used in reference [1] to address potential seismic-fire interaction cases using the approach recommended in the Fire Risk Scoping Study [14]. That approach identified the following four seismic-fire interaction issues:

- Seismically induced fires,
- Degradation of fire suppression systems and features,
- Spurious actuation of suppression and/or detection systems, and
- Degradation of manual firefighting effectiveness.

All four issues are applicable to plant conditions during LPSD POS(s). The main assumption about low risk of seismically induced fire events can be extrapolated to LPSD conditions. However, during LPSD conditions, many activities will occur in the plant that would not be observed, or will be undertaken in areas where they would be disallowed, during at-power operation. For example, welding and cutting operations could introduce portable compressed gas cylinders in unexpected locations, transient combustible control restrictions may be relaxed, maintenance activities may introduce a range of temporary storage items in various plant locations, and operations involving temporary hoisting or rigging equipment may be undertaken. These factors would tend to indicate that the probability of a seismic-fire interaction event *given an earthquake* (i.e., an event that can be attributed to one of the four issues listed above) is expected to be higher during a LPSD condition than at-power. Nonetheless, the overall risk is deemed to remain low largely because of the short duration of LPSD conditions.

The following assumptions are made relative to the seismic-fire analysis:

- An at-power Seismic-Fire Interaction Assessment exists.
- A post-earthquake plant response analysis exists for the specific POS being considered.
- An assessment should nominally be conducted for each postulated POS, although a combined effort is expected for many activities such as walkdowns and procedure reviews. That is, the intent is

that the seismic/fire interaction analysis include consideration of all applicable POSs, but not necessarily through separate reviews.

- The assessment should be walkdown-based and may be qualitative.

The same seven step approach applied to the at-power fire PRA can be used for LPSD. As a point of clarification, there is no expectation that this seven step review would be repeated for every defined LPSD POS. Rather, the expectation is that the review would be performed once encompassing all of the defined LPSD POSs. The main focus of the review would be to identify, assess (qualitatively), and potentially mitigate seismic fire interaction items that may be unique to LPSD plant conditions. The LPSD fire PRA should review seismic fire interaction items considered during the at-power fire PRA, but those items would not require re-assessment unless the relevant conditions are substantively different given LPSD conditions. Because all POSs are to be encompassed, the review should consider how plant conditions will change over the course of an outage and how those changes might impact the four seismic fire interaction issues identified above.

The following notes summarize the key issues of seismic-fire interaction assessment related to LPSD:

- Step 1: Identify key seismic-fire interaction analysis PAU:

  The PAUs that contain post-earthquake response components and circuits are identified in this step. Component and circuit conditions may be altered during LPSD conditions. Those PAUs where altered components and circuits are located should specifically be identified in this task. Similarly, those PAUs where a manual action is credited should be included in the analysis.

- Step 2: Assess potential impact of seismically induced fires:

  The special conditions during a POS should be taken into account to assess the potential impact of seismically induced fires. As in the at-power case, the assessment should be focused on the PAUs that were identified in Step 1. A plant walkdown and a review of potential special conditions during a POS are essential in this step.

- Step 3: Assess seismic degradation of fire suppression systems and features:

  The analysis conducted for at-power conditions can be reviewed and modified if any part of the fire suppression systems and features will be modified during the postulated POS.

- Step 4: Assess the potential impact of spurious fire detection signals:

  Spurious fire detection signal as a result of dust or steam (caused by equipment shaking or pipe break) could be more likely because of maintenance activities. The at-power analysis can be reviewed and modified to reflect the special conditions of postulated maintenance activities.

- Step 5: Assess the potential impact of spurious fire suppression system actuations:

  The at-power analysis can be used to establish the cases where spurious fire suppression actuations are possible. The impact of such events should be reviewed against the conditions postulated for each POS and modified accordingly.

- Step 6: Assess the potential impact of a seismic event on manual firefighting:

  For each compartment identified in Step 1, the manual firefighting possibility should be reviewed in the same way as for at-power analysis by taking into account the LPSD conditions.

- Step 7: Complete documentation:

  Apply the same guidelines as provided for the at-power analysis.

4.14 Task 14: Fire Risk Quantification

The objectives and overall approach for risk quantification is the same as in at-power fire PRA as described in reference [1]. However, the basis of quantification may vary depending on the intended objectives and applications. In this task, the final LPSD fire PRA model is quantified to obtain the final fire risk results in terms of CDF and LERF for each fire scenario defined in Task 11. The scope of this task will depend on the scope of the LPSD analysis. If an overall or average outage analysis is the main objective, the CDF and LERF calculations should be repeated for each POS and combined according to the equations in Section 3 above. If a specific POS (or subset of POSs) is analyzed, the CDF and LERF should be estimated using the same equation, except that only one POS (or a specific group of POSs) is considered.

Similar to at-power PRA, it is expected that the nature (e.g., type of sequences) of the screened out compartments/scenarios is at least identified. As a check of the cumulative screening criteria discussed in Task 7, it is recommended that the screened CDFs and LERFs also be summed separately to provide a perspective on the total residual risk from the screened compartments/scenarios. It should be emphasized that these screened portions of the results represent various levels of analysis (for instance, some may only involve fire scoping modeling; others may involve both detailed fire modeling and some detailed circuit analysis, etc.).

This task uses the LPSD fire PRA Model to quantify CDF and LERF. The model is initially developed in Task 5 (Fire Induced Risk Model), and modified in the quantitative screening performed in Task 7. This task also requires input from Task 10 (Circuit Failure Mode Likelihood Analysis), Task 11 (Detailed Fire Modeling), and Task 12 (Post-Fire Human Reliability Analysis).

The fire PRA analysts will need basic event occurrence probabilities from the Internal Events LPSD PRA Model to be able to quantify accident sequence frequencies where the fire scenario does not affect all basic events of the sequence. Also, the analyst should have access to the software tools required to quantify the PRA Model.

As noted above, the procedure in this task is the same as the RES/EPRI at-power fire PRA methodology. With the exception of fire-specific elements of the quantification process, this procedure relies heavily on the approach provided in the ASME/ANS PRA Standard [5]. The LPSD fire PRA Model developed in previous tasks is used to quantify CDFs and LERFs for each fire ignition event.

4.15 Task 15: Uncertainty and Sensitivity Analyses

This procedure provides an overall approach to all the other tasks on suggested ways to address the uncertainties associated with each task in the LPSD fire PRA process. In addition to uncertainty analysis, the identification of possible sensitivity analysis cases is addressed in this procedure. The discussions provided in Chapter 15 of reference [1] on uncertainty and sensitivity analyses and the guidance provided in reference [1] apply to LPSD cases as well. This task describes the approach for identifying and treating uncertainties and identifying sensitivity analysis cases. It also prescribes a review for the identified uncertainties among the fire PRA analysts to establish an integrated approach for addressing the effects of these uncertainties on the final results.

Many of the inputs that make up the LPSD CDF and LERF estimates, as in at-power fire PRA, are uncertain (e.g., fire frequencies, extent of fire growth, equipment failure probabilities, operator action probabilities, etc.). Additionally, there may be uncertainty in the fraction of the time that the plant could be in a specific POS. See Section 3 above for a brief discussion on the use of these fractions. Uncertainties in the input parameters lead to epistemic uncertainties in the LPSD Fire CDF and LERF. The same methods as for at-power fire PRA can be used to estimate the uncertainty distributions for the LPSD PRA analysis.

Similar to at-power fire PRA, it is important that users of the results of the LPSD fire PRA understand the fundamental modeling assumptions underlying the analysis and the sources of uncertainty associated with the results. Some uncertainties may be specifically included in the quantification of the results; others may only be qualitatively addressed or not addressed at all.

The analysts for Tasks 1 through 13 are expected to follow the overall approach provided in this procedure to articulate and quantify, when necessary, the uncertainties in their numerical results. For each affected task, the following information will be needed for uncertainty analysis:

- Sources of uncertainties, and
- Proposed approach for addressing each of the identified uncertainties.

It is expected that specific parameters and assumptions for which uncertainty or sensitivity analyses can provide valuable insights on the LPSD Fire CDF and LERF will be identified during the performance of a LPSD fire PRA. To that extent, the issues addressed here should be modified to reflect the key uncertainties identified on a plant-specific basis.

The same procedure as that described in reference [1] for at-power fire PRA applies here as well.

- Step 1: Identify Uncertainties Associated with Each Task:

  Where applicable, the outcome of each preceding task should include a discussion on the uncertainties in the results of the task. That information is collected and reviewed in this step. The uncertainties in the fraction of the time that the plant could be in a specific POS should also be addressed in this step. A determination should be made about the extent of those uncertainties and including them in the uncertainty analysis process.

- Step 2: Develop Strategies for Addressing the Uncertainties:

  Analysis strategies developed for the at-power fire PRA or LPSD internal events PRA could be applicable to LPSD conditions as well. Those strategies may be reviewed and adopted as appropriate.

- Step 3: Perform Review of Uncertainties to Make Final Decisions as to Which Uncertainties Will Be Addressed and How:

  A review of the parameters to identify those that will be included in the uncertainty analysis is conducted in this step. Another important result of this step is a set of sensitivity analysis cases.

- Step 4: Perform the Uncertainty and Sensitivity Analyses:

  Uncertainties are propagated through the model and sensitivity cases are performed. The same methods as in the at-power fire PRA or LPSD internal events PRA can be used to propagate the uncertainties. Sensitivity analyses may require their own unique approach depending on the sensitivity case, but should not be different from the methods used for at-power fire or LPSD internal events cases.

- Step 5: Include the Results of the Uncertainty and Sensitivity Analyses in the fire PRA Documentation:

  The same documentation approach can be used as in at-power case.

4.16 Task 16: Fire PRA Documentation

As in the case in the at-power fire PRA, the objective of this task is to ensure there is adequate documentation of the LPSD fire PRA to allow review of the PRA development and its results, as well as to provide a written basis for any future uses of that PRA. The recommended documentation in reference [1] applies to LPSD fire PRA as well. A recommended outline of the report and a list of supporting documents are provided in Tables 16-1 and 16-2 of reference [1]. That outline and recommended supporting documents apply to LPSD fire PRA as well.

It is recommended that the structure of the LPSD fire PRA documentation parallel closely that of the corresponding at-power fire PRA even if that structure differs from the recommendations of reference [1]. Maintaining a parallel structure for the two analyses has many advantages. In many areas the at-power PRA will already document most of the information used in the LPSD analysis. One example is the plant partitioning analysis. Recall that this framework recommends that the at-power partitioning decisions be transferred directly to the LPSD study with minimal changes. Hence, documentation of the LPSD fire PRA could be limited to a discussion of the partitioning analysis review with particular emphasis on any changes made to suit the LPSD analysis. In cases like this it is not expected that the detailed information provided in the at-power documentation would be repeated in the LPSD documentation. Rather, those aspects that remain unchanged should be identified but may be documented by reference.

Certainly the LPSD fire PRA report should have a clear discussion of the POSs analyzed and the assumptions made to define and model the POSs. This discussion should emphasize differences relative to the LPSD internal events PRA (e.g., new equipment modeled, new failure modes considered, etc.). As noted in reference [1], the documentation should provide an adequate summary of the development of the LPSD fire PRA, including the performance and results of all the previous tasks in this document and the results of the LPSD fire PRA itself (with uncertainties, sensitivities, observations, etc.). Here again, the emphasis should be on differences relative to the at-power fire PRA and LPSD internal events PRA including considerations that were unique to the LPSD fire PRA.

In summary, the goals of the LPSD fire PRA documentations are to:

(1) highlight differences between the at-power and LPSD fire PRAs,
(2) highlight differences between the LPSD internal events and fire PRAs,
(3) describe those elements that are unique to the LPSD fire analysis, and
(4) present the results and conclusions of the LPSD fire PRA.

4.17 Task 17: Plant Walkdowns (Support Task A)

Plant walkdown is defined in reference [1] as an inspection of local areas in an NPP where systems and components are physically located to ensure accuracy of procedures and drawings, equipment location, operating status of equipment, and environmental or system interaction effects on equipment during accident conditions. As noted in reference [1] and for LPSD conditions, paper and electronic documents are not sufficient to provide all the information needed for a proper fire PRA. Therefore, plant walkdowns are critically important when conducting a LPSD fire PRA.

The guidance provided in reference [1] applies to LPSD conditions as well. The walkdowns already conducted in support of at-power fire PRA should provide the baseline information that will be modified according to the special conditions imposed by the LPSD POS. It is anticipated that, at least nominally, a separate set of walkdowns might be necessary in support of each POS. However, some grouping of these activities is likely possible. For example, where POS's are reliant on the same set of PRA functions, they will also likely find that the fire PRA will focus on the same set of critical plant equipment and associated locations (including cables). Similarly, the plant fire protection posture (i.e., the nature of fire hazards present and the status of fire protection systems and features) may not vary significantly, may vary only in specific locations, or may vary only in certain specific details (e.g., where hot work or transients might be located, what equipment will be out of service, etc.) between otherwise similar POSs. Opportunities will likely exist to combine walkdowns for multiple POSs. Under such an approach, the walkdowns would likely focus on anticipated fire protection posture changes from POS to POS (and location to location). It is recommended that these types of opportunities be identified and explored via pilot applications if possible.

The pattern of the walkdowns (i.e., those defined in Table 17-1 of reference [1]) is expected to remain the same. However, not all walkdown types may be necessary. In addition to the guidance provided in Chapter 17 of reference [1], the following notes are provided for LPSD fire PRA related walkdowns:

- A separate set of walkdowns and especially walkdown notes should be created for each POS. This is intended to allow for combined walkdowns to cover multiple POSs but walkdowns during an actual outage for key POSs is recommended either as a part of PRA planning or as a part of PRA maintenance efforts.
- As part of the initial walkdown, a separate meeting with plant management should be requested. In this meeting the specific conditions of the POS being studied should be reviewed and verified.
- Engineering documents (e.g., plant layout drawings) may need to be taken to the plant and marked up to reflect the anticipated changes during a specific POS.
- An effort should be made to discuss anticipated POS related transient combustibles and hot work with plant personnel to establish the changes to the extent possible.
- Plant areas where changes may take place should be visited and the walkdown notes updated or new ones created for the affected compartments.
- A walkdown may be planned during the plant shutdown to confirm the information that was gathered prior to the shutdown. In practice, this walkdown may take place after LPSD fire PRA is completed. That is, as a practical matter, the LPSD fire PRA may be performed while the plant is in an operational state rather than during a shutdown. In this case it is recommended that efforts be made to observe plant conditions during a prior outage (i.e., advance planning) and/or that other alternative strategies (as described above) be employed to gain the needed insights. In such cases, post-analysis walkdowns would be confirmatory in nature. If marked differences are noted, management should be notified to make a determination about updating the PRA. As a general practice it is also recommended that additional walkdowns be performed periodically during future outages and that insights gained be addressed as a part of general PRA maintenance efforts.

4.18 Task 18: Fire PRA Database System (Support Task B)

The fire PRA Database System is a relational database of equipment, circuits and plant locations. It may also include cable raceway information and equipment failure modes. The main purpose of the database is to assist in fire scenario development, establishing the target set of each scenario and equipment failure modes given fire damage. The database developed for at-power fire PRA can be used in LPSD fire PRA as a starting point. The same assumptions apply to LPSD. Tasks 2 and 3 related information should be reviewed to identify components, circuits and cables other than those included in the at-power PRA. The database should be updated to include the new information. All other features of the database remain the same as those discussed in reference [1].

5 REFERENCES

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[12] NUREG/CR-6093, An Analysis of Operational Experience During Low Power and Shutdown and a Plan for Addressing Human Reliability Assessment Issues, U.S. Nuclear Regulatory Commission, Washington, DC, June 1994.

[13] NUREG-1792, Good Practices for Implementing Human Reliability Analysis (HRA), U.S. Nuclear Regulatory Commission, Washington, DC, April 2005.

[14] NUREG/CR-5088, Fire Risk Scoping Study: Investigation of Nuclear Power Plant Fire Risk, Including Previously Unaddressed Issues, U.S. Nuclear Regulatory Commission, Washington, DC, January 1989.

APPENDIX A: DETERMINATION OF LPSD GENERIC FIRE FREQUENCIES

A generic set of fire frequency distributions were developed to support at-power Fire PRA (see Table 6-1 of reference A-1). Those frequencies were based on EPRI Fire Events Database (FEDB) ending at January 1, 2000. A part of those frequencies that cover all operating states (i.e., at-power and shutdown phases) can be directly used in LPSD Fire PRA. These are bins in Table 6-1 of reference A-1 that are noted with "All" under the Mode column. The frequencies for the bins that are noted with "Power" had to be estimated for shutdown conditions. This Appendix is intended to describe the fire event data analysis and methodology used to estimate the fire frequencies to be applied in the LPSD Fire PRA.

Note that the original fire frequency analysis from reference A-1 included fires that occurred during plant startup and other low power operating states in the "power operation" fire frequency event set (i.e., that set used to count at-power fire events). This was confirmed by reviewing the original EPRI fire event database against table C-4 of Reference [1]. It is clear that fires occurring while a plant was operating at less than 100% power or that were identified as occurring during "startup" were included in the "power operations" event set. The events that are labeled as "low power operation" events in Table C-4 are actually fires that occurred in various plant shutdown modes. These modes are typically identified in rather general terms such as "shutdown," "outage," or "refueling outage" but also include a range of specific operational state descriptors associated with shutdown. Hence, the analysis here assumes that frequencies for all ignition source bins marked "power" under the "mode" column of Table 6-1 are actually applicable to operation at all power levels including low power operations (i.e., to plant operating modes 1 and 2). For these bins a complementary frequency has been calculated based on events occurring during shutdown operations (modes 3-5) based on the complimentary set of events from the EPRI database.

Also note that all frequencies as presented here are based on an "events per mode-year" basis.

A.1 Screening Events for Inclusion in the Calculation of Generic Fire Frequencies

There are 1,405 event records in FEDB that had been reviewed as part of the at-power frequency analysis for reference A-1. Events contained in the FEDB were screened for inclusion into (or exclusion from) the fire event frequency calculation based on two general considerations. The first consideration is when and where the fire occurred. The second consideration is whether or not a given event either did or could have become a potentially challenging fire (see the definition below).

A.1.1 Where and When a Fire Occurred

The FEDB was filtered to include only those events that were not assigned in the original study (i.e., the study supporting reference A-1) to "power" mode bins (which included low-power operations as noted above). Table A-1 provides the list of bins that were considered for shutdown specific fire frequency evaluation. Of the 1,405 events, 431[14] event records were assigned to a bin that needed a shutdown specific frequency analysis. The following notes are in order:

- Bin assignment was reviewed and one additional bin had to be defined to capture events in BWR containments. During power operation, BWR containments are inerted precluding the possibility of a fire event in that POS. Since BWR and PWR containments are quite different, a new bin is defined specifically for transient and hot-work fires in BWR containments (bin 3B) and the PWR containment

[14] One of the 431 events involved a gas-turbine based emergency generator. That event was not included in the frequency analyses.

transient and hot-work fire bin has been renamed (bin 3P rather than simply bin 3 as in the at-power set in reference A-1).

- Similar to the at-power case, although there were fire events associated with gas turbine-driven emergency generators, they are not included in this analysis because the number of emergency generators in nuclear power plants using gas turbines is not known.

Table A-1: Bins Considered for LPSD Data Analysis.

Bin #	Location	Ignition Source (Equipment Type)
2	Containment (PWR)	Reactor Coolant Pump
3B	Containment (BWR)	Transients and Hotwork
3P	Containment (PWR)	Transients and Hotwork
5	Control/Aux/Reactor Building	Cable fires caused by welding and cutting
6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting
7	Control/Aux/Reactor Building	Transients
11	Plant-Wide Components	Cable fires caused by welding and cutting
20	Plant-Wide Components	Off-gas/Hydrogen Recombiner (BWR)
22	Plant-Wide Components	RPS MG Sets
24	Plant-Wide Components	Transient fires caused by welding and cutting
25	Plant-Wide Components	Transients
27	Transformer Yard	Transformer – Catastrophic
28	Transformer Yard	Transformer - Non Catastrophic
29	Transformer Yard	Yard transformers (Others)
31	Turbine Building	Cable fires caused by welding and cutting
32	Turbine Building	Main Feedwater Pumps
34	Turbine Building	Turbine Generator Hydrogen
35	Turbine Building	Turbine Generator Oil
36	Turbine Building	Transient fires caused by welding and cutting
37	Turbine Building	Transients

A.1.2 Potentially Challenging Events

The second stage of event screening considered whether or not a particular event did, or had the potential to become challenging. The intent of this step is to identify reported events involving an incipient fire, fire ignition event, or explosion event that had the potential to develop into a self-sustaining fire. Events that lack this potential were screened out from the fire frequency calculation as "not-challenging". A detailed discussion of the screening process can be found in Appendix C of reference A-1. Although the FEDB events associated with the bins in Table A-1 were already screened for challenging fire, the entire set was reviewed anew to verify the original assignments. Since this screening process is one of the important steps of data analysis, the criteria are repeated below.

The criteria for identifying potentially challenging events include objective and subjective elements. The objective criteria are based on reportable facts related to the means of fire suppression, the extent of fire growth and/or damage, fire duration, and other indicators. The objective criteria are applied in a mechanical manner–i.e., yes/no checkboxes. The subjective criteria involve the application of judgment. Factual information related to the objective criteria is often lacking in the event reports. Hence, the analysts had to use judgment to determine whether or not the event was potentially challenging, typically based on a review of the descriptive text provided for the event.

Per the objective classification criteria, a fire event was classified as potentially challenging if any one of the following is true.

- A hose stream, multiple portable fire extinguishers, and/or a fixed fire suppression system (either manually or automatically actuated) were used to suppress the fire.
- One or more components outside the boundaries of the fire ignition source were affected where the term "outside the boundaries of the fire ignition source" will depend to some degree on the specific ignition source (see further discussions below).
- Combustible materials outside the boundaries of the fire ignition source were ignited (with a similar use of the term "outside the fire ignition source" implied).

A fire event was also classified as potentially challenging if two or more of the following features are cited in an event report:

- Actuation of an automatic detection system,
- A plant trip was experienced,
- A reported loss of greater than $5,000 (not including any lost business damages), or
- A burning duration or suppression time of 10 minutes or longer.

After the objective criteria are applied, a fire event may still be classified as potentially challenging if there are sufficient indications to determine that the fire was self-sustaining or that it might have affected components or ignited materials outside the fire ignition source. This subjective method may be based on the general tone of the event report or on the observation of specific aspects of a fire event. In general, observations of the following features in an event report can be indicative of a potentially challenging fire.

- It is apparent that active intervention was needed to prevent potential spread.
- There are indications that the heat that was generated had sufficient intensity and duration to affect components outside the fire ignition source, had such been in close proximity to the ignition source.
- There are indications that flames or heat were generated of sufficient intensity and duration to cause the ignition of secondary combustibles outside the fire ignition source, had such been in close proximity to the ignition source.
- Substantial smoke was generated (e.g., a room was reported to be smoke-filled when first responders arrived on the scene, or the report includes a description such as "heavy" or "dense" smoke).

The original "potentially challenging" or "not-challenging" assignments were reviewed for each event identified as occurring during plant low power or shutdown conditions, and the assignment was modified where deemed necessary. The assignments for events occurring during power operations were left as per the original NUREG/CR-6850 assessment (they were not revised).

A.1.3 Plant Operating Mode

Each event was also examined for the plant operating mode. Most event descriptions had a clear statement about the operating mode often included plant power level for events assigned to the "power" operating mode. Since the database was filtered excluding "power" operating mode, all the events that were analyzed either clearly stated that the plant (or one of the units) was in one of several possible shutdown modes or no information was provided. In the latter cases, the operating mode was assigned as "undetermined". In one case, the POS assignment of an event was modified to "at-power" based on the information available. In another case, the event had occurred during the de-commissioning phase of the plant and this event was excluded.

A.2 Event Counting Method

To estimate the fire occurrence frequency for each bin, the total number of events associated with the bin and years of plant experience are needed. The calculation method described in Section C.4 of reference A-1 applies in the case of shutdown frequency calculations. That is, the following equation is applicable to shutdown fire frequency computations (see Section C.4.1 of reference A-1 for a description):

$$F_{plant,i} = K_i + C_i \cdot q + B_i \cdot p + BC_i \cdot p \cdot q + A_i/N + (AC_i/N) \cdot q + (AB_i/N) \cdot p + (ABC_i/N) \cdot p \cdot q$$

All the parameters of this equation have the same definition as for the at-power case with the exception of "p". The parameter "p" in the case of shutdown is the fraction of the events of known operating mode that had occurred during shutdown. In effect $p_{shutdown} = 1 - p_{at\text{-}power}$.

Note that there was no attempt made to further classify the events that occurred during shutdown based on the specific shutdown POS of the plant when these events occurred. That is, there is an implicit assumption that each shutdown event applied, for ignition frequency purposes, equally throughout shutdown (i.e., equally to all potential POSs).

A.3 Uncertainty Analysis

Uncertainty distributions of bin frequencies were established using the non-homogeneous Bayesian analysis method option of the R-DAT computer program (reference A-2). Similar to the two-stage Bayesian approach, fire event statistics of each plant are entered into the uncertainty estimation process separately to allow plant-to-plant variability influencing the uncertainty distributions. The results of this process are shown in Table A-3 in terms of the mean, 5^{th}, 50^{th} and 95^{th} percentiles of the each distribution. The mean values can be used as point estimates for each ignition frequency bin.

A.4 Event Counts and Generic Frequencies

As noted above, the 431 events were reviewed and screened for challenging category and operating mode assignment. For a large number of cases, the challenging category was modified from the original study (i.e., reference A-1). Also, several of these events were concluded to be not applicable to LPSD Fire PRA. In a few cases the bin assignment had to be modified. Seven events were removed from analysis. Table A-2 provides the number of events by bins, power level (i.e., shutdown or not) and "challenging" assignment.

The total number of events that should be used for frequency calculation was estimated using the equation presented in Section A.2 above using 0.5 for q and p parameters. The results are presented in Table A-3. The corresponding total number of plant years is also presented in Table A-3 for each bin. The number of reactor years for shutdown operating mode is calculated in exactly the same way as that described in reference A-1 for the at-power operating mode.

The frequencies presented in Table A-3 are simple division of the number of fire events and the number of plant years noted.

A.5 Fire Type Split Fraction

As it is discussed in reference A-1, different fire types can be postulated for most of the ignition sources. For example, the bin "Containment (PWR) / Reactor Coolant Pumps" can refer to both electric and oil fires. The same six fire types, postulated in reference [1], are used here. Table A-4 provides the split fraction for each fire type for the shutdown specific bins. The split fractions are based on interpretations of the FEDB events.

A.6 Fire Event Classification

As it is discussed above, EPRI's FEDB events, filtered for non at-power operating mode, were reviewed to verify the appropriate ignition source bin, the status relative to potentially challenging determination, and the operating mode assignments. For a large number of cases, the challenging category was modified. Also, a few events were concluded to be not applicable to LPSD Fire PRA. In a few cases the bin assignment had to be modified. Table A-5 provides a complete list of the events that were reviewed. Corresponding bin assignment, operating mode and challenging category are also shown. Notes are provided to indicate changes in event assessment (e.g., if "challenging" assignment was altered from the original study). Also, it is noted if the event is not included in the frequency estimation.

A.7 References

A-1 "Fire PRA Methodology for Nuclear Power Facilities; Volume 2: Detailed Methodology", U.S. NRC and EPRI. NUREG/CR-6850 and EPRI 1011989, September 2005.

A-2 "R-DAT and R-DAT Plus 1.5 User's Manual", Prediction Technologies, College Park, MD, 2002.

Table A-2: Event Counts by Bin, Challenging Category and Operating Mode

Bin #	Location	Ignition Source	Power Level	Not Challenging	Potentially Challenging	Undetermined
2	Containment (PWR)	Reactor Coolant Pump	SD	1	3	1
			Undetermined	1	0	0
3P	Containment (PWR)	Transient fires caused by welding and cutting	SD	32	10	11
			Undetermined	7	2	0
3B	Containment (BWR)	Transient fires caused by welding and cutting	SD	45	10	11
			Undetermined	1	0	0
5	Control/Aux/Reactor Building	Cable fires caused by welding and cutting	SD	0	0	0
			Undetermined	0	0	1
6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	SD	32	4	5
			Undetermined	17	0	2
7	Control/Aux/Reactor Building	Transients	SD	8	1	2
			Undetermined	4	2	2
11	Plant-Wide Components	Cable fires caused by welding and cutting	SD	0	0	0
			Undetermined	0	0	1
20	Plant-Wide Components	Off-gas/Hydrogen Recombiner (BWR)	SD	0	3	0
			Undetermined	0	0	0
22	Plant-Wide Components	RPS MG sets	SD	5	1	4
			Undetermined	0	0	1
24	Plant-Wide Components	Transient fires caused by welding and cutting	SD	9	6	3
			Undetermined	12	1	0
25	Plant-Wide Components	Transients	SD	11	1	1
			Undetermined	12	1	7
27	Transformer Yard	Transformer – Catastrophic	SD	0	5	0
			Undetermined	0	0	0
28	Transformer Yard	Transformer - Non Catastrophic	SD	1	1	4
			Undetermined	1	0	0
29	Transformer Yard	Cable fires caused by welding and cutting	SD	1	1	0
			Undetermined	0	0	0
32	Turbine Building	Main feedwater pumps	SD	0	1	0
			Undetermined	0	0	1
34	Turbine Building	T/G Hydrogen	SD	0	2	0
			Undetermined	0	0	0
35	Turbine Building	T/G Oil	SD	2	1	0

Table A-2: Event Counts by Bin, Challenging Category and Operating Mode (continued)

Bin #	Location	Ignition Source	Power Level	Not Challenging	Potentially Challenging	Undetermined
			Undetermined	0	0	0
36	Turbine Building	Transient fires caused by welding and cutting	SD	38	8	8
			Undetermined	17	1	4
37	Turbine Building	Transients	SD	11	3	4
			Undetermined	8	2	3
			Totals	278	70(1)	76

(1) One fire event that was deemed as potentially challenging involved a gas-turbine. The event is not shown in this table.

Table A-3: Generic Fire Ignition Frequency Model for U.S. Nuclear Power Plants.

Bin #	Location	Ignition Source	# of Events	Total Reactor Years	Frequency (R-DAT Results)			
					Mean	5^{th}	50^{th}	95^{th}
2	Containment (PWR)	Reactor Coolant Pump	3.5	519.9(1)	6.6E-03	2.6E-04	3.3E-03	1.8E-02
3P	Containment (PWR)	Transients and Hotwork	16.5	519.9	3.1E-02	2.9E-03	2.1E-02	8.2E-02
3B	Containment (BWR)	Transients and Hotwork	15.5	298.5(2)	3.5E-02	2.3E-04	7.3E-03	1.2E-01
5	Control/Auxiliary/Reactor Building	Cable fires caused by welding and cutting	0.25	822.5(3)	1.2E-03	2.3E-05	3.8E-04	3.5E-03
6	Control/Auxiliary/Reactor Building	Transient fires caused by welding and cutting	7	822.5	9.3E-03	3.6E-04	5.0E-03	2.5E-02
7	Control/Auxiliary/Reactor Building	Transients	3.5	822.5	4.7E-03	2.0E-04	2.5E-03	1.3E-02
11	Plant-Wide Components	Cable fires caused by welding and cutting	0.25	822.5	8.8E-04	1.8E-05	2.9E-04	2.8E-03
20	Plant-Wide Components	Off-gas/Hydrogen recombiner (BWR)	3	298.5	2.0E-02	8.5E-05	3.1E-03	3.8E-02
22	Plant-Wide Components	RPS MG sets	3.25	822.5	3.2E-03	1.5E-04	1.7E-03	9.0E-03
24	Plant-Wide Components	Transient fires caused by welding and cutting	8	822.5	1.1E-02	4.0E-04	5.8E-03	3.0E-02
25	Plant-Wide Components	Transients	3.75	822.5	5.8E-03	2.1E-04	2.9E-03	1.5E-02
27	Transformer Yard	Transformer - catastrophic	5	822.5	7.2E-03	8.9E-05	2.3E-03	2.1E-02
28	Transformer Yard	Transformer - noncatastrophic	3	822.5	3.8E-03	1.6E-04	1.9E-03	1.1E-02
29	Transformer Yard	Yard Transformers (others)	1	822.5	2.0E-03	2.7E-05	6.1E-04	5.7E-03
31	Turbine Building	Cable fires caused by welding and cutting	0	822.5	1.3E-03	2.2E-05	4.0E-04	3.7E-03
32	Turbine Building	Main feedwater pumps	1.25	822.5	1.9E-03	7.6E-05	8.9E-04	5.6E-03
34	Turbine Building	T/G hydrogen	2	822.5	3.0E-03	4.8E-05	1.1E-03	8.7E-03
35	Turbine Building	T/G oil	1	822.5	2.5E-03	3.5E-05	7.5E-04	6.9E-03
36	Turbine Building	Transient fires caused by welding and cutting	13.5	822.5	2.2E-02	2.5E-04	5.5E-03	7.1E-02
37	Turbine Building	Transients	6.75	822.5	1.0E-02	2.2E-04	4.3E-03	3.0E-02

(1) Total number of years PWRs were in a SD POS up to December 31, 2000.
(2) Total number of years BWRs were in a SD POS up to December 31, 2000.
(3) Total number of years all NPPs were in a SD POS up to December 31, 2000.

Table A-4: Fire Type Split Fractions.

Bin #	Location	Ignition Source	Electrical	Oil	Transient	Hotwork	Hydrogen	HEAF
2	Containment (PWR)	Reactor Coolant Pump	0.25	0.75	0.00	0.00	0.00	0.00
3P	Containment (PWR)	Transients and Hotwork	0.00	0.00	0.39	0.61	0.00	0.00
3B	Containment (BWR)	Transients and Hotwork	0.05	0.00	0.24	0.71	0.00	0.00
5	Control/Auxiliary/Reactor Building	Cable fires caused by welding and cutting	0.00	0.00	0.00	1.00	0.00	0.00
6	Control/Auxiliary/Reactor Building	Transient fires caused by welding and cutting	0.00	0.00	0.09	0.91	0.00	0.00
7	Control/Auxiliary/Reactor Building	Transients	0.00	0.00	1.00	0.00	0.00	0.00
11	Plant-Wide Components	Cable fires caused by welding and cutting	0.00	0.00	0.0	1.00	0.00	0.00
20	Plant-Wide Components	Off-gas/Hydrogen recombiner (BWR)	0.33	0.00	0.33	0.00	0.33	0.00
22	Plant-Wide Components	RPS MG sets	1.00	0.00	0.00	0.00	0.00	0.00
24	Plant-Wide Components	Transient fires caused by welding and cutting	0.00	0.00	0.0	1.00	0.00	0.00
25	Plant-Wide Components	Transients	0.10	0.00	0.90	0.00	0.00	0.00
27	Transformer Yard	Transformer - catastrophic	0.70	0.30	0.00	0.00	0.00	0.00
28	Transformer Yard	Transformer - noncatastrophic	0.80	0.00	0.00	0.20	0.00	0.00
29	Transformer Yard	Yard Transformers (others)	1.00	0.00	0.00	0.00	0.00	0.00
31	Turbine Building	Cable fires caused by welding and cutting	0.00(1)	0.00	0.00	1.00	0.00	0.00
32	Turbine Building	Main feedwater pumps	0.00	1.00	0.00	0.00	0.00	0.00
34	Turbine Building	T/G hydrogen	0.25	0.00	0.00	0.00	0.75	0.00
35	Turbine Building	T/G oil	0.00	1.00	0.00	0.00	0.00	0.00
36	Turbine Building	Transient fires caused by welding and cutting	0.00	0.07	0.29	0.64	0.00	0.00
37	Turbine Building	Transients	0.00	0.04	0.96	0.00	0.00	0.00

(1) Since no events were recorded during SD, the split fraction of the at-power analysis (i.e., reference [1]) is used.

Table A-5: Fire Event Classification.

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
9	20	Plant-Wide Components	Off-gas/Hydrogen Recombiner (BWR)	Shutdown	FALSE	TRUE	FALSE	FALSE	
11	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
16	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	This event assessment was changed
18	?	Plant-Wide Components	Gas Turbines	Shutdown	FALSE	TRUE	FALSE	FALSE	This event assessment was changed
25	27	Transformer Yard	Transformer - Catastrophic	Shutdown	FALSE	TRUE	FALSE	FALSE	
26	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
30	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
33	20	Plant-Wide Components	Off-gas/Hydrogen Recombiner (BWR)	Shutdown	FALSE	TRUE	FALSE	FALSE	
56	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
60	32	Turbine Building	Main feedwater pumps	Shutdown	FALSE	TRUE	FALSE	FALSE	
80	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
88	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
95	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
96	2	Containment (PWR)	Reactor Coolant Pump	Shutdown	FALSE	TRUE	FALSE	FALSE	
107	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
112	2	Containment (PWR)	Reactor Coolant Pump	Shutdown	FALSE	TRUE	FALSE	FALSE	This event assessment was changed
123	37	Turbine Building	Transients	Shutdown	FALSE	TRUE	FALSE	FALSE	
148	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
149	34	Turbine Building	T/G Hydrogen	Shutdown	FALSE	TRUE	FALSE	FALSE	
152	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
153	28	Transformer Yard	Transformer - Non Catastrophic	Shutdown	FALSE	FALSE	FALSE	TRUE	
167	2	Containment (PWR)	Reactor Coolant Pump	Shutdown	FALSE	FALSE	FALSE	TRUE	
179	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	FALSE	TRUE	
187	25	Plant-Wide Components	Transients	Undetermined	FALSE	TRUE	FALSE	FALSE	
196	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	FALSE	TRUE	FALSE	
203	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
206	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	FALSE	The plant was decommissioned at the time of the event.

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
210	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
225	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
226	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	
227	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
232	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	
245	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
247	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
248	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
253	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
265	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
272	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
274	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
276	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
277	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
278	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
281	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
283	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
284	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
287	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
290	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
293	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
294	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
297	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
303	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
309	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
311	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
313	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
314	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
315	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
316	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	
325	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
334	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
335	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
336	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
337	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
339	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
342	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
343	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
344	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
345	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
348	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
350	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
355	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
356	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
359	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
360	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event was identified as Containment (PWR), Transient Fires Caused by Cutting and Welding. It was reworded it to Transient and Hotwork.
362	37	Turbine Building	Transients	Shutdown	FALSE	TRUE	FALSE	FALSE	
371	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
373	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
375	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
377	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
378	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
379	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
380	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
382	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
383	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
386	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
387	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
392	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
393	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
394	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
408	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
409	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
411	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
412	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
424	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
426	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
429	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
430	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
443	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
447	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
450	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	TRUE	FALSE	FALSE	
464	7	Control/Aux/Reactor Building	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
466	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
470	37	Turbine Building	Transients	Undetermined	FALSE	TRUE	FALSE	FALSE	
471	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
473	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
496	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
502	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
506	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	FALSE	This event was removed from the LPSD analysis because the Mode of Operation is "Power"
517	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
525	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
528	20	Plant-Wide Components	Off-gas/Hydrogen Recombiner (BWR)	Shutdown	FALSE	TRUE	FALSE	FALSE	
530	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	FALSE	TRUE	FALSE	
532	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	FALSE	FALSE	TRUE	
539	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
540	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
545	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
552	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
556	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
557	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	TRUE	FALSE	FALSE	
568	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
580	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
581	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
582	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	FALSE	TRUE	
583	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
586	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
588	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
589	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
590	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
591	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
592	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
594	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
599	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
600	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
601	35	Turbine Building	T/G Oil	Shutdown	FALSE	TRUE	FALSE	FALSE	
604	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
605	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
611	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
613	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
616	35	Turbine Building	T/G Oil	Shutdown	FALSE	FALSE	TRUE	FALSE	
618	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	FALSE	TRUE	
619	37	Turbine Building	Transients	Shutdown	FALSE	TRUE	FALSE	FALSE	
630	35	Turbine Building	T/G Oil	Shutdown	FALSE	FALSE	TRUE	FALSE	
635	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
638	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
639	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
640	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
641	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
643	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
647	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
648	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	
682	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
686	7	Control/Aux/Reactor Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
687	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
692	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
693	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
694	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
697	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
698	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
703	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
705	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
712	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
713	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
717	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
718	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
719	28	Transformer Yard	Transformer - Non Catastrophic	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
720	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
722	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
724	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
730	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
738	28	Transformer Yard	Transformer - Non Catastrophic	Shutdown	FALSE	FALSE	FALSE	TRUE	
740	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
751	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
754	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
761	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
772	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
773	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
779	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	
782	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	FALSE	TRUE	FALSE	
788	28	Transformer yard	Transformer - Non Catastrophic	Shutdown	FALSE	FALSE	FALSE	TRUE	
800	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	FALSE	TRUE	FALSE	
801	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
835	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
838	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
839	28	Transformer Yard	Transformer - Non Catastrophic	Shutdown	FALSE	FALSE	TRUE	FALSE	
840	21	Plant-Wide Components	Pumps	Shutdown	FALSE	FALSE	TRUE	FALSE	
845	27	Transformer Yard	Transformer - Catastrophic	Shutdown	FALSE	TRUE	FALSE	FALSE	
849	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
858	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
862	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
919	29	Transformer Yard	Cable fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
941	27	Transformer Yard	Transformer - Catastrophic	Shutdown	FALSE	TRUE	FALSE	FALSE	
963	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
964	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
965	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
966	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
968	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
969	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
970	3	Containment (BWR)	Transient and Hotwork	Undetermined	FALSE	FALSE	TRUE	FALSE	
972	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	
974	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
981	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
983	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
990	7	Control/Aux/Reactor Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
992	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
995	29	Transformer Yard	Cable fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
997	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
1004	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
1007	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
1009	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
1010	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
1011	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
1012	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
1025	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
1031	2	Containment (PWR)	Reactor Coolant Pump	Shutdown	FALSE	FALSE	TRUE	FALSE	
1032	27	Transformer Yard	Transformer - Catastrophic	Shutdown	FALSE	TRUE	FALSE	FALSE	
1040	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
1044	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
1051	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	FALSE	TRUE	
1054	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1060	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	
1094	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
1106	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	FALSE	FALSE	Decommissioned plant. Removed from LPDS analysis.
1109	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
1111	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
1117	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1120	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1121	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1136	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
1138	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
1143	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1144	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	
1145	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1146	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
1149	37	Turbine Building	Transients	Undetermined	FALSE	TRUE	FALSE	FALSE	
1153	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	FALSE	TRUE	
1154	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	FALSE	TRUE	
1157	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1158	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
1161	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
1164	7	Control/Aux/Reactor Building	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	
1165	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
1166	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
1172	7	Control/Aux/Reactor Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
1177	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
1180	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1192	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	
1198	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	Changed the location to Control/Rx/Aux Bldg
1199	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1202	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
1203	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1221	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1222	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1228	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
1229	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1230	25	Plant-Wide Components	Transients	Shutdown	FALSE	TRUE	FALSE	FALSE	This event assessment was changed
1231	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1233	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1204	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1206	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1208	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	
1209	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1210	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	FALSE	TRUE	
1214	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1216	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	
1219	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
1234	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	TRUE	FALSE	FALSE	This event assessment was changed
1235	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1237	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
1242	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1243	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1247	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	
1249	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	This event assessment was changed
1252	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1272	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1273	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1275	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
1278	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
1291	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
1299	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	
1300	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1301	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1302	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
1303	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	TRUE	FALSE	FALSE	This event assessment was changed
1304	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	TRUE	FALSE	FALSE	
1305	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1306	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1307	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1311	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1312	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
1313	7	Control/Aux/Reactor Building	Transients	Undetermined	FALSE	TRUE	FALSE	FALSE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
1316	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
1324	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
1325	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	FALSE	TRUE	
1329	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1341	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
1345	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
1347	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1352	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
1354	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
1360	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
1361	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
1388	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
1389	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
1398	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
1401	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
1424	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	
1427	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
1505	28	Transformer Yard	Transformer - Non Catastrophic	Shutdown	FALSE	FALSE	FALSE	FALSE	This event was moved to Bin 16 (HEAF) and was not considered for LPSD analysis.
2100	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2102	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
2106	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
2108	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2110	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2111	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2113	5	Control/Aux/Reactor Building	Cable fires caused by welding and cutting	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
2115	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2116	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2117	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
2118	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2126	11	Plant-Wide Components	Cable fires caused by welding and cutting	Undetermined	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
2129	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2131	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2132	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
2134	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2137	28	Transformer Yard	Transformer - Non Catastrophic	Undetermined	FALSE	FALSE	TRUE	FALSE	
2138	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2143	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	FALSE	TRUE	
2145	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2146	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2147	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
2148	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2149	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2150	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2154	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2162	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
2166	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2169	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2173	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2177	27	Transformer Yard	Transformer - Catastrophic	Shutdown	FALSE	TRUE	FALSE	FALSE	This event was reassigned to Bin #27.
2182	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2183	32	Turbine Building	Main feedwater pumps	Undetermined	FALSE	FALSE	FALSE	TRUE	
2184	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
2188	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2190	22	Plant-Wide Components	RPS MG sets	Undetermined	FALSE	FALSE	FALSE	TRUE	
2192	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2193	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2196	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2198	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2199	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2201	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2203	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2215	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2216	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2220	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
2223	2	Containment (PWR)	Reactor Coolant Pump	Shutdown	FALSE	TRUE	FALSE	FALSE	
2232	22	Plant-Wide Components	RPS MG sets	Shutdown	FALSE	FALSE	FALSE	TRUE	
2238	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2241	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	TRUE	FALSE	FALSE	
2244	2	Containment (PWR)	Reactor Coolant Pump	Undetermined	FALSE	FALSE	TRUE	FALSE	
2245	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2247	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2248	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	FALSE	FALSE	FALSE	This event was moved to Bin 12, which is not included in LPSD PRA
2257	7	Control/Aux/Reactor Building	Transients	Undetermined	FALSE	TRUE	FALSE	FALSE	
2258	24	Plant-Wide Components	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2259	34	Turbine Building	T/G Hydrogen	Shutdown	FALSE	TRUE	FALSE	FALSE	
2260	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2270	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2271	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2279	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	TRUE	FALSE	FALSE	
2286	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
2291	7	Control/Aux/Reactor Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2293	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2296	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2298	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2299	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2300	37	Turbine Building	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
2306	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2307	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2320	28	Transformer Yard	Transformer - Non Catastrophic	Shutdown	FALSE	TRUE	FALSE	FALSE	
2321	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
2324	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	FALSE	FALSE	"Outside the engineering office" most likely means that the location of this fire was at a place that normally gets screened out in a Fire PRA. This event was removed from the LPSD analysis.
2327	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
2330	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
2340	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2347	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2363	3	Containment (BWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2376	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2379	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2384	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2385	25	Plant-Wide Components	Transients	Shutdown	FALSE	FALSE	TRUE	FALSE	
2398	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
2403	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2414	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2415	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2421	21	Plant-Wide Components	Pumps	Shutdown	FALSE	FALSE	TRUE	FALSE	
2423	36	Turbine Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2444	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2446	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2448	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2450	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2455	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	FALSE	TRUE	FALSE	
2458	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2459	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	FALSE	TRUE	FALSE	
2460	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2461	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2462	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
2463	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2464	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2465	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2466	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2467	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2469	24	Plant-Wide Components	Transient fires caused by welding and cutting	Undetermined	FALSE	TRUE	FALSE	FALSE	
2470	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2472	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2473	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2477	37	Turbine Building	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2480	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2482	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2483	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	

Table A-5: Fire Event Classification (continued)

Incident No.	Bin #	Location	Ignition Source	Power Level	High Energy Arcing Fault	Challenging	Not-Challenging	Undetermined	Comments
2484	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2485	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2486	36	Turbine Building	Transient fires caused by welding and cutting	Undetermined	FALSE	FALSE	TRUE	FALSE	
2488	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	FALSE	TRUE	FALSE	
2491	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2492	25	Plant-Wide Components	Transients	Undetermined	FALSE	FALSE	TRUE	FALSE	
2493	3	Containment (PWR)	Transient and Hotwork	Undetermined	FALSE	FALSE	TRUE	FALSE	
2495	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2496	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	
2497	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	This event assessment was changed
2504	3	Containment (PWR)	Transient and Hotwork	Shutdown	FALSE	FALSE	TRUE	FALSE	
2505	7	Control/Aux/Reactor Building	Transients	Shutdown	FALSE	FALSE	FALSE	TRUE	This event assessment was changed
2511	6	Control/Aux/Reactor Building	Transient fires caused by welding and cutting	Shutdown	FALSE	FALSE	TRUE	FALSE	

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10. SUPPLEMENTARY NOTES

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11. ABSTRACT (200 words or less)

This document presents a probabilistic risk assessment (PRA) framework for quantitatively analyzing fire risk in commercial nuclear power plants during low power and shutdown (LPSD) conditions, including the determination of core damage frequency (CDF) and large early release frequency (LERF). It is expected that future updates will be made to this document as experience is gained with LPSD quantitative risk analyses of both internal events and fires.

This LPSD fire PRA framework is intended to be used in combination with an at-power fire PRA performed using the method documented in Nuclear Regulatory Commission (NRC) Office of Nuclear Regulatory Research (RES) publication NUREG/CR-6850 and Electric Power Research Institute (EPRI) publication TR-1011989, "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities." This LPSD fire PRA framework directly parallels that at-power fire PRA method with respect to the structure and objectives of its technical analysis tasks, addressing those aspects of the at-power fire PRA that require unique treatment in the context of low-power or shutdown conditions. This LPSD fire framework also requires a LPSD internal events PRA; that is, both the at-power fire PRA and the LPSD internal events PRA are needed as starting points for conducting a LPSD fire PRA using the framework described in this document.

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