ANS/ASME-58.22-2014

Requirements for Low Power and Shutdown Probabilistic Risk Assessment

TRIAL USE AND PILOT APPLICATION

Publication of this standard for trial use has been approved by The American Society of Mechanical Engineers and the American Nuclear Society. Distribution of this standard for trial use and comment shall not continue beyond 36 months from the date of publication, unless this period is extended by action of the Joint Committee on Nuclear Risk Management. It is expected that following this 36-month period, this draft standard, revised as necessary, will be submitted to the American National Standards Institute (ANSI) for approval as an American National Standard. A public review in accordance with established ANSI procedures is required at the end of the trial-use period and before a standard for trial use may be submitted to ANSI for approval as an American National Standard. This trial-use standard is not an American National Standard.

Comments and suggestions for revision should be submitted to:

Secretary, Joint Committee on Nuclear Risk Management
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990

The American Society of Mechanical Engineers

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Nonmandatory Appendix

(This Foreword is not a part of "Requirements for Low Power and Shutdown Probabilistic Risk Assessment," ANS/ASME-58.22-2014.)

FOREWORD

The American Society of Mechanical Engineers (ASME) Board on Nuclear Codes and Standards (BNCS) and the American Nuclear Society (ANS) Standards Board mutually agreed in 2004 to form the Nuclear Risk Management Coordinating Committee (NRMCC). The NRMCC was chartered to coordinate and harmonize standards activities related to probabilistic risk assessment (PRA) between ASME and ANS. A key activity resulting from NRMCC was the development of PRA standards structured around the Levels of PRA (i.e., Level 1, Level 2, and Level 3) to be jointly issued by ASME and ANS. In 2011, ASME and ANS decided to combine their respective PRA standards committees to form the ASME/ANS Joint Committee on Nuclear Risk Management (JCNRM).

Publication for Trial Use

Publication of this standard for trial use has been approved by the JCNRM as a stand-alone standard. However, the writing of this standard began under the ANS Risk Informed Standards Committee; hence, ANS writing guidance has been followed. The current plan is for this standard, once approved as an ANSI standard, to be incorporated into RA-S-1.1, the "Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications."

The previous drafts of this standard have gone through several rounds of reviews by the JCNRM members, and all comments have been addressed in this version published for trial use. While the comments were resolved, there are remaining technical issues that are best resolved by testing this standard against different actual applications. This will ensure that the lessons learned from pilot applications are adequately addressed in this standard. Examples of pilot applications might include a gap analysis for an existing Low Power and Shutdown (LPSD) PRA model, or the development of new LPSD PRA models according to this standard. The JCNRM encourages any form of trial use of this proposed standard and requests feedback from trial users.

The project team and the readiness review team of this standard have identified the following potential issues, and it is hoped that these can be addressed in the trial use applications. Both the project team and the consensus ballot readiness review team believe that any of the requirements included in the LPSD Standard can be addressed with existing methods and data or supplemented by modest research of existing industry experience data. Nevertheless, the project team believes this should be verified during the trial use applications.

Potential Low Power and Shutdown PRA Standard Issues for Which Trial Use Feedback Is Desired	
Potential Issue	**Background and Project Team Assessment**
1. Whether the required number of plant operating states (POS) needed to satisfy the requirements of the standard are so excessive as to make the analysis impractical.	This issue was identified by comments on earlier drafts. The LPSD Standard has chosen to define specific attributes whose collective states make up the definition of each POS. These attributes were selected by experienced analysts that have performed LPSD analyses on real plants. Owner's groups have also developed guidance for developing LPSD models in which specific POSs are defined as examples. A non-mandatory appendix has been added to the standard to describe considerations in developing POSs. The project team does not believe the requirements will pose an excessive analysis burden.
2. Whether POSs are suitable when defined at a level of detail consistent with plant configurations sufficient to evaluate time-dependent risk metrics, as opposed to just considering the attributes listed in LPOS-A3.	This issue was identified by a commenter who wanted the flexibility to declare each plant configuration as a POS. This standard published for trial use allows either the use of plant configurations to define the POSs or the definition of POSs by collections of states of plant attributes to be used. POSs are widely used in existing PRA models for shutdown events.
3. Whether the requirements for at-initiator human actions analysis are reasonable and effective (at-initiator actions are human failure events that cause an initiating event; see Section 1.2.2).	This issue was first identified by a writing group member concerned about the possible omission of such considerations from earlier drafts of the standard. More recent commenters have expressed concerns that requirements added in response to this issue are too onerous. The project team believes that the available industry data for initiating events during shutdown conditions are adequate to identify the HRA contribution, although additional research to focus on this question would benefit this process. The project team believes that the main concern here is to identify and account for potential dependencies between the initial error and subsequent actions called on in response to the initial error. Such dependencies may be identified and considered to some degree by a review of operating experience to identify the conditions in which events originate. This conclusion limits the scope of the response needed to address the standard's requirements. Further research expanding the set of events reviewed would require a focused effort.
4. Whether the methods for human error probability (HEP) quantification are suitable for shutdown conditions.	This issue was first identified by a commenter concerned about the applicability of HRA methods developed for full power plant operating conditions to LPSD conditions where different sets of procedures apply. The project team notes that the methods developed for full power conditions are not restricted to full power, nor were they specifically calibrated to those conditions. This comment made more sense in past years when the procedures for shutdown conditions were less developed; however, at present, such procedures are better developed. Furthermore, The project team believes that the use of existing HRA methods for sequences initiating from full power conditions are also applicable for shutdown conditions.

Potential Low Power and Shutdown PRA Standard Issues for Which Trial Use Feedback Is Desired	
Potential Issue	**Background and Project Team Assessment**
5. Whether the approach to external hazards adequately captures the needed requirements for LPSD PRA for those hazards, for which only a few applications exist in the literature.	This is a general question that recognizes that plant conditions change during the different stages of a low power and shutdown evolution. The LPSD Standard acknowledged this in purposely excluding requirements for assessing internal fire hazard events as part of this version of the LPSD Standard. For other external event hazards, the standard states that these changes should be considered on a POS-by-POS basis. The project team believes that this set of requirements is appropriate and can be applied despite limited experience.
6. Whether the use of basic event risk significance summed over all POSs is a suitable measure for ranking importance for establishing modeling fidelity, or, since some models change the basic event evaluation in different POSs, whether other measures must be found.	The issue was identified by a comment in an earlier LPSD Standard ballot. Alternate metrics could be defined, and all can be handled by available software. It is a suitable question for a trial use application.
7. Whether the analyst can screen out the entire category of external hazards (e.g., earthquakes) on the basis of POS duration combined with external hazards initiating event frequencies.	This issue was identified by the readiness team review of this standard. In the introduction, Section 1.1.8.2 has been added to clarify how the screening of hazards can be accomplished for each POS, where appropriate.

This standard sets forth requirements for low power and shutdown probabilistic risk assessments (PRA) and also requirements for shutdown qualitative risk assessment (QLRA) that can be used to support risk-informed decisions for commercial nuclear power plants. This standard also prescribes a method for applying these requirements for specific applications.

The PRA requirements in this standard are intended to be used together with other PRA standards that cover different aspects of PRA scope. Specifically, they are intended to be used directly with the PRA standard developed by the ASME and the ANS ("Standard for Level 1 / Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications," ASME/ANS RA-Sa-2009 [1]).

While this LPSD Standard was being drafted for trial use ballot, a later addendum of the internal and external events at power standard, RA-Sb-2013, was published. It is the intent that this LPSD Standard will be revised to align with the available addenda or edition of the internal events at power standard prior to publication of the LPSD Standard as an ANSI standard.

This standard covers PRAs for both internal hazard events and external hazard events for a commercial nuclear power plant operating at low power or in a shutdown condition. Similarly, these PRA requirements are intended to be used with other standards now under development, including the

ASME/ANS PRA-methodology standards covering Level 2 (ASME/ANS RA-S-1.2) and Level 3 (ASME/ANS RA-S-1.3) risk assessments.

The PRA scope covered by this standard is limited to analyzing accident sequences initiated by "internal hazard events" (e.g., reactor trip, LOCAs, losses of service water, losses of offsite power, and internal flooding) or "external hazard events" (e.g., earthquakes, high winds, external flooding, etc.) that might occur while a nuclear power plant is operating at low power or is in a shutdown (i.e., non-power) condition. The exception to this scope is internal fire hazard, which is currently excluded from this standard due to the lack of methodology and applications in this area. Therefore, this standard covers all potential accident initiators arising at low power and shutdown conditions except for internal fires. The only other initiators explicitly excluded are accidents resulting from purposeful human-induced security threats (e.g., sabotage).

This standard's PRA technical requirements are presented in support of a quantitative PRA for time-averaged core damage frequency (CDF) or LERF. For applications involving a specific LPSD evolution, modifications to the technical requirements are presented in Part 10.

The PRA requirements in this standard are further restricted to requirements for: (a) a full Level 1 analysis of the CDF; and (b) a limited Level 2 analysis sufficient to evaluate the large early release frequency (LERF).

The scope is also limited to analyzing accident sequences involving fuel while it is in the reactor vessel. Events involving fuel while it is in the spent fuel pool are not covered.

The shutdown QLRA requirements in this standard are for models used in support of configuration risk assessments while in a shutdown condition (e.g., modes 3 to 6 for PWRs and modes 3 to 5 for BWRs for mode definitions for plants with improved technical specifications).

The types of risk-informed PRA applications contemplated under this standard are very broad. Both regulatory risk-informed applications and applications independent of regulations are contemplated. While the NRC currently does not require the use of this standard for any specific risk-informed applications, its use is expected to be common in such applications. In this regard, this standard's approach is intended to be identical to that used in the closely related standard, ASME/ANS RA-Sa-2009 [1]. The approach and supporting logic of ASME/ANS RA-Sa-2009 [1] are relied upon heavily in this standard's guidance in this area.

PREPARATION OF TECHNICAL INQUIRIES TO THE JOINT COMMITTEE ON NUCLEAR RISK MANAGEMENT

INTRODUCTION

NOTE FOR TRIAL USE: The text of this section describes the technical inquiry process for approved standards. However, during the trial use period, users are encouraged to provide feedback, ask questions, and interact with the LPSD project team on either a formal or informal basis. Such feedback may be provided via the Secretary, Joint Committee on Nuclear Risk Management, as noted below, or by contacting the LPSD project team chair or another member of the project team or the JCNRM.

The ASME/ANS Joint Committee on Nuclear Risk Management (JCNRM) will consider written requests for the interpretation and revision of risk management standards and the development of new requirements as dictated by technological development. JCNRM's activities in this latter regard are strictly limited to interpretations of the requirements or to the consideration of revisions to the requirements on the basis of new data or technology. As a matter of published policy, The American Society of Mechanical Engineers (ASME) does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity, and, accordingly, inquiries requiring such considerations will be returned. Moreover, ASME does not act as a consultant on specific engineering problems or on the general application or understanding of the standard's requirements. If, based on the inquiry information submitted, it is the opinion of the JCNRM that the inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

To be considered, inquiries will require sufficient information for JCNRM to fully understand the request.

INQUIRY FORMAT

Inquiries shall be limited strictly to interpretations of the requirements or to the consideration of revisions to the present requirements on the basis of new data or technology. Inquiries shall be submitted in the following format:

(a) *Scope.* The inquiry shall involve a single requirement or closely related requirements. An inquiry letter concerning unrelated subjects will be returned;

(b) *Background.* State the purpose of the inquiry, which would be either to obtain an interpretation of the standard's requirement or to propose consideration of a revision to the present requirements. Concisely provide the information needed for JCNRM's understanding of the inquiry (with sketches as necessary), being sure to include references to the applicable standard edition, addenda, part, appendix, paragraph, figure, or table;

(c) *Inquiry Structure.* The inquiry shall be stated in a condensed and precise question format, omitting superfluous background information and, where appropriate, composed in such a way that "yes" or "no" (perhaps with provisos) would be an acceptable reply. This inquiry statement should be technically and editorially correct;

(d) *Proposed Reply.* State what it is believed that the standard requires. If, in the inquirer's opinion, a revision to the standard is needed, recommended wording shall be provided;

(e) *Typewritten/Handwritten.* The inquiry shall be submitted in typewritten form; however, legible, handwritten inquiries will be considered;

(f) *Inquirer Information.* The inquiry shall include the name, telephone number, and mailing address of the inquirer;

(g) *Submission.* The inquiry shall be submitted to the following address: Secretary, Joint Committee on Nuclear Risk Management, The American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

USER RESPONSIBILITY

Users of this standard are cautioned that they are responsible for all technical assumptions inherent in the use of PRA models, computer programs, and analysis performed to meet the requirements of this standard.

CORRESPONDENCE

Suggestions for improvements to the standard or inclusion of additional topics shall be sent to the following address: Secretary, Joint Committee on Nuclear Risk Management, The American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016-5990.

COMMITTEE ROSTERS

CONTRIBUTORS TO THE REQUIREMENTS FOR LOW POWER AND SHUTDOWN PROBABILISTIC RISK ASSESSMENT

(The following is a roster of the Joint Committee on Nuclear Risk Management at the time of the approval of this standard.)

This standard was processed and approved for release as a trial use and pilot application by the ASME/ANS Joint Committee on Nuclear Risk Management. Committee approval of the standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, the JCNRM had the following members:

ASME/ANS Joint Committee on Nuclear Risk Management (JCNRM)

R. J. Budnitz, *Cochair*, Lawrence Berkeley National Laboratory
C. R. Grantom, *Cochair*, South Texas Project Nuclear Operating Company
D. W. Henneke, *Vice Cochair,* General Electric
P. F. Nelson, *Vice Cochair*, National Autonomous University of Mexico

P. J. Amico, Hughes Associates, Inc.
V. K. Anderson, Nuclear Energy Institute
R. A. Bari, Brookhaven National Laboratory
S. A. Bernsen, Individual
J. R. Chapman, Scientech, Inc.
M. Drouin, U.S. Nuclear Regulatory Commission
D. J. Finnicum, Westinghouse Electric Company (retired)
K. N. Fleming, KNF Consulting Services, LLC
H. A. Hackerott, Omaha Public Power District–Nuclear Energy Division
E. A. Hughes, Etranco, Inc.
K. L. Kiper, Westinghouse Electric Company
S. Kojima, Kojima Risk Institute, Inc.
G. A. Krueger, Exelon Corporation
J. L. Lachance, Sandia National Laboratories
R. H. Lagdon, U.S. Department of Energy
S. H. Levinson, AREVA Inc.
S. R. Lewis, Electric Power Research Institute
M. K. Ravindra, MKRavindra Consulting
M. B. Sattison, Idaho National Laboratory
R. E. Schneider, Westinghouse Electric Company
B. D. Sloane, ERIN Engineering & Research, Inc.
D. E. True, ERIN Engineering & Research, Inc.
D. J. Wakefield, ABS Consulting, Inc.
I. B. Wall, Individual
J. W. Young, GE Hitachi
G. L. Zigler, Enercon Services

ANS/ASME-58.22 (of the Standards Committee of the American Nuclear Society) was responsible for the development of this standard. It had the following membership when first formulated:

R. J. Budnitz, *Chair 1999-2003*, Lawrence Berkeley National Laboratory
D. C. Bley, Buttonwood Consulting, Inc.
W. Burchill, Texas A & M University
M. T. Drouin, U.S. Nuclear Regulatory Commission
J. A. Julius, Curtiss Wright
D. W. Stillwell, South Texas Project Nuclear Operating Company
D.W. Whitehead, Sandia National Laboratories

Additional members participating in the project team for parts of the time after inception and before completion of the final version included:

K. L. Kiper, *Chair 2003-2007,* Florida Power and Light Company

E. T. Chow, U.S. Nuclear Regulatory Commission
C. R. Grantom, South Texas Project Nuclear Operating Company
Y. F. Khalil, Yale University
D. M. O'Neal, U.S. Nuclear Regulatory Commission

The following project team members were participating at the time the standard was approved:

D. J. Wakefield, *Chair 2007- present,* ABS Consulting Inc.

R. J. Budnitz, Lawrence Berkeley National Laboratory
D. Hance, Electric Power Research Institute
G. Hughes, ETRANCO Inc.
J. A. Julius, Curtiss Wright
K. L. Kiper, Westinghouse Electric Company
J. Li, GE Hitachi Nuclear Energy
Z. Ma, Idaho National Laboratory
J. Mitman, U.S. Nuclear Regulatory Commission
L. Shanley, ERIN Engineering and Research, Inc.
R. Weston, Westinghouse Electric Company
F. Yilmaz, South Texas Project Nuclear Operating Company
D. W. Henneke, GE Hitachi Nuclear Energy

JCNRM Subcommittee on Standards Development

B. D. Sloane, *Chair*, ERIN Engineering & Research, Inc.
D. W. Henneke, *Vice Chair*, General Electric Company

A. Afzali, Southern Nuclear Company
V. K. Anderson, Nuclear Energy Institute

S. Bernsen, Individual
J. R. Chapman, Scientech, Inc.
H. L. Detar, Westinghouse Electric Company
M. Drouin, U.S. Nuclear Regulatory Commission
K. N. Fleming, KNF Consulting Services, LLC
C. Guey, Tennessee Valley Authority
E. A. Hughes, Etranco, Inc.
M. T. Leonard, dycoda, LLC
S. R. Lewis, Electric Power Research Institute
R. J. Lutz, Individual
Z. Ma, Idaho National Laboratory
M. B. Sattison, Idaho National Laboratory
V. Sorel, EDF Group
F. Tanaka, Mitsubishi Heavy Industries, Ltd.
D. J. Wakefield, ABS Consulting, Inc.
T. A. Wheeler, Sandia National Laboratories
K. Woodard, ABS Consulting
K. Canavan, *Alternate*, Electric Power Research Institute
G. W. Kindred, *Alternate*, Tennessee Valley Authority

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A. Maioli, *Vice Chair*, Westinghouse Electric Company
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V. Andersen, ERIN Engineering & Research, Inc.
V. K. Anderson, Nuclear Energy Institute
K. R. Fine, FirstEnergy Nuclear Operating Company
D. Finnicum, Westinghouse Electric Company
H. A. Hackerott, Omaha Public Power District–Nuclear Energy Division
D. C. Hance, Electric Power Research Institute
D. G. Harrison, U.S. Nuclear Regulatory Commission
T. G. Hook, Arizona Public Service
E. A. Hughes, Etranco, Inc.
K. L. Kiper, NextEra Energy
S. Kojima, Kojima Risk Institute, Inc.
E. A. Krantz, Scientech, Inc.
J. L. Lachance, Sandia National Laboratories
S. H. Levinson, AREVA Inc.
D. N. Miskiewicz, Engineering Planning and Management, Inc.
P. F. Nelson, National Autonomous University of Mexico
S. P. Nowlen, Sandia National Laboratories
M. K. Ravindra, MKRavindra Consulting
J. B. Savy, Savy Risk Consulting
R. E. Schneider, Westinghouse Electric Company
I. B. Wall, Individual

R. A. Weston, Westinghouse Electric Company
J. W. Young, GE Hitachi
G. L. Zigler, Enercon Services

JCNRM Subcommittee on Risk Application

Kenneth L. Kiper, *Chair,* Westinghouse Electric Company
Stanley H. Levinson, *Vice Chair,* AREVA Inc.
Robert J. Budnitz, Lawrence Berkeley National Laboratory
Gary M. Demoss, PSEG Nuclear, LLC
Diane M. Jones, Maracor, A Division of Enercon Services, Inc.
Gerry W. Kindred, Tennessee Valley Authority
Lynn A. Mrowca, U.S. Nuclear Regulatory Commission
Pamela F. Nelson, National Autonomous University of Mexico
Patrick J. O'Regan, Electric Power Research Institute
Vish Patel, Southern Nuclear Operating Company
Kent Sutton, INGRID Consulting Services, LLC
Carroll Trull, Westinghouse Electric Company

Part 1 General Requirements for an LPSD PRA and QLRA

Text that is new in this part compared to Part 1 of Reference [1] is underlined below.

1.1 Introduction

1.1.1 Objective

This standard[1] sets forth the requirements for Low Power and Shutdown (LPSD) probabilistic risk assessments (PRA) and for LPSD Qualitative Risk Assessments (QLRA), both of which are used to support risk-informed decisions for commercial light water reactor nuclear power plants. This standard also prescribes a method for applying those parts of the requirements as necessary to support specific applications.

The discussion of requirements for LPSD PRAs is presented in Parts 1 through 10, and the discussion of the method for applying them is presented in Section 1.3. These requirements would be used for applications requiring quantitative risk-informed insights during low power and shutdown conditions. The discussion of requirements and a method for applying them for LPSD QLRA are presented in Part 11. These requirements would be used for applications in which qualitative risk-informed insights suffice, such as for plant configuration control during shutdown conditions.

1.1.2 Scope and Applicability for LPSD PRA

This standard establishes requirements for a Level 1 PRA of internal and external hazards for low power and shutdown modes. These modes include operating states ranging from those in which the plant is at power levels substantially below nominal full power (low power) to operating states in which the plant is shutdown with the reactor subcritical and the primary system depressurized and cooled sufficiently to be placed on Residual Heat Removal (RHR) cooling. This standard bases these requirements in large part on ASME/ANS RA-Sa-2009 [1][2], which at present is restricted to requirements for plant operating states at-power[3].

This standard has been developed to specify the requirements for an evaluation of risk during LPSD conditions. Depending on the application, these evaluations are likely to focus on two end states: (a) a full Level 1 analysis of the core damage frequency (CDF); and (b) a limited Level 2 analysis sufficient to evaluate the large early release frequency (LERF). This is consistent with Reference [1]. The emphasis for the Level 2 analysis during shutdown conditions is more on containment isolation failure than containment structural failure for many applications since there may be LPSD plant operating states where the containment has an equipment hatch removed or other large openings to permit maintenance activities. Also, the dissipated decay heat during shutdown results in a reduced source term when compared to full power (although the radiological impact of the source term decreases at a slower rate

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1 The current standard, ANS/ASME-58.22-2014, is herein referred to as "this standard."

2 Numbers in brackets refer to corresponding numbers in Section 12, "References."

3 Reference [1] is defined to apply broadly to "at-power" plant states. The LPSD PRA Standard includes "low power" states, which could be considered part of the broad "at-power" definition. To avoid confusion, this standard defines (and applies to) "low power" states in contrast to "full power" or "nominal-full-power " states. The "low power" states are defined to include all at-power operations below nominal full power. See the definitions of these terms in Section 1.2.2.

than the decay heat does). Thus, while the definition of LERF is the same as for full power states, the determination of "large" releases must include additional considerations to those for full power.

It is recognized that alternative risk metrics to CDF and LERF have been used in many assessments of LPSD conditions. These alternative risk metrics include approaching coolant boiling in the core, depletion of coolant to the point of core uncovery, and radioactivity release. For consistency with the requirements of this standard, the alternate metric(s) are to be computed as a frequency of an accident class, and the selected metric(s) are to be surrogates for both CDF and LERF. Note that one alternative metric may, by itself, be a surrogate for both CDF and LERF. The alternate metric(s) are to be justified in the context of an application, against which the scope of the PRA is to be compared against all requirements. Any deviations from the requirements herein are to be justified for the alternate metric(s). Non-mandatory Appendix 2-B discusses risk metrics further.

Furthermore, the scope of the requirements for LPSD PRA in this standard excludes sources of radioactive material other than nuclear fuel within the reactor vessel; i.e., only "core" damage accidents are considered. Thus, accidents involving nuclear fuel in the spent fuel pool, in dry storage, or in transit are excluded from the scope of this standard. Accidents involving radioactive material sources other than nuclear fuel are also excluded.

This standard's technical requirements are presented in a manner to support a range of applications including the calculation of time-averaged[4] CDF or LERF, consistent with Reference [1]. Additionally, alternative risk metrics may be used. This standard may also be used for LPSD PRA applications involving a specific outage. Modifications to the LPSD PRA technical requirements to support time-dependent risk metrics of a specific LPSD evolution are noted in Section 1.3.7.

The only initiating event hazards explicitly excluded from the LPSD PRA scope are accidents resulting from purposeful human-induced security breaches (e.g., sabotage) and accidents initiated by internal fires.

This standard applies to PRAs used to support applications of risk-informed decision-making related to operating power plants[5]. They may be used for plants under design or construction, for advanced LWRs, or for other reactor designs, but revised or additional requirements may then be needed.

This version of the LPSD PRA Standard provides specific requirements for the following hazard groups:

- *(a)* Internal Events (Part 3);
- *(b)* Internal Flooding (Part 4);
- *(c)* Seismic Events (Part 5);
- *(d)* High Winds (Part 7);
- *(e)* External Floods (Part 8);
- *(f)* Other External Hazards (Part 9).

In addition to providing technical requirements for detailed PRAs of these hazards, this standard provides requirements for Screening and Conservative Analyses of External Hazards (Part 6). Technical

[4] "Time-averaged" risk metrics refer to the occurrence of low power and outage evolutions averaged over time, in contrast to risk metrics applied to a specific outage (e.g., refueling number 4). All PRAs have other elements averaged over time, such as initiating event frequencies and component failure rates.

[5] Here, "operating power plants" means plants that have operated and, thus, have spent fuel and decay heat. An operating plant could be "operating" at-power or in shutdown.

requirements for Seismic Margin Analysis, unlike for full power operating states, are not provided for LPSD PRAs.

Many of the technical requirements for internal events in Parts 2 and 3 are fundamental requirements for performing a PRA for any hazard group and are therefore relevant to Parts 4 through 10 of this standard. They are incorporated by reference in those requirements that address the development of the plant response to the damage states created by hazard groups addressed in Parts 4 through 10. Their specific allocation to Parts 2 and 3 is partially a historical artifact of the way Reference [1] was developed, with the full power internal event requirements being developed first, and those of the remaining hazard groups being developed later. However, it also is a reflection of the fact that a fundamental understanding of the plant response to a reasonably complete set of initiating events (as defined in Section 1.2.2) provides the foundation for modeling the impact of various hazards on the plant. Hence, even though Part 3 is given a title associated with the internal event hazard group, it is understood that the requirements in this section are applicable to all the hazard groups within the scope of the LPSD PRA.

1.1.3 Structure of LPSD PRA Requirements

1.1.3.1 LPSD PRA Elements

The technical requirements for the LPSD PRA model in each section are organized by their respective LPSD PRA technical elements. The LPSD PRA technical elements define the scope of the analysis for each section of the standard.

This standard specifies technical requirements for the LPSD PRA elements listed in Table 1.1.3-1. The first element listed in Table 1.1.3-1 in the internal event hazard group, Plant Operating States (POS), is the only element unique to this LPSD PRA Standard. Otherwise, these elements are consistent with those defined in [1] for full power plant operating states. During LPSD operations, the plant physical conditions such as temperature, pressure, decay heat level, operating and maintenance configurations can vary dramatically; and these variations can significantly impact the accident progression and the resulting risk assessment. Thus, the concept of the POS was developed and implemented to identify and translate the important plant differences into states affecting the risk model. Part 2 provides the LPSD PRA Standard requirements associated with POSs; and Appendix 2.A presents a non-mandatory primer on POS analysis methodology.

Table 1.1.3-1 LPSD PRA Elements Addressed by Standard

	Hazard Group	**PRA Elements**
Internal Hazards	Internal Events	*(a)* Plant Operating State Analysis (LPOS) *(b)* Initiating Events Analysis (LIE) *(c)* Accident Sequence Analysis (LAS) *(d)* Success Criteria (LSC) *(e)* Systems Analysis (LSY) *(f)* Human Reliability Analysis (LHR) *(g)* Data Analysis (LDA) *(h)* Quantification (LQU) *(i)* LERF Analysis (LLE)
	Internal Flooding	*(a)* Internal Flood Plant Partitioning (LIFPP) *(b)* Internal Flood Source Identification and Characterization (LIFSO) *(c)* Internal Flood Scenarios (LIFSN) *(d)* Internal Flood-induced Initiating Events (LIFEV) *(e)* Internal Flood Accident Sequences and Quantification (LIFQU)
External Hazards	Seismic Events	*(a)* Probabilistic Seismic Hazard Analysis (LSHA) *(b)* Seismic Fragility Analysis (LSFR) *(c)* Seismic Plant Response Analysis (LSPR)
	High Winds	*(a)* High Wind Hazard Analysis (LWHA) *(b)* High Wind Fragility Analysis (LWFR) *(c)* High Wind Plant Response Analysis (LWPR)
	External Floods	*(a)* External Flood Hazard Analysis (LXFHA) *(b)* External Flood Fragility Analysis (LXFFR) *(c)* External Flood Plant Response Analysis (LXFPR)
	Other External Hazards	*(a)* External Hazard Analysis (LXHA) *(b)* External Hazard Fragility Analysis (LXFR) *(c)* External Hazard Plant Response Analysis (LXPR)

1.1.3.2 High Level Requirements

A set of objectives and high level requirements (HLR) is provided for each LPSD PRA Element in the Technical Requirements section of each respective section of this standard. The HLRs set forth the minimum requirements for a technically acceptable baseline LPSD PRA, independent of an application. The HLRs are defined in general terms and present the top level logic for the derivation of more detailed supporting requirements for each of the LPSD PRA Capability Categories. The HLRs reflect not only the diversity of approaches that have been used to develop the existing LPSD PRAs, but also the need to accommodate future technological innovations.

1.1.3.3 Supporting Requirements

A set of SRs is provided for each HLR (that is provided for each LPSD PRA technical element) in the Technical Requirements portion of each respective section of this standard. The SRs for the technical elements are presented as action statements using the three Capability Categories described below. For each Capability Category, the SRs define the minimum requirements necessary to meet that Capability Category. In these tables, some action statements apply to only one Capability Category, and some extend across two or three Capability Categories. When an action statement spans multiple categories, it applies equally to each Capability Category. When necessary, the differentiation between Capability Categories is made in other associated SRs. The interpretation of an SR whose action statement spans multiple categories is stated in Table 1.1.3-3 . It is intended that, by meeting all the SRs under a given HLR, an LPSD PRA will meet that HLR. The Technical Requirements portion of each respective section of this standard also specifies the required documentation to facilitate PRA applications, upgrades, and peer review.

This standard is intended for a wide range of applications that require a corresponding range of LPSD PRA capabilities. Applications vary with respect to which risk metrics are employed, which decision criteria are used, the extent of reliance on the LPSD PRA results in supporting a decision, and the degree of resolution required for the factors that determine the risk significance of the subject of the decision. In developing the different portions of the LPSD PRA model (e.g., system model), it is recognized that not every item will be or need be developed to the same level of detail, the same degree of plant-specificity, or the same degree of realism.

Although the range of capabilities required for each portion of the LPSD PRA to support an application falls on a continuum, three levels are defined and labeled either Capability Category I, II, or III, so that requirements can be developed and presented in a manageable way. Table 1.1.3-2 describes, for three principal attributes of any PRA, the bases for defining the Capability Categories. This table was used to develop the SRs for each HLR.

Table 1.1.3-2 Bases for PRA Capability Categories

Attributes of PRA	I	II	III
1. **Scope and level of detail:** The degree to which the scope and level of detail of the plant design, operation, and maintenance are modeled.	Resolution and specificity sufficient to identify the relative importance of the contributors at the system or train level, including associated human actions.	Resolution and specificity sufficient to identify the relative importance of the significant contributors at the component level and associated human actions, as necessary [see Note (1)].	Resolution and specificity sufficient to identify the relative importance of the contributors at the component level including associated human actions, as necessary [see Note (1)].
2. **Plant specificity**: The degree to which plant-specific information is incorporated such that the as-built and as-operated plants are addressed	Use of generic data/models acceptable except for the need to account for the unique design and operational features of the plant.	Use of plant-specific data/models for the significant contributors.	Use of plant-specific data/models for all contributors, where available.
3. **Realism**: The degree to which realism is incorporated such that the expected response of the plant is addressed.	Departures from realism will have moderate impacts on the conclusions and risk insights as supported by good practices [see Note (2)].	Departures from realism will have small impacts on the conclusion and risk insights supported by good practices [see Note (2)].	Departures from realism will have negligible impacts on the conclusion and risk insights supported by good practices [see Note (2)].

NOTES:
(1) The definitions for Capability Categories II and III are not meant to imply that the scope and level of detail includes the identification of every component and human action, but only those needed for the function of the system being modeled.
(2) The differentiation among moderate, small, and negligible is determined by the extent to which the impacts on the conclusions and risk insights could affect a decision under consideration. This differentiation recognizes that the PRA would generally not be the sole input to a decision. A moderate impact implies that the impact (of the departure from realism) is of sufficient size that it is likely that a decision could be affected, a small impact implies that it is unlikely that a decision could be affected, and a negligible impact implies that a decision would not be affected.

The intent of the delineation of the Capability Categories within the SRs is generally that the degree of scope and level of detail, the degree of plant-specificity, and the degree of realism increases from Capability Category I to Capability Category III. However, the Capability Categories are not based on the level of conservatism (i.e., the tendency to overestimate risk due to simplifications in the LPSD PRA) in a particular aspect of the analysis. The level of conservatism may decrease as the Capability Category increases and more detail and more realism are introduced into the analysis. However, this is not true for all requirements and should not be assumed. Realism, however, does increase with increasing Capability Category.

The boundaries between these Capability Categories can only be defined in a general sense. When a comparison is made between the capabilities of any given LPSD PRA and the SRs of this standard, it is expected that the capabilities of an LPSD PRA's elements or portions of the LPSD PRA within each of the elements will not necessarily all fall within the same Capability Category, but rather will be distributed among all three Capability Categories. There may be LPSD PRA elements or portions of the LPSD PRA within the elements that fail to meet the SRs for any of these Capability Categories. While all portions of the LPSD PRA need not have the same capability, the LPSD PRA model should be coherent. The SRs have been written so that within a Capability Category, the interfaces between portions of the LPSD PRA are coherent, e.g., requirements for event trees are consistent with the definition of initiating event groups.

When a specific application is undertaken, judgment is needed to determine which Capability Category is needed for each portion of the LPSD PRA and hence which SRs apply to the applications.

Table 1.1.3-3 Interpretation of Supporting Requirements

Action Statement SR Spans:	Peer Review Finding	Interpretation of the Supporting Requirement
All Three Capability Categories (I/II/III)	Meets SR	Capable of supporting applications in all Capability Categories
	Does not meet SR	Does not meet minimum standard
Single Capability Category (I or II or III)	Meets individual SR	Capable of supporting applications requiring that Capability Category or lower
	Does not meet any SR	Does not meet minimum standard
Lower Two Capability Categories (I/II)	Meets SR for Capability Categories I/II	Capable of supporting applications requiring Capability Category I or II
	Meets SR for Capability Category III	Capable of supporting applications in all Capability Categories
	Does not meet SR	Does not meet minimum standard
Upper Two Capability Categories (II/III)	Meets SR for Capability Categories II/III	Capable of supporting applications in all Capability Categories
	Meets SR for Capability Category I	Capable of supporting applications requiring Capability Category I
	Does not meet SR	Does not meet minimum standard

The SRs specify what to do rather than how to do it, and, in that sense, specific methods for satisfying the requirements are not prescribed. Nevertheless, certain established methods were contemplated during the development of these requirements. Alternative methods and approaches to the requirements of this standard may be used if they provide results that are equivalent or superior to the methods usually used and meet the HLRs and SRs presented in this standard. The use of any particular method for meeting an SR shall be documented and shall be subject to review by the peer review process described in Section 1.6.

1.1.4 Risk Assessment Application Process

The use of an LPSD PRA and the Capability Categories that are needed for each part of the LPSD PRA and for each of the LPSD PRA Elements will differ among applications. Section 1.3 describes the activities to determine whether a PRA has the capability to support a specific application of risk-informed decision making. Three different LPSD PRA Capability Categories are described in Subsection 1.1.3. LPSD PRA capabilities are evaluated for applicable parts of an LPSD PRA and each associated SR rather than by specifying a Capability Category for the entire LPSD PRA. Therefore, only those parts of the LPSD PRA required to support the application in question need the Capability Category appropriate for that application. For a given application, supplementary analyses may be used in place of or to augment those aspects of an LPSD PRA that do not fully meet the requirements in the Technical Requirements section of each respective part of this standard. Requirements for supplementary analysis are outside the scope of this standard.

1.1.5 PRA Configuration Control

Section 1.5 provides requirements for configuration control of an LPSD PRA (i.e., maintaining and upgrading a plant-specific LPSD PRA) such that the LPSD PRA reflects the as-built, as-operated nuclear power plant to a degree sufficient to support the application for which it is used.

1.1.6 Peer Review Requirements

Section 1.6 provides the general requirements for a peer review to determine if the LPSD PRA methodology and its implementation meet the requirements of the Technical Requirements section of each respective part of this standard. Scope-specific requirements are contained in the Peer Review section of the respective parts of this standard.

1.1.7 Addressing Multiple Hazard Groups

The technical requirements to determine the technical adequacy of an LPSD PRA for different hazard groups to support applications are presented in Parts 2 through 10. The approaches to modeling the plant damage resulting from different hazard groups vary in terms of the degree of realism and the level of detail achievable by the state of the art. For example, there are uncertainties that are unique to the modeling of the different hazards and their effects on the plant, and the assumptions made in dealing with these uncertainties can lead to varying degrees of conservatism in the estimates of risk. Furthermore, because the analyses can be resource intensive, it is normal to use screening approaches to limit the number of detailed scenarios to be evaluated and the number of mitigating systems credited while still achieving an acceptable evaluation of risk. These screening approaches are unique to each hazard group.

For many applications, it is necessary to consider the combined impact on risk from those hazard groups for which it cannot be demonstrated that the impact on the decision being made is insignificant. This can be done by using a single model that combines the LPSD PRA models for the different hazard groups or by combining the results from separate models. In either case, when combining the results from the different hazard groups, it is essential to account for the differences in levels of conservatism and levels of detail so that the conclusions drawn from the results are not overly biased or distorted. To support this objective, the standard is structured so that requirements for the analysis of the LPSD PRA results, including identification of significant contributors, identification and characterization of sources of uncertainty, and identification of assumptions, are included in each section separately.

In some cases, the requirements for developing a PRA model in Parts 4 through 10 refer back to the requirements of Parts 2 and 3. The requirements of Parts 2 and 3 should be applied to the extent needed given the context of the modeling of each hazard group. In each section, many of the requirements that differentiate between Capability Categories, either directly or by incorporating the requirements of Parts 2 and 3, do so on the basis of the treatment of significant contributors and significant accident sequences/cut sets for the hazard group being addressed. Because, as discussed above, there are differences in the way the LPSD PRA models for each specific hazard group are developed, the requirements are best treated as being self-contained for each hazard group separately when determining significant contributors and significant accident sequences/cut sets. In other words, these are identified with respect to the CDF and LERF summed over each POS for each hazard group separately. While there may be a need in some applications to assess the significance with respect to the total CDF or LERF, this assessment has to be done with a full understanding of the differences in conservatism and level of detail introduced by the modeling approaches for the different hazard groups as well as within each hazard group.

To determine the Capability Category at which the SRs have been met, it is necessary to have a definition of the term “significant”. Consequently, the term “significant” is used in various definitions in this standard and is thereby explicitly incorporated into specific SRs. Generally, the philosophy used in Capability Category II ensures a higher level of realism for “significant” contributors. This manifests itself in SRs related to the scope of plant-specific data, detailed HRA (versus screening values), CCF treatment, documentation, and others.

The only consequence of not meeting the standard definition of “significant” for a specific SR is that the LPSD PRA would not meet Capability Category II for that SR. Thus, in the context of an application, if a hazard group is a small contributor, it should be acceptable to meet Capability Category I by using screening HEPs, not using plant-specific data for equipment reliability, etc. The applicable portion of the LPSD PRA will simply be considered as meeting Capability Category I for that specific SR for that hazard group.

Additionally, from a practical standpoint, LPSD PRA models are generally developed on a hazard group basis (i.e., a seismic PRA, a high wind PRA, etc.). While they may be integrated into a single model with multiple hazards, the development is done on a hazard group basis. In Capability Category II, this standard strives to ensure that the more “significant” contributors to each hazard group are understood and treated with an equivalent level of resolution, plant specificity, and realism, so as not to skew the results for that hazard group. The definitions also acknowledge that there may be cases where the proposed quantitative definition is inappropriate; e.g., the hazard group risk is very low, or bounding methods are used.

In summary, the definitions that use the term “significant” simply help to define how much realism is necessary to meet Capability Category II of some SRs. They are NOT intended to be definitions of what is “significant” in a particular application. Indeed, in the context of a specific application, they may be either too loose or too restrictive, depending on what is being evaluated. In the context of this standard, the decisions on applying these definitions and/or defining what is significant to a decision would be addressed in the Risk Assessment Application Process (see Section 1.3).

1.1.8 LPSD Requirements for External Hazards

1.1.8.1 Scope of External Hazards in Parts 5 to 9

External hazards are covered in this standard in separate sections grouped by "hazard group." Within the scope, included in Parts 5, 6, 7, 8, and 9, are both natural external hazards (e.g., earthquakes, high winds, and external flooding) and human-made external hazards (e.g., airplane crashes, explosions at nearby industrial facilities, and impacts from nearby transportation activities) that occur while the plant is at low power or shutdown in any of the considered LPSD evolutions.

Internal floods during LPSD evolutions are categorized as internal hazards rather than external hazards; they are instead covered in Part 4. Appendix 6-A of the ASME/ANS PRA Standard [1] contains an extensive list of the external hazards generally considered within an external hazards PRA and hence within the scope here. That appendix is incorporated here by reference.

1.1.8.2 Screening of External Hazards

There are many external hazards that might affect a nuclear plant during low power or shutdown conditions, but not all of them would contribute significantly to the overall risk for any given plant. As explained in Section 6-1.1 of the ASME/ANS PRA Standard [1], it is necessary for the analysis team to ascertain:

> "… which of these many external events can be screened out so that no further PRA analysis is needed. This allows the team to focus on those external events that remain (unscreened) within the analysis. Experience reveals that earthquakes can never be screened out using the methods herein; that sometimes high winds and external flooding can be screened out but sometimes they require further analysis, either a bounding analysis, a semi-quantitative analysis, or perhaps even a full PRA; and that occasionally one or more other external events also require a full PRA."

It is important to note that, consistent with the Initiating Events discussion and requirements in Part 3 of this standard, it may be feasible to screen out any specific external hazard for a given POS based on the combination of POS duration and hazard frequency or on other considerations. Concerning earthquakes specifically, a comment is in order about the quotation from the ASME/ANS PRA Standard [1] in the paragraph above: "Experience reveals that earthquakes can never be screened out." This sentence is intended to explain that for full power operation, the category of earthquake-initiated accidents can never be screened out entirely. However, in the context of LPSD analysis covered by this standard, it is possible that for a specific POS, the analyst may screen out the entire category of earthquakes on the basis of POS duration combined with earthquake frequency while retaining the highest risk POSs from earthquake-initiated accidents. This screening out requires a defined basis; see SR LPOS-B2. See also SR's LIE-C6 and LIE-C6a, which permit screening POS-and-initiating-event combinations for internal events.

For high winds and external flooding, either or both of these may be screened out at a specific site for a particular POS, in whole or in part, depending on the circumstances and including possible seasonal-variation considerations. If not screened out, high winds and external flooding may be analyzed using either the specific technical requirements in Parts 7 and 8, respectively, or the general technical requirements for "other external hazards" in Part 9.

Part 6 of the ASME/ANS PRA Standard [1] contains a full discussion of the considerations involved in this screening analysis and in various approaches to conservative bounding analysis as well as the rationale, the HLRs, and the SRs. These requirements, notated by EXT, are found in Part 6 of the

ASME/ANS PRA Standard [1]. The HLRs and SRs cover various types of successive screening activities and conservative analysis activities. The analyst needs to consider any special circumstances that would differentiate a given LPSD POS from the full-power situation.

1.1.8.3 Structure of an External Hazard PRA

The following discussion applies to any external hazard that is not screened out as discussed above in Section 1.1.8.2.

The PRA of an "external hazard" during LPSD conditions consists of the following seven broad categories of analysis work. For each of these, the discussion below notes the character of the technical requirements in this standard and their relation to similar technical elements either in the ASME/ANS PRA Standard [1] (i.e., full power external events PRA) or elsewhere in this standard. The ASME/ANS PRA Standard [1] Appendix 5-A, "Seismic PRA Methodology – Primer," provides useful background information for all of the external hazards PRA work covered in this section.

(a) Hazard analysis. This is the analysis of the hazard "size" vs. hazard "annual frequency" for a specific external hazard.

Relation to Technical Requirements in ASME/ANS PRA Standard [1]: The LPSD external-event hazard analysis is identical to that for full power operation. Technical Requirements are already in the ASME/ANS PRA Standard [1] in Section 5-2 for earthquakes (designated as SHA), in Section 7-2 for high winds (designated as WHA), in Section 8-2 for external floods under (designated as XFHA), and in Section 9-2 for other external hazards (designated as XHA). Seasonal variations in certain external hazards may need to be accounted for on a case-by-case basis.

(b) Identification of each POS included in the external-events PRA analysis. This consists of identifying each POS, assessing whether it may be screened out compared to other POSs, and including a sufficiently detailed specification of that POS (or groups of POSs) to enable the rest of the analysis to proceed. The remaining five technical elements in items *(c)* through *(g)* below are each to be accomplished separately for every POS or group of POSs identified here.

Relation to Technical Requirements elsewhere in this standard: The work of identifying the POSs is identical to that for LPSD internal-events quantitative PRA analysis. HLRs and SRs for this aspect of PRA are presented in Part 2 of this standard.

(c) Identification of the relevant list of SSCs. This is the list of SSCs whose functions are important for the particular POS (or group of POSs) and that could be affected by the external hazard, either as part of the "initiating event" being studied or otherwise. The identification work explicitly involves using systems analysis methods to identify the SSCs along with information about the plant configuration so as to identify which SSCs are important to that POS and which SSCs could be affected by the hazard. This list of SSCs is identified through the collaborative work of systems-analysis and fragility-analysis experts for each hazard type. A plant walkdown is usually required to verify or confirm the information about plant configuration. Note that some non-safety SSCs may need to be considered, and that many safety-related SSCs may be disabled in certain POSs.

Relation to Requirements in the ASME/ANS PRA Standard [1]: The work of identifying the potentially affected SSCs in LPSD conditions is nearly identical to that for full power operation, including a specialized walkdown when appropriate. The relevant HLRs and SRs are in the ASME/ANS PRA Standard [1]; they are discussed in detail in that standard in Section 5-2 for earthquakes (designated under SPR), in Section 7-2 for high winds (designated as WPR-A), in Section 8-2 for external floods (designated as XFPR-A), and in Section 9-2 for other external hazards (designated as XPR-A).

(d) Fragility analysis. This is the analysis of the fragility (probability of "damage" vs. "size" of hazard) for each SSC on the list from *(c)* above. This work must include the analysis of correlated damage, if appropriate (such as for groups of SSCs affected by the same flooding in a room.)

Relation to Technical Requirements in the ASME/ANS PRA Standard [1]: The fragility analysis work is conceptually identical to that for full power operation, although the scope of the analysis of course must be tailored to the POS and its configuration. The relevant HLRs and SRs are in the ASME/ANS PRA Standard [1], as discussed in detail for earthquakes in Section 5-2 (designated as SFR), for high winds in Section 7-2 (designated as WFR), for external floods in Section 8-2 (designated as XFFR), and for other external hazards in Section 9-2 (designated as XFR).

(e) Identification of the character of the "hazard-induced initial damage states" caused by the hazard. This identification needs to be done as a function of hazard "size" and of the POS. Here, a "hazard-induced initial damage state" is intended to mean a set of specified initial damage or other effects on the plant such as "loss of system X, combined with failure of shear wall Y." This explicitly involves addressing each POS (or group of POSs) separately, because the combination of failures or problems resulting from the hazard may be unique to that POS.

Relation to Technical Requirements in the ASME/ANS PRA Standard [1]: HLRs and SRs for the work of identifying the character of all "initiating events" caused by the external hazard during LPSD states are already in the ASME/ANS PRA Standard [1]; they are discussed in detail for earthquakes in Section 5-2 (designated as SPR), for high winds in Section 7-2 (designated as WPR-A), for external floods in Section 8-2 (designated as XFPR-A), and for other external hazards in Section 9.2 (designated as XPR-A). The analyst needs to account not only for the POS, but also for any special effects of the given external hazard such as damage that might be caused by the external hazard that would not otherwise be modeled in the LPSD PRA along with any special activities or configurations such as whether the reactor vessel head is off or whether crane use involving heavy-loads could be affected by an earthquake or high winds.

(f) Systems analysis. This is the development of initiating-event systems analysis and event-tree/fault-tree systems analysis, accounting for any special analysis features as needed. These special analysis features are likely to differ in many POSs from the models for internal events analysis and might include special effects of the external hazard on the structure of the systems analysis or special types of initiating events that would need tailored treatment in the analysis.

Relation to Technical Requirements in the ASME/ANS PRA Standard [1]: The systems analysis work is similar to that for external hazards PRA for full power operation. It must be addressed separately for each POS (or group of POSs). The relevant HLRs and SRs for this element are in the ASME/ANS PRA Standard [1], as discussed in detail for earthquakes in Section 5-2 (designated as SPR), for high winds in Section 7-2 (designated as WPR-A), for external floods in Section 8-2 (designated as XFPR-A), and for other external hazards in Section 9-2 (designated as XPR-A).

(g) Integration of hazard analysis with SSC fragility analysis and with systems analysis to quantify CDF and LERF. This portion of the analysis consists of integrating the intermediate results of the earlier phases to quantify CDF and LERF values.

Relation to Technical Requirements in the ASME/ANS PRA Standard [1]: The integration work is identical to that for external hazards PRA for full power operation. The HLRs and SRs for this element are in the ASME/ANS PRA Standard [1]; they are discussed in detail for earthquakes in Section 5-2 (designated as SPR-E), for high winds in Section 7-2 (designated as WPR-B), for external floods in Section 8-2 (designated as XFPR-B), and for other external hazards in Section 9-2 (designated as XPR-B).

In addition to the technical elements above, an additional and vital task is the documentation of the work. Requirements for documentation are also included throughout this standard.

1.1.8.4 High Winds PRA and External Flooding, LPSD PRA

The ASME/ANS PRA Standard [1] contains separate sections with technical requirements for high winds PRA (Part 7) and external flooding PRA (Part 8). It also contains guidance that permits the analyst to use either the requirements in these specific sections or the more general requirements that cover any other external hazard, found in Part 9 of that standard. As noted just above in Section 1.1.8.2, this approach is also followed here.

1.1.8.5 High Level Requirements for a Specific External Hazard for Each POS Separately

All of the requirements in Parts 5 through 9 are to be carried out separately for each POS (or set of POSs) identified as relevant.

1.2 Acronyms and Definitions

The list of acronyms and definitions from Reference [1] is adopted for this standard by reference. Additional acronyms and definitions are provided in this section to ensure the understanding of terms as they are used in this standard.

1.2.1 Acronyms

BWR: boiling water reactor
CCDP: conditional core damage probability
CCF: common cause failure
CDF: core damage frequency
CLERP: conditional large early release probability
CT: completion time
DID: defense-in-depth
DHR: decay heat removal
EDG: emergency diesel generator
EOP: emergency operating procedure
FMEA: failure modes and effects analysis
HEP: human error probability
HFE: human failure event
HLR: high-level requirement

HPSI: high-pressure safety injection
HRA: human reliability assessment
HRE: higher risk evolution
HVAC: heating, ventilation, and air conditioning
LER: large early release
LERF: large early release frequency
LOCA: loss-of-coolant accident
LOOP: loss of offsite power
LPSD: low power and shutdown
LPSI: low-pressure safety injection
NA: not available
NPP: nuclear power plant
OPDRC: operations with the potential to drain the reactor cavity
OPDRV: operations with the potential to drain the reactor vessel
PDS: plant damage state
POS: plant operating state
PRA: probabilistic risk assessment
PSHA: probabilistic seismic hazard analysis
PWR: pressurized-water reactor
QLRA: qualitative risk assessment
RCIC: reactant core isolation cooling
RCS: reactor coolant system
RHR: residual heat removal
RSR: residual heat removal
SG: steam generator
SGTR: steam generator tube rupture
SR: supporting requirement
SSCs: structures, systems, and components
TS: technical specifications
USNRC: U.S. Nuclear Regulatory Commission

1.2.2 Definitions

accident class: A grouping of accident sequences with similar characteristics such as common POS, initiating event type, or containment challenge; e.g., accident sequences initiated by a transient with a loss of decay heat removal, loss of coolant accidents, station blackout accidents, and containment bypass accidents.

accident sequence: A representation in terms of an initiating event defined for a set of initial plant conditions (characterized by a plant operating state) followed by a sequence of failures or successes of events (such as system, function, or operator performance) that can lead to undesired consequences with a specified end state (e.g., core damage or large early release).

activity: A planned interaction with the plant such as the performance of maintenance to re-align the plant operating configuration or to change the plant operating parameters, e.g., power level.

at-initiator human failure event: A type of initiating event; human failure events that cause or contribute to an initiating event (e.g., the human failure events that directly involve plant personnel actions at the time of the initiating event, including actions correctly performed but which are based on erroneous indications). This group does not include malicious acts such as sabotage.

cold shutdown: A set of POSs during which the reactor is subcritical with the primary system depressurized at relatively low temperature (< 200ºF) and the reactor vessel intact (head on) with heat removal via RHR shutdown cooling. Cold shutdown is defined by the Technical Specifications (Mode 5 for PWRs, Mode 4 for BWRs) for the condition with the primary temperature below 200ºF and with the reactor vessel head tensioned.

conditional core damage frequency: The frequency per year of core damage given the occurrence of a specific plant configuration at a given instant in time; e.g., a plant operating state, external hazard damage state, or a component out of service.

conditional core damage probability (CCDP): The probability of core damage given the occurrence of a specific plant configuration (e.g., a plant operating state, external hazard damage state, or a component out of service) over a limited period of time.

conditional large early release probability (CLERP): The probability of large early release given the occurrence of a specific plant configuration (e.g., a plant operating state, external hazard damage state, or a component out of service) over a limited period of time.

controlled manual shutdown: A POS evolution during which the reactor power level is decreased from full power to low power and finally to zero power with control rods inserted.

defense in depth: The concepts of providing access controls and multiple physical barriers to radionuclide release, successive measures to prevent an accident or mitigate the consequences of an accident, and the use of redundancy and diversity to accomplish key safety functions.

demand-based initiating event: An initiating event that is linked to a specific activity as opposed to occurring randomly in time over the POS duration. For example, in a PWR, the initiator "over-draining while reducing RCS level to mid-loop" that leads to a loss of decay heat removal would be considered a demand-based initiating event since the activity for drain down to mid-loop has been associated with historical over-draining events.

end state: The set of conditions at the end of an accident sequence that characterizes the impact of the sequence on the plant or the environment. In most PRAs, end states typically include success states (i.e., those states with negligible impact), plant damage states for Level 1 sequences, and release categories for LERF sequences. For QLRA purposes, end state is also the term used to describe the end points of decision trees describing the status of key safety functions.

forced outage: An unscheduled plant shutdown that is required due to administrative or hardware issues. See "outage types" for further discussion.

full power or nominal full power: A POS during which the reactor power is at or near its normal designed value. In this POS, the primary system configuration (power level, pressure, temperature, boundaries, etc.) is maintained essentially constant. The "low power" state is defined to include all at-power operations below nominal full power.

higher risk evolution: Outage activities, plant configurations, or conditions during shutdown where the plant is more susceptible to an event causing the loss of a key safety function

hot shutdown: A set of POSs during which the reactor is subcritical with the primary temperature between 200ºF and 350°F and with the reactor vessel intact. Hot shutdown is defined by the Technical Specifications (Mode 4 for PWRs, Mode 3 for BWRs).

hot standby: A POS (or set of POSs) during which the reactor is subcritical with the primary temperature above 350ºF and the reactor vessel intact. Hot standby is defined by the Technical Specifications (Mode 3 for PWRs, not used for BWRs).

initiating event: A perturbation during a plant operating state that challenges plant control and safety systems and whose failure could potentially lead to core damage or core damage with radioactivity release. An initiating event could require a response or degrade the reliability of a normally operating system, cause a standby mitigating system to be challenged, or require that the plant operators respond in order to mitigate the event or to limit the extent of plant damage caused by the initiating event.

interfacing systems LOCA (ISLOCA) [6]: A LOCA when a breach occurs in a system that interfaces with the RCS, where isolation between the breached system and the RCS fails. An ISLOCA is usually characterized by the over-pressurization of a low-pressure system when subject to RCS pressure and can result in containment bypass.

key safety functions: The minimum set of safety functions that must be maintained to prevent core damage and/or large early release. These include reactivity control, reactor pressure control, reactor coolant inventory control, decay heat removal, and containment integrity in appropriate combinations to prevent core damage and large early release. This is the definition from ASME/ANS RA-Sa-2009 [1] for full power conditions. This term is assumed to be equivalent to "critical safety functions," as used in other references. The term "key safety functions" is used in this standard for consistency with ASME/ANS RA-Sa-2009 [1], except in Section 11. The term "key safety functions" for LPSD QLRA is instead taken from NUMARC 91-06 [2], as presented in Section 11.2.3.

LOCA: Loss of coolant accident. This includes "traditional" full power accident initiators such as pipe break and relief valve opening, while it also includes maintenance-induced flow diversions, RCS boundary failure due to drain-down events, and other potential losses of RCS inventory that are unique to shutdown conditions (and are typically more likely than pipe breaks at low system pressure).

low power: A POS (or set of POSs) during which the reactor is at reduced power below nominal full-power conditions. In these POSs, the power level may be changing as the reactor is shutting down or starting up, or the power level may be constant at a reduced level. The power level that distinguishes nominal full power from low power is the power level below which there may be a significant increase in the likelihood of a plant trip, e.g., taking manual control of feedwater level.

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 full-power plant conditions. LPSD evolutions are modeled as a series of POSs. Outage types are sub-types of an LPSD evolution, though not all LPSD evolutions involve an outage. A refueling outage is a specific example of an LPSD evolution. Reducing power to 30% in order to conduct maintenance or an operational activity is another example of a low power evolution. LPSD evolutions may be described by a transition down to the POS where the activity is conducted followed by a transition back to full power.

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[6] Events can occur during *shutdown* that have similar consequences to those at-power — bypass of containment and loss of RCS coolant from the containment sump. However, during *shutdown*, these events may evolve quite differently; e.g., maintenance-induced drain-down of RCS outside containment through RHR suction valves that are open to support the decay heat mode rather than passive boundary failures. Since these events are analyzed much differently, the term ISLOCA is not used for such drain-down events, but is reserved for events that involve passive boundary failures.

mid-loop: A POS (or set of POSs) in a PWR during which the water level in the reactor vessel is drained below the top of the hot legs. This evolution occurs to support primary system maintenance such as steam generator tube inspection during a refueling outage. This is termed “hot” or “early” mid-loop when it occurs early in an outage prior to fuel offload with relatively high decay heat levels. This is contrasted with “cold” mid-loop or “late” mid-loop, which refer to this evolution occurring towards the end of the outage following fuel reload.

mode: Status of plant operation, as defined by plant technical specifications.

outage: The entire set of POSs with the plant subcritical. This term is used interchangeably with the term “shutdown” (see discussion under “shutdown”).

outage types: Term used to describe the general cause of the plant being subcritical. Different outage types result from maintenance and refueling requirements that necessitate different LPSD evolutions and resulting POSs. For example, a “refueling” outage type leads to cold shutdown with some or all of the fuel elements transferred out of the reactor pressure vessel. In contrast, a “maintenance” outage conducted at cold shutdown to repair steam piping would be a different outage type.

per calendar year: Units for CDF or LERF, the calculation of which includes contributions from each POS and takes into account the fraction of time spent in that POS normalized to one calendar year. Thus, the results from each POS per calendar year can be summed to give the total quantitative risk results. Also, note that the total risk “per calendar year” does not represent any actual year of operation since it includes all possible POSs, some which may occur only in outages that occur less frequently than yearly.

plant condition: A measureable or observable parameter related to plant system state, e.g., RCS temperature, core decay heat level, Mode 4, SI secured, train A RHR running, or head off. A specific set of plant conditions is used to define the plant operating state modeling elements, and a larger set of plant conditions is used to define plant configurations.

plant configuration: The status of a specific set of plant conditions that includes all those used to define a plant operating state plus specific equipment alignments and equipment outages. These plant conditions include mode, primary system conditions (e.g., temperature, pressure), primary system status (e.g., mid-loop operation, vessel level during shutdown), equipment alignment (e.g., number of pumps operating, number of pumps in standby), and equipment out of service for test and maintenance. For configuration risk management, other conditions external to the plant may be defined, e.g., weather, grid-related activities, etc. One or more plant configurations may occur within the same plant operating state because they are defined in terms of more plant conditions.

plant operating state (POS): A standard arrangement of the plant during which the plant conditions are relatively constant, are modeled as constant, and are distinct from other configurations in ways that impact risk. POS is a basic modeling device used for a phased-mission risk assessment that discretizes the plant conditions for specific phases of an LPSD evolution. Examples of such plant conditions include core decay heat level, primary water level, primary temperature, primary vent status, containment status, and decay heat removal mechanisms. Examples of risk impacts that are dependent on POS definition include the selection of initiating events, initiating event frequencies, definition of accident sequences, success criteria, and accident sequence quantification.

qualitative risk assessment (QLRA): As applied to outage risk assessment, the use of defense-in-depth principles to support risk assessment and risk management for shutdown operations applicable to hot standby, hot shutdown, cold shutdown, and refueling modes of operation.

refueling outage: An outage type that occurs on a periodic basis during which a portion of the spent nuclear fuel is replaced with new (unburned) fuel.

representative LPSD evolution: A category of LPSD evolutions used for evaluating time-averaged CDF during LPSD conditions, often using a separate model for each representative category. For most LPSD PRAs performed to date, the representative LPSD evolutions consist of refueling outages, controlled shutdowns, and forced outages resulting in safe, stable states such as hot shutdowns and cold shutdowns with and without RCS draining.

shutdown: The collection of POSs during which the reactor is subcritical. This term is interchangeable with the term outage. Also see the related term, "controlled shutdown."

significant accident sequence: One of the set of accident sequences resulting from the analysis of a specific hazard group defined at the functional or systematic level that, when rank-ordered by decreasing frequency, sum to a specified percentage of the core damage frequency for that hazard group or that individually contribute more than a specified percentage of the total core damage frequency summed over all the POSs in that hazard group.[7] For this version of the standard,[8] the summed percentage is 95%, and the individual percentage is 1% of the applicable hazard group CDF (see Part 3, Requirements LIE-B3, LHR-H1, LQU-B2, LQU-C1, LQU-D1, LQU-D5, and LQU-F2.) For hazard groups that are analyzed using methods and assumptions that can be demonstrated to be conservative or bounding, alternative numerical criteria may be more appropriate and, if used, should be justified.

significant basic event: A basic event that contributes significantly to the computed risks for a specific hazard group summed over all the POSs in that hazard group. For internal events, this includes any basic event that has a Fussell-Vesely importance greater than 0.005 or a RAW importance greater than 2 (see Part 3, Requirements LDA-C13, LDA-D1, LDA-D3, LDA-D5, LDA-D8, LHR-D2, and LHR-G1.) For hazard groups that are analyzed using methods and assumptions that can be demonstrated to be conservative or bounding, alternative numerical criteria may be more appropriate and, if used, should be justified.

significant contributor: In the context of

(a) an internal events accident sequence/cut set, a significant basic event, POS, LPSD evolution, or an initiating event that contributes to a significant sequence;
(b) accident sequences/cut sets for hazard groups other than internal events, the following are also included: the hazard source, hazard intensity, and hazard damage scenario;
(c) an accident progression sequence, a contributor that is an essential characteristic (e.g., containment failure mode, physical phenomena) of a significant accident progression sequence that, if not modeled, would lead to the omission of the sequence.

significant plant operating state (POS): One of the set of accident classes specified by a given POS and hazard group that when rank ordered by decreasing frequency, sum to a specified percentage of core

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[7] For purposes of determining significance, the rank ordering for each hazard group can also be based on a subset of the entire PRA scope (e.g., for just one POS or accident class) since such a rank ordering will be more restrictive than when applied to the entire scope.

[8] Alternative criterion may be appropriate for specific applications. In particular, an alternative definition of "significant" may be appropriate for a given application where the results from PRA models for different hazard groups need to be combined.

damage frequency or large early release frequency for that hazard group or that individually contribute more than a specific percentage of core damage frequency or large early release frequency for that hazard group. For this version of the standard, the summed percentage is 95%, and the individual percentage is 1% of the applicable hazard group CDF or LERF.

Note that the evaluation of significance in terms of CDF or LERF for each specific hazard group that is to be combined over all LPSD evolutions and all POSs is also implicitly required in the definitions for the following terms from Reference [1] that are not repeated here, i.e., significant accident progression sequence, significant containment challenge, significant accident progression sequence, and significant cut set.

startup: A POS during which the reactor power level is increased from low power to full power following a plant outage.

startup mode: A plant mode defined by the Technical Specifications (Mode 2) during which the power level is less than 5% with the reactor critical for PWRs or the position (e.g., startup) of the Mode Selector Switch for BWRs.

time-averaged CDF: A risk metric for the expected number of core damage events per calendar year summed over all modeled LPSD evolution types. No one specific evolution is to be considered an "average" LPSD evolution; rather, an average LPSD evolution of each LPSD evolution type is one whose POS durations and equipment outage durations in each POS are consistent with the data from plant operation averaged over many years from all LPSD evolutions of that same type. LPSD evolution types are described in Part 2 and non-mandatory Appendix 2.A.

time-dependent CDF: The computation of CDF (expected number of core damage events per unit of time) at one particular time and for a single plant configuration in one POS. The plant configuration is characterized by the specific plant system alignments and maintenance conditions at that point in time rather than by time-averaged maintenance alignments. The average of the time dependent CDF over a year is the time-averaged CDF for that year. When averaged over a long period of time, the result is equivalent to the time-averaged CDF, i.e., one of the risk metrics of a baseline PRA.

1.3 LPSD Quantitative Risk Assessment Application Process

1.3.1 Purpose

The risk assessment application process is accomplished according to the requirements found in Section 1-3 ("Risk Assessment Application Process") of the ASME/ANS PRA Standard [1].

This section summarizes the required activities to determine the capability of a PRA needed to support a particular risk-informed application. As stated in the ASME/ANS PRA Standard [1]:

> "For a specific application, PRA capabilities are evaluated in terms of Capability Categories for individual Supporting Requirements rather than by specifying a single Capability Category for the whole PRA. Depending on the application, the required PRA capabilities may vary over different parts of this standard. ….The SRs relevant to the different portions of a PRA within the scope, across the elements, and possibly within each element, may be required to have different Capability Categories to support the application, and some portions of a PRA may be irrelevant to the application."

Section 1-3 of the ASME/ANS PRA Standard [1] describes a five-stage process for applying the standard to a specific issue. While this process is the same for LPSD as for full power conditions, two specific examples from shutdown conditions are provided below.

1.3.2 Identification of Application and Determination of Capability Categories

1.3.2.1 Identification of Application

Define the application by:

(a) Evaluating the plant design change or operational change being assessed;
(b) Identifying the SSCs and plant activities affected by the change including the cause-effect relationship between the plant design change or operational change and the LPSD PRA model;
(c) Identifying the LPSD PRA scope and risk metrics that are needed to assess the change.

Example A: *A change in technical specifications (TS) is proposed that redefines the requirements for an operable residual heat removal (RHR) system for a PWR with a large dry containment while in Mode 4. This change extends the TS requirement for the completion time (CT) of actions to be taken if the RHR subsystem(s) are inoperable. The changes in TS and/or procedures that are involved need to be identified in detail.*

In order to assess the impact of the proposed change in the TS, the SSCs affected by the proposed change, such as the RHR system and cross-tie lines, need to be identified. The plant RHR system has two redundant loops, each having two full capacity RHR pumps and an RHR heat exchanger. The RHR system removes heat from the RHR heat exchangers during shutdown cooling mode of RHR system operation. The RHR system consists of two loops, each of which supplies cooling water to its respective heat exchanger. The operability requirements are determined by the POS.

The proposed change in the completion time impacts the core damage frequency (CDF) by increasing the time that an RHR loop can be out of service. This change is evaluated by considering the impact on system unavailability and on the frequency of sequences involving unavailability of either one or both RHR loops (depending on the POS).

Example B: *A plant located along the southeastern U.S. seaboard has always scheduled its refueling outages in the springtime when hurricanes, which mostly occur later in the year, are too rare to be of great concern. This coming year, it will be forced to take a three-month outage for major repairs, and the time chosen is April to June. This is still well before the usual "hurricane season." However, three months before the outage is to begin, delivery problems with major equipment force a delay so that the three-month outage must occur from August to October, which is right in the middle of the season with the highest hurricane potential. The plant already performed a hurricane PRA for full power, but has not done one for outage conditions.*

The plant has approved technical specifications in place for outages that consider actions needed in case of a hurricane, but these are not "risk-informed." Therefore, although the plant would certainly use these technical specifications to assure that it is in full compliance with all applicable regulations, the plant management desires to use an LPSD PRA to assess whether any special vulnerabilities that had not been considered or that might require additional protective measures might exist during the outage. Using such a PRA, the plant *can schedule outage actions and manage specific activities to minimize hurricane-induced risks.*

The CDF for the three-month outage period during "hurricane season" is not known, nor are the principal contributors to whatever extra "risk" might exist. Therefore, an LPSD PRA for hurricanes is needed to provide these insights. The scope of that LPSD PRA is to be guided by the insights gained from the existing full power hurricane PRA, which has already identified those buildings, structures, and other SSCs that contribute importantly to the leading accident sequences from a hurricane that might occur at full power. This full power PRA must be adapted for the shutdown condition and must cover those shutdown POSs that the plant will be in during the "hurricane season." It is possible that hurricane risk had been eliminated from the full power PRA on the basis that hurricanes always come with warning time, and that the plant would shut down if a hurricane threatened. Obviously, this logic would not apply at shutdown, although actions might be taken to put the plant in a safer configuration. In this event, a hurricane PRA would need to be developed.

The management decides that CDF is the appropriate measure to use, and that LERF is not as significant because the containment would be closed long before the hurricane arrived The plant management is also interested in whether any equipment not previously identified might be found to be vulnerable to damage from a postulated hurricane.

Note that for this application, it is not expected that the LPSD PRA would be used to support any regulatory action. The application is to support the plant management's desire to better understand a wide range of possible hurricane-caused risks, for example, risks to its investment even if there is no important additional "CDF"-related risk.

1.3.2.2 Determination of Capability Categories

Parts 3 to 9 of this standard set forth SRs for three PRA Capability Categories whose attributes are described in Subsection 1.1.3. For the application, determine the Capability Category for each part of the PRA needed to support the application considering each applicable POS. This determination dictates which SRs are used to evaluate the capabilities of each part of the PRA to support the application. To determine these capabilities, an evaluation is performed of the application to assess the role of the PRA in supporting that application.

Example A (continued): *Continuing with the RHR loop completion time change example, the proposed change is a risk-informed application to justify a change to an operating license in accordance with the NRC Regulatory Guides 1.174 [3] and 1.177 [4]. If the plant has a baseline CDF and LERF of 1.0 × 10^{-5} /yr. and 1.0 × 10^{-6} /yr, respectively, including CDF and LERF contributions from both full power and LPSD conditions, and it is expected that the changes in CDF can be shown to be small, then the parts of the PRA that are impacted by changes in RHR loop unavailability may be determined to require PRA Capability Category II, whereas the remaining parts of the LPSD PRA needed to determine CDF are determined to only require PRA Capability Category I. Hence, the initiating events, accident sequences, data parameters, system models, human actions, and quantification process for those sequences and cut sets impacted by the completion time changes are in PRA Capability Category II, and the remaining parts of the PRA needed to evaluate CDF are in Capability Category I. The LERF is determined to be not needed for this application based on a qualitative evaluation and hence does not have to meet any of the Capability Categories.*

Example A Variation: *If the above example application was being evaluated at a plant with a* baseline *core damage frequency greater than 1.0 × 10^{-4} /yr. or baseline LERF greater than 1.0 × 10^{-5} /yr., or the changes in CDF or LERF were expected to be* important *such that the degree of confidence in the risk evaluation needed to be much greater than in the previous example, it may be determined that those* parts *of the* LPSD *PRA impacting the change might need to be upgraded. In addition, in this example, it might be necessary to expand the application to include a determination of LERF to confirm that the impacts on LERF are acceptable. This need might mean the expansion of the applicable SRs in the LERF PRA element in comparison with the previous example.*

Example B (continued): *Continuing with the hurricane-season example above, the plant management decides that it desires a high-winds-hurricane LPSD PRA that generally meets Capability Category II requirements so as to have a high confidence that the PRA will be able to determine whether any special risk-management measures are needed. A few aspects of the plant (specifically, some of the trains of safety equipment) are judged not to be important to CDF initiated by high winds based on the full power high-winds-hurricane quantitative PRA, and a LPSD PRA that generally meets Capability Category I requirements is judged adequate for those aspects.*

1.3.3 Assessment of PRA for Necessary Scope, Results, and Models

For each specific application, the user of this standard must assess whether the PRA has the necessary scope, results, and models to support that application. To do so, the user determines if the PRA provides the results needed to assess the plant change or operational change. In identifying the LPSD PRA scope required, the user considers the LPSD evolutions, plant operating states, and hazard groups defining the sequences affected by the plant design change or operational change. If some aspects of the PRA are insufficient to assess the change, they then need to be upgraded according to the SRs of Parts 3 through 9 for the appropriate Capability Category; alternatively, supplementary analyses may be generated.

Example A (continued): *The proposed change in the RHR completion time has been determined to affect the RHR unavailability. This unavailability is determined by the RHR pumps, the RHR service water pumps, the RHR heat exchangers, control valves, cross-tie lines with motor-operated valves, and the Emergency Core Cooling System (ECCS) fill system supplied by the Core Spray system to keep the RHR lines filled and the RHR discharge headers pressurized to approximately 85 psig (6.9 × 10^5 Pa) at all times during plant operation. Thus, the scope of the Systems Analysis and Data elements of the PRA must include each of these SSCs.*

Example B (continued): *After the new high-winds-hurricane LPSD PRA for the outage condition has been completed using Capability Category II requirements everywhere except for a few LPSD PRA aspects that were judged to require only Capability Category I requirements, the leading contributors are examined. Certain safety systems that are not important for hurricane-induced CDF during full power operation and hence were analyzed using only Capability Category I requirements turn out to be much more important than anticipated; if these LPSD PRA insights are correct, the management would find it appropriate to invest in extra high-winds protection before entering the extended hurricane-season outage. The plant management decides to upgrade the LPSD PRA analysis of these safety systems using Capability Category II and Capability Category III requirements (e.g., for SR WFR-A1 calling for the use of plant-specific data and incorporating the findings of a walkdown) so as to gain even higher confidence in the numerical results of the analysis.*

The user determines whether the SSCs or plant activities affected by the plant design or operational change are modeled in the LPSD PRA. If the affected SSCs or plant activities were not modeled, the user then needs either to upgrade the LPSD PRA to include the SSCs in accordance with the SRs of Part 4 for their corresponding Capability Categories or to generate supplementary analyses (see Subsection 3.6).

> Example A (continued): *Continuing with the previous Example A, the action to be taken when the required RHR loop(s) are out of service is to "verify an alternate method of decay heat removal is available". Besides various alignments using cross-ties, this alternative may include the Fuel Pool Cooling and Reactor Water Cleanup systems if their success criteria were met, e.g., late after shutdown when the decay heat level is low. Thus, either the PRA must include systems models, data, and success criteria to represent these alternates, or supplementary analyses, which are outside the scope of the standard, may be used.*

> Example B (continued): *Continuing with the high-winds-hurricane example, the new LPSD PRA did not model the structural failure from high winds of certain switchgear equipment inside the auxiliary building because it was judged that it could not be damaged. After completing the new LPSD PRA, an unexpected structural vulnerability of a shear wall adjacent to that equipment is found possibly to cause damage to the switchgear. Either the LPSD PRA must be modified to account for this issue, or a supplemental engineering analysis must be performed to demonstrate that the failure of the switchgear cannot lead to unacceptable consequences.*

1.3.4 Determination of the Standard's Scope and Level of Detail

The user determines if the scope of coverage (i.e., the LPSD evolutions, plant operating states, and hazard groups modeled) and level of detail of the SRs stated in Parts 3 through 9 for the corresponding Capability Categories determined in Section 1.3.2.2 are sufficient to assess the application under consideration.

If it is determined that the standard lacks certain specific requirements, their importance to the application is assessed. If the absent requirements are not important, the requirements of the standard are sufficient for the application. The bases for determining the sufficiency of this standard is documented. If the absent requirements are important, supplementary requirements may be used.

1.3.5 Comparison of LPSD PRA Model to Standard

The user determines if each part of the LPSD PRA satisfies the SRs at the appropriate Capability Category needed to support the application. The results of the peer review may be used. If the LPSD PRA meets the SRs necessary for the application, the LPSD PRA is acceptable for the application being considered. The basis for this determination is to be documented.

If the LPSD PRA does not satisfy an SR for the appropriate Capability Category, the user then determines if the difference is significant. Acceptable requirements for determining the significance of this difference include:

(a) The difference is not applicable or does not affect quantification relative to the impact of the proposed application; or
(b) Modeled accident sequences accounting for at least 90% of CDF/LERF, as applicable, are not affected by appropriate sensitivity studies or bounding evaluations. Note that this is 90% of the total CDF/LERF in any one POS or POS group. These studies or evaluations should measure the

aggregate impact of the exceptions to the requirements in Parts 4 through 9 as applied to the application.

Determination of significance will depend on the particular application being considered and may involve determinations made by an expert panel. Note: a short POS duration (e.g., less than one percent of a calendar year) may be insufficient grounds for screening the POS unless it can be shown, for example, that there are no demand-related initiating events (independent of duration) that may be important contributions to CDF/LERF.

If the difference is not significant, the *LPSD PRA* is then acceptable for the application. If the difference is significant, the user then either upgrades the *LPSD PRA* to address the corresponding SRs stated in Parts 4 through 9, or generates supplementary analyses (see Subsection 1.3.6). Any upgrade of the PRA is done and documented in accordance with Section 1.5.

Example: *The examples provided under Section 1.3.3 are applicable.*

1.3.6 Use of Supplementary Analyses/Requirements

In the event that the scope of either the LPSD PRA or the standard is insufficient, supplementary analyses or requirements may be used. These supplementary analyses will depend on the particular application being considered but may involve deterministic methods such as bounding or screening analyses and determinations made by an expert panel. They are to be documented.

Examples of sources for a supplementary analysis: *Supplementary requirements are drawn from other recognized codes or standards whose scopes complement that of this standard and which are applicable to the application; however, they may be generated by an expert panel if no such recognized code or standard can be identified.*

If it has been determined that the PRA has sufficient capability, its results can be used to support the application. If not, the results of supplementary analyses, some of which may respond to supplementary requirements, can also be used to support the application. Such supplementary analyses/requirements are outside the scope of this standard.

1.4 LPSD PRA Technical Requirements

1.4.1 Purpose

Consistent with Reference [1], the purpose of this section is to provide requirements by which adequate PRA capability can be identified when an *LPSD PRA* is used to support applications of risk-informed decision making. The specific focus of this section is the set of unique and specific requirements by which an adequate *LPSD PRA* can be identified.

1.4.2 Process Check

Consistent with Reference [1], the process of reviewing analyses and/or calculations used directly by the *LPSD PRA* or used to support the *LPSD PRA* shall be performed by knowledgeable individuals who did not perform those analyses or calculations. Documentation of this review may take the form of hand-written comments, signatures or initials on the analyses/calculations, formal sign-offs, or other equivalent methods.

1.4.3 Use of Expert Judgment

The requirements for the use of expert judgment outside the LPSD PRA analysis team are the same as those described in Section 1-4.3 of Reference [1] and are incorporated by reference.

1.4.4 Derivation of PRA Requirements

Consistent with Reference [1], objectives were established for each technical element used to characterize the respective scope of a PRA. These objectives form the basis for the development of the high level requirements for each element that were used, in turn, to define the supporting requirements.

In setting the HLRs for each element, the goal was to derive, based on the objectives, an irreducible set of firm requirements applicable to PRAs that support all levels of application to guide the development of SRs. This goal reflects the diversity of approaches that have been used to develop existing PRAs and the need to allow for technological innovations in the future. An additional goal was to derive a reasonably small set of HLRs that capture all the important technical issues that were identified in the efforts to develop this standard.

The HLRs generally address attributes of the PRA element such as:

(a) scope and level of detail;
(b) model fidelity and realism;
(c) output or quantitative results (if applicable);
(d) documentation.

Three sets of SRs were developed to support the HLRs in the form of action statements for the various Capability Categories in the standard. Therefore, there is a complete set of SRs provided for each of the three PRA Capability Categories.

1.4.5 PRA Requirements

Consistent with Reference [1], tables of HLRs and SRs for the technical elements are provided for each PRA scope. The SRs are numbered and labeled to identify the HLR that is supported. For each Capability Category, the SRs define the minimum requirements necessary to meet that Capability Category. In these tables, some action statements apply to only one Capability Category, while some extend across two or three Capability Categories. When an action spans multiple categories, it applies equally to each Capability Category. When necessary, the differentiation between Capability Categories is made in other associated SRs. The interpretation of a Supporting Requirement whose action statement spans multiple categories is stated in Table 1.1.3-3. It should be noted that some action statements span Capability Categories II and III because the authors were unable to specify a distinguishing requirement for Capability Category III at this time. It is intended that by meeting all the SRs under a given HLR, a PRA will meet that HLR.

1.5 LPSD PRA Configuration Control

This section repeats the language from Section 1.5 of Reference [1], except that PRA is replaced by LPSD PRA.

1.5.1 Purpose

This section provides requirements for the configuration control of an LPSD PRA to be used with this standard to support risk-informed decisions for nuclear power plants.

1.5.2 LPSD PRA Configuration Control Program

AN LPSD PRA Configuration Control Program shall be in place. It shall contain the following key elements:

- *(a)* a process for monitoring LPSD PRA inputs and collecting new information;
- *(b)* a process that maintains and upgrades the LPSD PRA to be consistent with the as-built, as operated plant;
- *(c)* a process that ensures that the cumulative impact of pending changes is considered when applying the LPSD PRA;
- *(d)* a process that maintains configuration control of computer codes used to support LPSD PRA quantification;
- *(e)* documentation of the program.

1.5.3 Monitoring LPSD PRA Inputs and Collecting New Information

The LPSD PRA Configuration Control Program shall include a process to monitor changes in the design, operation, maintenance, and industry-wide operational history that could affect the LPSD PRA. These changes shall include inputs that impact operating procedures, design configuration, initiating event frequencies, system or sub-system unavailability, and component failure rates. The program should include monitoring of changes to the LPSD PRA technology and industry experience that could change the results of the LPSD PRA model.

1.5.4 LPSD PRA Maintenance and Upgrades

The LPSD PRA shall be maintained and upgraded such that its representation of the as-built, as-operated plant is sufficient to support the applications for which it is being used.

Changes in LPSD PRA inputs or the discovery of new information identified pursuant to Subsection 1.5.3 shall be evaluated to determine whether such information warrants LPSD PRA maintenance or LPSD PRA upgrade (see Section 1.2 for the distinction between LPSD PRA maintenance and LPSD PRA upgrade). Changes that would impact risk-informed decisions should be incorporated as soon as practical. Changes that are relevant to a specific application shall meet the SRs pertinent to that application as determined through the process described in Subsection 1.3.5.

Changes to an LPSD PRA due to LPSD PRA maintenance and LPSD PRA upgrade shall meet the requirements of the Technical Requirements section of each respective part of this standard. Upgrades of an LPSD PRA shall receive a peer review in accordance with the requirements specified in the Peer Review section of each respective section of this standard but limited to aspects of the LPSD PRA that have been upgraded.

1.5.5 Pending Changes

This standard recognizes that immediately following a plant change (e.g., modifications, procedure changes, plant performance [data]) or upon the identification of a subject for model improvement (e.g., new human error analysis methodology, new data update methods), an LPSD PRA may not represent the plant until the subject plant change or model improvement is incorporated into the LPSD PRA. Therefore, the LPSD PRA configuration control process shall consider the cumulative impact of pending plant changes or model improvements on the application being performed. The impact of these plant changes or model improvements on the results of the LPSD PRA and the decision under consideration in the application shall be evaluated in a fashion similar to the approach used in Section 1.3.

1.5.6 Use of Computer Codes

The computer codes used to support and to perform LPSD PRA analyses shall be controlled to ensure consistent, reproducible results.

1.5.7 Documentation

Documentation of the Configuration Control Program and of the performance of the above elements shall be adequate to demonstrate that the LPSD PRA is being maintained consistent with the as-built, as-operated plant.

The documentation typically includes:

(a) a description of the process used to monitor LPSD PRA inputs and collect new information;
(b) evidence that the aforementioned process is active;
(c) descriptions of proposed changes;
(d) description of changes in an LPSD PRA due to each LPSD PRA upgrade or LPSD PRA maintenance;
(e) record of the performance and results of the appropriate LPSD PRA reviews (consistent with the requirements of Section 1.6.6);
(f) record of the process and results used to address the cumulative impact of pending changes;
(g) a description of the process used to maintain software configuration control.

1.6 LPSD PRA Peer Review

This section repeats the language of Section 1-6 of Reference [1], with the exception of the underlined text and that PRA is replaced by LPSD PRA.

1.6.1 Purpose

This section provides requirements for peer review of an LPSD PRA to be used in risk-informed decisions for commercial nuclear power plants. LPSD PRAs used for applications shall be peer reviewed. Peer reviews for this purpose shall be performed against the requirements in those sections of this standard applicable to the portions of the LPSD PRA that are being used to support such applications. The peer review shall assess the LPSD PRA to the extent necessary to determine if the methodology and its implementation meet the requirements of this standard. Another purpose of the peer review is to determine strengths and weaknesses in the LPSD PRA. The peer review need not assess all aspects of the LPSD PRA against all requirements in the Technical Requirements section of each respective part of this standard; however, enough aspects of the LPSD PRA shall be reviewed for the reviewers to achieve consensus on the adequacy of methodologies and their implementation for each LPSD PRA technical element.

1.6.1.1 Frequency

Only a single complete peer review is necessary prior to using an LPSD PRA. In addition, Section 1.5 of this standard requires peer review for upgrades of an LPSD PRA. When peer reviews are conducted on LPSD PRA upgrades, the latest review shall be considered the review of record. The scope of an additional peer review may be confined to changes to the LPSD PRA that have occurred since the previous review.

This applies to a specific-outage model as well as to a time-averaged CDF or LERF LPSD PRA model. Only a single complete peer review is required for a specific-outage model. This specific-outage model could be used for subsequent outages without additional peer review as long as the changes required for the subsequent outages are classified as PRA maintenance changes rather than PRA upgrades.

1.6.1.2 Methodology

The review shall be performed using a written methodology that assesses the requirements of the Technical Requirements section of each respective part of this standard and addresses the requirements of the Peer Review section of each respective part of this standard.

The peer review methodology shall consist of the following elements:

(a) process for selection of the peer review team;
(b) training in the peer review process;
(c) an approach to be used by the peer review team for assessing if the LPSD PRA meets the supporting requirements of the Technical Requirements section of each respective part of this standard;
(d) a process by which differing professional opinions are to be addressed and resolved;
(e) an approach for reviewing the LPSD PRA configuration control;
(f) a method for documenting the results of the review.

1.6.2 Peer Review Team Composition and Personnel Qualifications

1.6.2.1 Collective Team

The peer review team shall consist of personnel whose collective qualifications include:

(a) the ability to assess all the LPSD PRA technical elements of the Technical Requirements section of each respective part of this standard, as applicable, and the interfaces between those elements;
(b) the collective knowledge of the plant nuclear steam supply system (NSSS) design, containment design, and plant operation.

1.6.2.2 Individual Team Members

The peer review team members individually shall:

(a) be knowledgeable of the requirement in this standard for their area of review;
(b) be experienced in performing the activities related to the LPSD PRA Elements for which the reviewer is assigned.

To avoid any perception of a technical conflict of interest, the peer review team members shall have neither performed nor directly supervised any work on the portions of the LPSD PRA being reviewed.

1.6.2.3 Review Team Members for LPSD PRA Upgrades

When a peer review is being performed on an LPSD PRA upgrade, reviewers shall have knowledge and experience appropriate for the specific LPSD PRA technical elements being reviewed. However, the other requirements of this section shall also apply.

1.6.2.4 Specific Review Team Qualifications

The peer reviewer shall also be knowledgeable (by direct experience) of the specific methodology, code, tool, or approach (e.g., accident sequence support state approach, MAAP code, THERP method) that was used in the LPSD PRA technical element assigned for review. Understanding and competence in the assigned area shall be demonstrated by the range of the individual's experience in a number of different, independent activities performed in the assigned area as well as the different levels of complexity of these activities. Note that the peer review may be best conducted separately for each part of the standard, and that each of these peer reviews could then need its own team and schedule.

(a) One member of the peer review team (the technical integrator) shall be familiar with all the LPSD PRA technical elements identified in the section of this standard under review and shall have demonstrated the capability to integrate these LPSD PRA technical elements. When more than one part is under review, a separate technical integrator may be used for each part.
(b) The peer review team shall have a team leader to lead the team in the performance of the review. The team leader need not be the technical integrator.
(c) The peer review should be conducted by a team with a minimum of five members and shall be performed over a minimum period of one week. If the review is focused on a particular LPSD PRA technical element such as a review of an upgrade of an LPSD PRA technical element, then the peer review should be conducted by a team with a minimum of two members and performed over a time necessary to address the specific LPSD PRA Element.
(d) Exceptions to the requirements of this paragraph may be taken based on the availability of appropriate personnel to develop a team. A single-person peer review shall only be justified when the review involves an upgrade of a single technical element and the reviewer has acceptable qualifications for the technologies involved in the upgrade. All such exceptions shall be documented in accordance with Subsection 1.6.6 of this standard.

1.6.3 Review of LPSD PRA Technical Elements to Confirm the Methodology

The peer review team shall use the requirements of the Peer Review section of each respective part of this standard for the LPSD PRA technical elements being reviewed to determine if the methodology and the implementation of the methodology for each LPSD PRA technical element meet the requirements of this standard. Additional material for those technical elements may be reviewed depending on the results obtained. These suggestions are not intended to be a minimum or comprehensive list of requirements. The judgment of the reviewer shall be used to determine the specific scope and depth of the review in each LPSD PRA technical element.

The results of the overall LPSD PRA including models and assumptions along with the results of each LPSD PRA technical element shall be reviewed to determine their reasonableness given the design and operation of the plant, e.g., investigation of cut set or sequence combinations for reasonableness.

The HLRs and the composite of the SRs of the requirements section of each respective part of this standard shall be used by the peer review team to assess the completeness of an LPSD PRA technical element. Whenever a requirement herein refers back to the ASME/ANS Standard [1], the work to fulfill that requirement is subject to the peer review requirements herein as if the underlying ASME/ANS requirement were written out in full in this standard. Work previously performed and peer reviewed for full power conditions still needs to be peer reviewed to ensure that the requirements of this standard are also met, but previously performed peer reviews can be relied on, as appropriate.

1.6.4 Expert Judgment

The use of expert judgment to implement requirements in this standard shall be reviewed using the considerations in Section 1.4.3.

1.6.5 LPSD PRA Configuration Control

The peer review team shall review the process including implementation for maintaining or upgrading the LPSD PRA against the configuration control requirements of this standard.

1.6.6 Documentation

1.6.6.1 Peer Review Team Documentation

The peer review team's documentation shall demonstrate that the review process appropriately implemented the review requirements.

Specifically, the peer review documentation shall include the following:

(a) identification of the version of the LPSD PRA reviewed;
(b) a statement of the scope of the peer review;
(c) the names of the peer review team members;
(d) a brief resume on each team member describing the individual's employer, education, LPSD PRA training, and PRA and LPSD PRA technical element experience and expertise;
(e) the technical elements of the LPSD PRA reviewed by each team member;

(f) a discussion of the extent to which each LPSD PRA technical element was reviewed, including justification for any supporting requirements within the peer review scope that were not reviewed;
(g) results of the review identifying any differences between the requirements in the Technical Requirements section of each respective part of this standard, Section 1.5 of this standard, and the methodology implemented, defined to a sufficient level of detail that will allow the resolution of the differences;
(h) identification and significance of exceptions and gaps relative to the standard's requirements in sufficient detail to allow the resolution of the gaps that the peer reviewers have determined to be material to the PRA;
(i) an assessment of LPSD PRA assumptions that the peer reviewers have determined to be relevant;
(j) at the request of any peer reviewer, differences or dissenting views among peer reviewers;
(k) recommended alternatives for resolution of any differences;
(l) identification of the strengths and weaknesses that have a significant impact on the LPSD PRA;
(m) an assessment of the Capability Category of the SRs (i.e., identification of what Capability Category is met for the SRs);
(n) identification of the written process that was used to conduct the peer review.

1.6.6.2 Resolution of Peer Review Team Comments

Resolution of Peer Review Team comments shall be documented. Exceptions to the alternatives recommended by the Peer Review team shall be justified.

Part 2 Plant Operating State Analysis

2.1 Overview of POS Analysis for LPSD PRA

This Part 2 establishes technical requirements for POS analysis for internal events. There is no equivalent to this part in the ASME/ANS PRA Standard for full power conditions (Part 2 of ASME/ANS RA-Sa-2009 [1]). POS analysis is not a separate hazard group. It is presented here in a separate part in order to preserve the section numbering which follows for internal events. The POS analysis presented in this part for internal events is therefore utilized in Parts 3 through 9 for each of the hazard groups.

2.1.1 Introduction

LPSD PRA involves the analysis of LPSD evolutions during which plant conditions are changing, which is different than the steady state conditions typically modeled in full power PRAs. The activities taking place during LPSD evolutions produce different combinations of equipment availability and capacities, thus creating different sets of initial plant conditions for the modeled initiating events. The frequencies of accident sequences that progress to core damage or large early release can also be impacted by these changing conditions. In theory, these differences mean a separate PRA model would need to be developed for each point in time as the plant conditions change. To reduce the complexity of LPSD PRA models, time intervals are identified and defined as POSs within each LPSD evolution, during which the plant conditions are assumed constant. This section introduces the concept of LPSD evolutions and POSs. Non-mandatory Appendix 2.A provides additional details regarding POS analyses.

2.1.2 LPSD Evolutions

A necessary first step in the identification of applicable POSs is to choose the LPSD evolutions to be represented in the analysis. AN LPSD evolution is formally defined in Section 1.2, and its definition is repeated here along with examples for convenience.

> *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 full-power plant conditions. LPSD evolutions are modeled as a series of POSs. Outage types are sub-types of an LPSD evolution, though not all LPSD evolutions involve an outage. A refueling outage is a specific example of an LPSD evolution. Reducing power to 30% in order to conduct maintenance or an operational activity is another example of a low power evolution. LPSD evolutions may be described by a transition down to the POS where the activity is conducted followed by a transition back to full power.

There are a number of types of LPSD evolutions for commercial nuclear reactors. Those selected for analysis in an LPSD PRA are a function of the model scope and intended PRA applications. Consistent with the PRA Capability Categories described in Table 1.1.3-2, the choice of LPSD evolutions and the level of detail in their analyses are dependent on the needed level of detail, plant specificity, and realism required. Non-mandatory Appendix 2.A includes a discussion of this LPSD evolution selection process.

2.1.3 The Concept of Plant Operating States

A POS is formally defined in Section 1.2, and this definition is repeated here for convenience.

> *plant operating state (POS):* a standard arrangement of the plant during which the plant conditions are relatively constant, are modeled as constant, and are distinct from other configurations in ways that impact risk. POS is a basic modeling device used for a phased-mission risk assessment that discretizes the plant conditions for specific phases of an LPSD evolution. Examples of such plant conditions include core decay heat level, primary water level, primary temperature, primary vent status, containment status, and decay heat removal mechanisms. Examples of risk impacts that are dependent on POS definition include the selection of initiating events, initiating event frequencies, definition of accident sequences, success criteria, and accident sequence quantification.

A set of exclusive POSs is identified for each LPSD evolution selected for analysis. The complete set of POSs cover all time periods represented in each selected LPSD evolution. A POS can be a quasi-steady state set of plant conditions or involve a transition of one or more plant conditions between steady state POSs. For example, multiple POSs may be defined to model the LPSD evolution from nominal full power to cold shutdown with residual heat removal cooling. Specifically, a hot standby POS that covers a transition temperature range of 350°F to 200°F may be modeled as one POS with an assumed constant temperature of 350°F. The complete set of exclusive POSs for a specific LPSD evolution represents a discretization of the LPSD evolution time line.

Each identified POS represents the plant initial conditions in a time interval where they are relatively constant, are modeled as constant, and are distinct from other POSs that make up the LPSD evolution in ways that impact risk. Quantification of sequence frequencies for time-averaged CDF is performed separately for each POS. CDF and LERF are thereby calculated and reported naturally at the POS level for each POS. All the important aspects of plant operation and configuration that affect the quantification of CDF and LERF must generally be assumed constant within a POS.

Several different plant conditions could be used to define a POS, but model understanding and configuration control are facilitated when the set of plant conditions chosen is consistent with those used by plant personnel to govern LPSD operations (i.e., plant operating modes or operating conditions as defined in plant technical specifications). The process of identifying the exclusive set of POSs and their associated plant conditions modeled as constant within the POS interval is referred to as POS analysis. POS analysis is facilitated when the list of plant conditions used to identify and define the POSs is kept to the minimum required to distinguish the differences in risk.

In addition to making quantification of an LPSD evolution practical, POS analysis serves another very important purpose. POSs form the basis for the LPSD PRA model development. The selection of initiating events, development of initiating event frequencies, definition of accident sequences, justification of success criteria, and accident sequence quantification are performed separately for each POS or groups of POSs that are not otherwise screened out. Subsequent peer reviews of these other PRA elements are then performed using the POS discretization. Therefore, the set of plant conditions used to define each POS is also chosen to achieve these additional functions.

An example set of plant conditions that could be used to define POSs is provided in Supporting Requirement LPOS-A3. The Grand Gulf [5] and Surry [6] LPSD PRAs developed by the USNRC contain examples of POSs selected to model different LPSD evolutions including refueling outages for a BWR and PWR, respectively. Further description of POS analysis is provided in non-mandatory Appendix 2.A.

2.2 High Level and Supporting Requirements for the POS Analysis

Objectives: The objective of the POS analysis is to define multiple sets of unique reactor and plant conditions (i.e., POSs) for the purpose of identifying and evaluating the plant response to off-normal conditions with potential to lead to core damage and/or large early release. Each POS is also used to separately evaluate the selection of applicable initiating events, definition of accident sequences, establishment of system success criteria, and for accident sequence quantification. Together, the sets of POSs cover the entire spectrum of low power and non-power operation within the scope of the LPSD PRA. Once defined, the POSs have the following characteristics:

(a) Low power and shutdown sets of reactor and plant conditions affecting the PRA are divided into POSs based on their unique impacts on plant response.
(b) Each low power and shutdown POS so identified is to be defined in terms of important plant conditions that may affect the delineation and evaluation of core damage and large early release.
(c) Low power and shutdown POSs that are grouped together are shown to be represented by the relevant characteristics of the combined group.
(d) POS frequencies, durations, and decay heat levels are characterized and quantified.
(e) For each POS, the relationship between decay heat level, reactor level, and pressure and the systems available for decay heat removal are well characterized.

Table 2-1 High Level Requirements for Plant Operating State Analysis (HLR-LPOS)

Designator	Requirement
HLR-LPOS-A	The POS analysis shall use a structured, systematic process to identify and define a complete set of plant operating states to be analyzed in the LPSD PRA.
HLR-LPOS-B	The POS analysis shall justify all screening and grouping of POSs or LPSD evolutions to facilitate an efficient but realistic estimation of CDF and LERF and to support subsequent requirements to be evaluated by a POS or group of POSs.
HLR-LPOS-C	The POS analysis shall determine the POS frequencies and durations along with the representative decay heat levels associated with each POS.
HLR-LPOS-D	The POS analysis shall be documented consistent with the applicable supporting requirements.

The supporting requirements for POS analysis that follow apply to the full scope LPSD PRA for internal events. Specific applications may require only a subset of the hazard groups, LPSD evolutions, and associated POSs that would make up a full scope LPSD PRA. The supporting requirements for POS analyses of the internal events hazard group may have to be supplemented when other hazard groups are included in the model scope. The requirements for hazard groups in Parts 4 through 9 include revisiting the POS analysis for internal events to ensure that they remain applicable when considering changing plant conditions within a specific hazard group, e.g., changing fire boundaries, flood barriers, etc. (see Supporting Requirement LPOS-A7).

Table 2-2(a) Supporting Requirements for Plant Operating State Analysis – High Level Requirement A

The POS analysis shall use a structured, systematic process to identify and define a complete set of POSs to be analyzed in the LPSD PRA (HLR-LPOS-A).

<table>
<tr><th></th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td>LPOS-A1</td><td>IDENTIFY a representative set of LPSD evolutions (e.g., refueling outages) to be analyzed.</td><td>IDENTIFY a representative set of LPSD evolutions to be analyzed, including refueling outages, other controlled shutdowns, and observed forced outages (e.g., refueling outages, drained-down maintenance outages, non-drained maintenance outages, hot shutdowns).</td><td>IDENTIFY a representative set of LPSD evolutions to be analyzed, including refueling outages, other controlled shutdowns, and observed forced outages (e.g., refueling outages, drained-down maintenance outages, non-drained maintenance outages, hot shutdowns).
In addition, IDENTIFY unique LPSD evolutions including forced outages from nominal full power conditions that involve relatively low-frequency safe stable states (e.g., feed and bleed conditions, high pressure recirculation states, and low pressure recirculation states).</td></tr>
<tr><td>LPOS-A2</td><td colspan="3">For each identified LPSD evolution, REVIEW plant-specific documentation (such as Technical Specifications and normal shutdown, refueling, and startup procedures) and records (such as recent outage plans and records, maintenance plans and records, operations data, trip history, control room logbooks, and thermal-hydraulic data such as refueling outage time to boil and time to core damage calculations) for the following:
(a) operating modes or operational conditions as defined in plant Technical Specifications
(b) RCS configurations such as vented or not vented, and whether temporary RCS penetrations are installed and their differential pressure capability along with the presence of vessel internals, which in some plants limits natural circulation cooling, and decay heat removal mechanisms such as steaming or residual heat removal
(c) range of RCS parameters, e.g., power level or decay heat level, average reactor coolant temperatures, pressures, and water level
(d) available RCS level instrumentation
(e) mode switch position (for BWRs)
(f) activities that may lead to changes in the above parameters, e.g., drain down, filling and venting, dilution, fuel movement, and/or cooldown
(g) containment status (e.g., deinerted, intact, open)</td></tr>
</table>

Table 2-2(a) Supporting Requirements for Plant Operating State Analysis – High Level Requirement A (Cont'd)

	Capability Category I	Capability Category II	Capability Category III
LPOS-A3	For each LPSD evolution, DEFINE a set of exclusive POSs that cover the entire LPSD evolution, where modeled, in terms of unique combinations of plant conditions such as the following: *(a)* operating modes or operational conditions as defined in plant Technical Specifications *(b)* RCS configurations such as vented or not vented and decay heat removal mechanisms such as steaming or residual heat removal *(c)* the range of RCS parameters and the selected representative parameter value chosen for each POS for purposes of computing time-averaged CDF and LERF, e.g., for power level or decay heat level including typical POS entry times after plant trip, average reactor coolant temperatures, pressures, and water levels. Available RCS level instrumentation *(d)* mode switch position (for BWRs) *(e)* activities that may lead to changes in the above parameters used to define the POS, e.g., drain down, filling and venting, dilution, fuel movement, and cooldown. RCS pressure capability, presence of temporary hatches, or nozzle dams/loop isolation *(f)* containment status (e.g., deinerted, intact, open) Alternatively, a more detailed set of plant conditions may be used so long as they cover those listed above. ENSURE the set of POSs is sufficient to support the selection of initiating events, the justification of success criteria, the evaluations of POS frequency and duration parameters, the evaluations of human failure events, the accounting for planned equipment outages, the definition of accident sequences, and the quantification of time-averaged CDF and LERF, and provides a finite number of sets of plant conditions for peer reviews. The combination of all POSs covers all of the modeled LPSD evolutions.		
LPOS-A4	REVIEW existing plans for future LPSD evolutions to ensure the selections made in SR LPOS-A3 remain valid and appropriate. As a minimum, consider the following: *(a)* POSs involving higher risk that were not previously encountered, for example *(1)* if a PWR did not previously have a hot mid-loop POS in its history, but will have this state in the next refueling outage or in future forced equipment outages *(2)* if a BWR did not previously consider maintenance on a RWCU drain line requiring freeze seals but may have this state in future outages *(b)* earlier entry into a POS, resulting in substantially higher decay heat, or later entry into a POS, resulting in substantially lower decay heat *(c)* durations of POSs (see SR LPOS-C1)		

Table 2-2(a) Supporting Requirements for Plant Operating State Analysis – High Level Requirement A (Cont'd)

	Capability Category I	Capability Category II	Capability Category III
LPOS-A5	No requirements for interviews.	INTERVIEW appropriate plant personnel (e.g., operations, maintenance, engineering, safety analysis, and outage planning) to determine if potential POSs of past or future LPSD evolutions have been overlooked. Information from interviews conducted at similar plants may also be used but these interviews are not a substitute for plant-specific interviews.	
LPOS-A6	ENSURE that the plant conditions defined for each POS of the modeled LPSD evolutions allow the analysis to meet the requirements of the remaining LPSD PRA elements for the internal events hazard group [see Table 1.1.3-1 for a list of PRA elements].	ENSURE that the plant conditions defined for each POS of the modeled LPSD evolutions allow the analysis to meet the requirements of the remaining LPSD PRA elements for the internal events hazard group. **MODIFY the selected parameter conditions or SUB-DIVIDE the POS interval into different sets of plant conditions if the current selections would cause risk significant contributors to be otherwise evaluated conservatively** [see Table 1.1.3-1 for a list of PRA elements].	
LPOS-A7	When evaluating the hazard groups whose requirements are presented in Parts 4 through 9, EXAMINE the plant conditions defined for each POS to ENSURE that the appropriate features of the POS are identified for the evaluation of the particular hazard. VERIFY that the POS characterization remains sufficient to support the selection of initiating events, the justification of success criteria, POS frequency and duration parameters, the evaluations of human failure events, the accounting for planned equipment outages, the quantification of time-averaged CDF and LERF, and to provide a finite number of sets of plant conditions for peer reviews. For example, consider changing plant conditions that may impair hazard barriers, affect propagation pathways, or modify fragilities of structures, systems, or components.		

Table 2-2(b) Supporting Requirements for Plant Operating State Analysis – High Level Requirement B

The POS analysis shall justify all screening and grouping of POSs or LPSD evolutions to facilitate an efficient but realistic estimation of CDF and LERF and to support subsequent requirements to be evaluated by a POS or group of POSs (HLR-LPOS-B).

	Capability Category I	Capability Category II	Capability Category III
LPOS-B1	GROUP LPSD evolutions into a set of representative evolutions. For example, different causes of a forced outage may be grouped into the same representative evolution. Forced outages of the same evolution type may be quantified together with a single representative cause of the start of the evolution such as loss of main feed water. ENSURE that: *(a)* the evolutions within a group can be considered similar in terms of the set of POSs that they contain *(b)* the evolutions are bounded by the worst case impact within the group	GROUP LPSD evolutions into a set of representative evolutions. For example, different causes of a forced outage may be grouped into the same representative evolution. Forced outages of the same evolution type may be quantified together with a single representative cause of the start of the evolution such as loss of main feed water. ENSURE that: *(a)* the evolutions can be considered similar in terms of the set of POSs that they contain *(b)* the evolutions are bounded by the worst case impact within the group *(c)* the grouping does not impact significant accident sequences	GROUP LPSD evolutions into a set of representative evolutions. For example, different causes of a forced outage may be grouped into the same representative evolution. Forced outages of the same evolution type may be quantified together with a single representative cause of the start of the evolution, such as loss of main feed water. ENSURE that: *(a)* the evolutions can be considered similar in terms of the set of POSs that they contain *(b)* the evolutions are bounded by the worst case impact within the group *(c)* the grouping does not impact significant accident sequences *(d)* the impact from each evolution is comparable to those of the remaining evolutions in the group

Table 2-2(b) Supporting Requirements for Plant Operating State Analysis – High Level Requirement B (Cont'd)

	Capability Category I	Capability Category II	Capability Category III
LPOS-B2	ENSURE that any screening of individual POSs does not eliminate any risk significant accident sequences. If screening is used, APPLY the following quantitative criteria and qualitative comparisons to demonstrate that risk significant accident sequences and risk significant accident progression sequences would not be screened out: *(a)* The frequencies of accident sequences from POSs to be screened out are qualitatively show to be less than 1×10^{-7} per calendar year for those that result in core damage and less than 1×10^{-8} per calendar year for those that result in large early release; or *(b)* The frequency of accident sequences from a POS to be screened out that result in core damage is qualitatively demonstrated to be lower in frequency than another POS that is quantitatively demonstrated to not be a risk significant POS, and the POS to be screened out is not susceptible to ISLOCA, containment bypass, containment pressure capability reduced, or containment being unisolable; or *(c)* The frequency of accident sequences from the POS to be screened out that result in core damage is qualitatively shown to not occur without failure of at least two trains of additional mitigating systems as compared to another POS whose frequency of core damage is less than 1×10^{-6} per calendar year. JUSTIFY any use of alternate frequency or consequence screening criteria.		
LPOS-B3	If desired for efficient modeling, conservatively GROUP POSs appearing in the same LPSD evolution type and considered similar in terms of plant response, success criteria, frequency, and the effect on the operability and the performance of operators and relevant mitigating systems.	If desired for efficient modeling, conservatively GROUP non-risk significant POSs appearing in the same LPSD evolution type and considered similar in terms of plant response, success criteria, frequency, and the effect on the operability and the performance of operators and relevant mitigating systems. VERIFY that **risk significant POSs are grouped realistically so as not to mask risk contributors or risk insights.**	If desired for efficient modeling, GROUP POSs appearing in the same LPSD evolution type and considered similar in terms of plant response, success criteria, frequency, and the effect on the operability and the performance of operators and relevant mitigating systems. **VERIFY that POS groupings are realistic** so as not to mask risk contributors or risk insights
LPOS-B4	ENSURE that POSs with different plant response impacts (i.e., those with different success criteria) or those that could have more severe radionuclide release potential (e.g., LERF) remain separated.		

Table 2-2(b) Supporting Requirements for Plant Operating State Analysis – High Level Requirement B (Cont'd)

	Capability Category I	Capability Category II	Capability Category III
LPOS-B5	GROUP or DELINEATE POSs that involve initiating events that are "demand-based" with initiators that are time-based (see SR LIE-C5 and LHR-K4).	**EVALUATE the need to create separate POSs that are used for those brief time periods involving activities (test-, maintenance-, and evolution-related) that lead to initiating events that are "demand-based" from those that are time-based** **If necessary, DELINEATE such POSs to avoid averaging the short duration of the demand over an entire POS duration or, if needed, to ensure that the representative plant conditions defined for the POS apply at the time of the "demand-based" initiating events** (see SR LIE-C5 and LHR-K4).	
LPOS-B6	If POSs from an LPSD evolution are combined into groups, ENSURE that the most severe or constraining of the representative plant conditions is selected for the group (with respect to core damage or large early release) and that the type and frequency of applicable initiating events of any POS within the group are chosen for the combined group.		
LPOS-B7	No re-evaluation required.	RE-EVALUATE the POS grouping scheme, including possible subdivision of the grouped POSs, if a review of the initial quantitative results indicates that the POS groupings mask significant contributors or risk insights.	

Table 2-2(c) Supporting Requirements for Plant Operating State Analysis – High Level Requirement C

The POS analysis shall determine the POS frequencies and durations along with the representative decay heat levels associated with each POS (HLR-LPOS-C).

	Capability Category I	Capability Category II	Capability Category III
LPOS-C1	CALCULATE the average frequency and average duration of LPSD evolutions based on a review of applicable plant-specific records (such as operating profile and trip history) and, as appropriate, the frequency of forced outages assigned to each identified safe, stable state from the plant-specific full power PRA. LPOS-C1 can be addressed in conjunction with LPOS-A1, LPOS-A2, and LPOS-A3.		
LPOS-C2	Within the LPSD evolutions selected, CALCULATE the average duration and average time after shutdown for each POS based on a review of applicable plant-specific records (such as outage plans, maintenance records, and logbooks).		
LPOS-C3	SUM the durations of the POSs within each group to obtain the durations of the POS groups. The entry frequencies of the grouped POSs are the same (see LPOS-B1), although the frequencies differ for each LPSD evolution type.		

Table 2-2(c) Supporting Requirements for Plant Operating State Analysis – High Level Requirement C (Cont'd)

	Capability Category I	Capability Category II	Capability Category III
LPOS-C4	CALCULATE the decay heat level associated with each POS for use in defining and applying success criteria and the timing for operator actions.		
LPOS-C5	REVIEW existing future plans or upcoming LPSD evolution schedules to ensure that the quantification of assumed decay heat levels and POS durations remain valid.		

Table 2-2(d) Supporting Requirements for Plant Operating State Analysis – High Level Requirement D

The POS analysis shall be documented consistent with the applicable supporting requirements (HLR-LPOS-D).

	Capability Category I	Capability Category II	Capability Category III
LPOS-D1	DOCUMENT the POS analysis in a manner that facilitates PRA applications, upgrades, and peer review.		
LPOS-D2	DOCUMENT the processes used to identify, define, group, and characterize the LPSD evolutions and POSs and to quantify the POS frequencies, durations, and decay heat levels, including the inputs, methods, and results. For example, the documentation typically includes: *(a)* selection and definitions of the LPSD evolutions *(b)* the process and criteria used to identify POSs *(c)* the process and criteria used to group POSs *(d)* the definition of each POS group *(e)* the defining characteristics of each POS *(f)* the evolution types, average durations, and average frequencies *(g)* the average durations and average frequencies of POSs. *(h)* the decay heat associated with each POS of each LPSD evolution *(i)* specific interfaces with other PRA tasks for traceability, and to facilitate configuration control when interfacing tasks are updated		
LPOS-D3	DOCUMENT the sources of model uncertainty and related assumptions associated with the POS analysis.		

Appendix 2.A (Non-Mandatory) Plant Operating State Analysis Methodology for LPSD PRA

This appendix provides a suggested approach for determining an adequate set of plant operating states to reasonably represent the risk from LPSD operation. It provides suggested simplifications and screening to help make this task manageable. However, the guidance provided cannot be used as the basis for such simplifications and screening. That must be justified, either generically or on a plant-specific or evolution-specific basis.

2.A.1 Background

The objective of the POS analysis task is to categorize the many possible plant configurations encountered during LPSD evolutions into discrete sets of plant conditions affecting the LPSD PRA. These sets of plant conditions are termed *plant operating states* (POSs). The definition of a POS is reprinted below from Section 1.2.

> *POS (plant operating state): Each POS is a standard configuration of the plant during which the plant conditions are relatively constant, are modeled as constant, and are distinct from other configurations in ways that impact risk. POS is a basic modeling device used for a phased-mission risk assessment that discretizes the plant conditions for specific phases of an LPSD evolution. Examples of such plant conditions include core decay heat level, primary water level, primary temperature, primary vent status, containment status, and decay heat removal mechanisms. Examples of risk impacts that are dependent on POS definition include the selection of initiating events, initiating event frequencies, definition of accident sequences, success criteria, and accident sequence quantification*

This task is specific to the LPSD PRA, although "full-power" in the Full Power PRA can be thought of a single POS, where the plant availability factor represents the POS probability. This section describes the general process used to develop the POSs for the low power and shutdown analysis, including the methods and general inputs and outputs. The process of analyzing the POSs includes the following steps:

- *(a)* select a representative set of LPSD evolutions to be included in the scope of the model, e.g., refueling, forced outages, and controlled shutdowns;
- *(b)* define a set of POSs and the associated representative plant conditions for each POS for the modeled LPSD evolution types; and
- *(c)* calculate the entry time after shutdown and the duration of each POS.

These steps are the primary subject of this appendix. At the end of this appendix, we also discuss some differences in the selection and definition of POSs for time-dependent applications versus those described earlier for time-averaged risk applications.

2.A.2 Selection of Representative LPSD Evolutions

A necessary first step in the identification of applicable POSs is to first choose the representative LPSD evolutions to be included in the analysis. The selection of evolutions is governed by the risk-informed applications the model is to be used for. The discussion that follows applies to a full-scope LPSD PRA, and the requirements for selecting LPSD evolutions to meet the different PRA Capability Categories are distinguished.

We first review the set of accident sequences already covered in the full power PRA models to avoid double counting the risk from full power when constructing the LPSD PRA. As defined in ASME/ANS RA-Sa-2009 [1]:

nominal full power: those plant operating states characterized by the reactor being critical and producing power, with automatic actuation of critical safety systems not blocked and with essential support systems aligned in their normal power operation configuration.

The accident sequences already covered in full power PRAs are those beginning from full power or nominal full power POSs (i.e., the initiating event occurs with the plant at nominal full power). Note that the definition of nominal full power does not include a specific power level above which conditions are said to be full power (rather than low power). Rather, such power level conditions may differ for each plant and are thus instead tied to plant conditions when the status of frontline systems change, critical safety system actuation systems are at least partially degraded, or essential support systems are changed, e.g., when one of two main feedwater pumps is tripped.

For a PRA of full power conditions, the initial portions of the following LPSD evolutions are included, as described in [1]:

(a) automatic plant trips from nominal full power conditions;
(b) manual plant trips from nominal full power conditions;
(c) controlled plant shutdown from nominal full power conditions, where the shutdown is required to occur before the initiating condition can be detected and corrected (see IE-C6 in [1]);
(d) plant power swings within the range of nominal full power conditions.

In the full power PRA models, the successfully mitigated accident sequences are developed to the point where the plant is safe and stable for at least 24 hours after the plant trip. The full power sequences for manual trips and forced outages are therefore largely analyzed just up to the point where repairs are performed.

Controlled plant shutdowns (e.g., for refueling or to comply with plant technical specifications) are not included in the full power PRA models (except as identified in (c) above), even though they initiate from nominal full power conditions.

Typically, in full power PRAs, plant power swings are implicitly represented by at-power steady state conditions. Plant trips that may occur during such power swings are then grouped together with other plant trips from steady-state full power conditions. However, this modeling assumption is also not justified in any detail.

This leaves the following as candidates for LPSD evolutions to be analyzed as part of an LPSD PRA:

(a) refueling outages;
(b) controlled shutdowns beginning from nominal full power conditions, including those mandated by exceedance of a plant technical specification requirement, except as identified in (c) above;
(c) plant power swings beginning from power levels initially less than nominal full power conditions, i.e., when the status of frontline systems changes from nominal full power conditions, when automatic actuation of critical safety systems is at least partially blocked, or when essential support systems are not aligned in their normal power operation configuration;
(d) automatic plant trips from power levels less than nominal full power conditions;
(e) unplanned manual plant trips from power levels less than nominal full power conditions;
(f) automatic plant trips from full power conditions but starting with the initiation of repair and including the subsequent POSs representing a return to power, i.e. starting from hot shutdown or cold shutdown while on RHR;

(g) manual plant trips from full power conditions starting with the initiation of repair (after the first 24 hours) and including the POSs representing a return to power, i.e., starting from hot shutdown or cold shutdown while on RHR;

(h) accident sequences starting from full power conditions that are successfully mitigated prior to core damage but that may involve substantial system failures leading to degraded plant conditions, e.g., safe, stable states other than those mentioned above for items (f) and (g), such as successful mitigation using feed and bleed cooling and recirculation from the containment sump in a PWR. Other examples are sequences resulting in high- or low-pressure recirculation from the containment sump following a LOCA and shutdowns without control rod insertion. Such accident sequences are relatively low frequency, as evidenced by their not having been observed in industry experience. Note that the accident sequences through the first 24 hours are typically modeled in the full-power model, so the entry condition for the LPSD PRA is a safe, stable state with the plant shut down for 24 hours.

Refueling outages (item (a) above) are generally the focus of LPSD PRAs because of their frequency and are assigned to a separate evolution type.

Controlled shutdowns (item (b) above) can be grouped by failure cause and assigned to one of the forced outage LPSD evolutions discussed below (for items (f) and (g)).

Regarding item (c) above, ramping power down to 30% for two days of maintenance is a typical example of a power swing evolution. Plant power swings starting from less than nominal full power conditions and not involving a plant trip are not common in the USA commercial power industry experience. Such power swings would likely pose only a limited increase in risk due to changes from the nominal full power condition. With justification, it is possible that such power swings would not be modeled separately as an LPSD evolution. They could instead be conservatively represented as additional time spent during nominal full power.

Candidate LPSD Evolutions (d)–(h) are often collectively called forced outages.

Candidate LPSD Evolutions (d) and (e) above occur only if the plant is initially at less than nominal full power conditions for another reason, i.e., another LPSD evolution is already in progress. Therefore, these items are to be included in other LPSD evolutions and need not be represented separately.

PWRs LPSD evolutions involving automatic (item (f)) and manual plant trips (item (g)) from nominal full power conditions are often grouped into three LPSD evolution types according to their intended safe, stable states: (1) plant trips resulting in an outage down to hot standby followed by a return to power; and plant trips where there is a cooldown to cold shutdown and either (2) the RCS is left full or (3) drained to complete repairs. For BWRs, the corresponding safe, stable end state is either hot shutdown or cold shutdown. Such plant evolutions have been repeatedly observed in industry experience.

The POSs at the beginning of these nominal full power initiated sequences are typically again modeled as part of an LPSD evolution. Any added component or system failures that may have failed in earlier POSs of the full power models and are relevant for mitigation in an LPSD evolution are thereby questioned anyway during the first 24 hours of the LPSD PRA models. Therefore, to the extent that such impacts are important to accident sequence mitigation in the LPSD PRA, the additional failures are also represented with the proper failure probabilities.

Once repair is affected (for items (f) and (g)), the startup POSs for these LPSD evolutions are similar to those for refueling outages, but with decay heat levels governed by different times after plant shutdown.

More severe accident sequences (i.e., Item (h)) that do not result in core damage are assumed successful in full power PRA models if they reach a safe and stable state for the first 24 hours. Such successful accident sequences in the full power PRA represent many different levels of system degradation. It can be argued that each such successful accident sequence should be evaluated separately by the LPSD PRA to examine potential failures during repair and through startup. Examples of such additional safe, stable states that could define these LPSD evolutions are feed and bleed cooling, high pressure recirculation, low pressure recirculation, and states with reactivity controlled but without the control rods inserted. These initial conditions for LPSD evolutions following more severe accident sequences are much lower in frequency than those represented by Items 6 and 7. Therefore, these candidate LPSD evolutions are often neglected in existing LPSD PRAs.

The times more than 24 hours after plant shutdown of accident sequences starting from automatic or manual plant trips from full power conditions (i.e., Items 6 and 7) are not included in full power PRAs, but the earlier parts of the same sequences are included. It might be argued that they can be neglected from a time-averaged core damage frequency calculation for LPSD PRA in the same way that full power PRA models also argue that these same risks after the first 24 hours are small compared to the risks during the first 24 hours. Instead, the repair times and startup portions of these evolutions (i.e., Items 6 and 7) are included as separate LPSD evolutions in an LPSD PRA.

Note that the many different candidate LPSD evolutions can be reduced by grouping those that nevertheless have similar POSs.

We summarize the above insights in the next few paragraphs. For many LPSD PRAs, there is typically only one LPSD evolution selected, i.e., for refueling outages (Item (a)). This selection is judged the minimum required for Capability Category I. There may be two or more LPSD evolution types needed to represent refueling outages depending on the optional approaches to refueling allowed by plant policies at the specific plant, e.g., with or without entry to mid-loop early in the refueling outage. If refueling outages of each type are anticipated to be utilized in the future, and the distinction between refueling outage types affects the LPSD evolution risks, then both LPSD evolution types could be selected for analysis. Typically, such operational approaches only affect a limited number of the refueling POSs.

For Capability Category II, refueling outages (Item (a)) and the relatively higher frequency forced outages that begin from nominal full power conditions are included. Controlled shutdowns are not modeled at all in full power PRAs and thus must be included in their entirety for LPSD PRAs. These higher frequency forced outages are partially modeled in full power PRAs, i.e., for the early part of the sequence until a safe, stable state is assured for at least 24 hours. The LPSD PRA then needs to complete these forced outage sequences for the time intervals that represent repair and startup back to full power (Items 4–7). It is common practice to include as LPSD evolutions only those forced outages resulting in stable states repeatedly seen in industry experience, e.g., hot shutdowns and cold shutdowns with or without RCS drain down. The frequencies and durations of these forced outage types can be readily computed from industry and plant experience data, as can the average POS durations needed for repair and startup. Forced outages from full power conditions that do not result in these safe, stable states are not required for Capability Category II.

For Capability Category III LPSD evolutions, the additional, lower-frequency accident sequences that result in safe, stable states are to be considered as the starting points for additional LPSD evolutions (Item (h)). These LPSD evolutions include feed and bleed conditions, low-pressure recirculation states, high-pressure recirculation states, and states without all the control rods inserted. These states are clearly lower frequency than those considered in Capability Category II models. The frequencies of such states can generally not be determined from industry and plant historical experience. Instead, such frequencies may be determined by examination of the success sequence frequencies represented in a full power PRA. The authors are not aware of any LPSD PRA models that have as yet included such low frequency LPSD evolutions.

The requirements for LPSD evolutions are outlined above for Capability Categories I, II, and III. For Capability Category I, none of the severe accident sequences considered in full power PRAs need to be considered again.

For Capability Category II, full power sequences resulting in hot shutdowns or cold shutdowns with or without drain downs are included as LPSD evolutions to represent the periods of repair and startup back to full power conditions. It is not necessary to separately quantify each full power initiating event and associated accident sequences that end in these states through the LPSD PRA models. Instead, the total frequency of accident sequences assigned to these plant evolutions can be determined from industry and plant-specific data and the impacts associated with representative accident sequence causes leading to these three safe, stable states assumed. For example, a turbine trip may be used to represent the cause of a hot shutdown evolution, a loss of main feedwater may be used to represent the cause of a cold shutdown without RCS drain down, and an RCS leakage event may be assumed to represent the cause of a cold shutdown state in which RCS drain down for repair is required.

For Capability Category III, the relatively lower frequency but still successful accident sequences resulting from forced outages from full power conditions (Item (h)) must also be considered as additional LPSD evolutions in order to represent the periods of repair and startup.

Additionally, for Capability Category III, the initiating events that contribute significantly to the relatively low-frequency plant evolutions and to the higher-frequency LPSD evolutions are quantified separately. This may include relatively low-frequency initiators (e.g., loss of an AC bus) and higher-frequency initiators. Such Capability Category III models need only be separately quantified for the full power initiators up to and including the periods of repair since the subsequent POSs representing plant startup and rise to full power conditions are essentially the same (with the possible exception of decay heat levels) after repair.

2.A.3 Defining the Set of POSs

After the representative set of LPSD evolutions are identified, the next step is to identify and define the POSs for each LPSD evolution. Each LPSD evolution has its own set of POSs, though often times they share very similar POSs. While the defined POSs must be exclusive, they need not be contiguous in time. For example, if multiple POSs share all but one defined plant condition (e.g., status of containment isolation), the POSs with the same plant condition status may be grouped even if they are not contiguous.

During an LPSD evolution, the plant may transition through a number of low power and shutdown plant conditions, each with many potential operating and maintenance alignments. The plant condition differences are typically reflected as differences in the LPSD PRA models, resulting in important differences in risk estimates. In some POSs (e.g., PWR mid-loop operation), the conditional core damage frequency (i.e., the CDF given that you are in that state) may be much higher than the conditional core damage frequency given one is in a full power state. In other POSs (e.g., PWR with reactor cavity flooded), the conditional CDF may be considerably lower than for full power. These differences in risk estimates are due primarily to the reactor coolant system (RCS) configuration and decay heat removal mechanism and secondary to the equipment out of service. Thus, while there is essentially one POS for full power operations, the plant condition differences during an LPSD evolution necessitate the quantification of multiple POSs whose risks are then summed to obtain the risk assessment for an entire LPSD evolution.

Generic guidance for non-power system models is provided in the Surry Low Power and Shutdown Events study sponsored by the USNRC (NUREG/CR-6144) [6]. This generic guidance is consistent with international guidance documented in IAEA-TECDOC-1144 [7]. The general method for defining and selecting the POSs for LPSD evolutions is described below.

Three steps are taken in defining POSs. First, the key safety functions necessary to control or mitigate possible accidents during shutdown are identified. The key safety functions are based on information contained in the full power analysis and applied to shutdown states, with additional functions identified as needed for refueling. Second, a procedure review of the shutdown and start-up procedures is conducted to determine the impact of the start-up and shutdown on the safety systems used to fulfill the key safety functions. Finally, the impact of varying LPSD evolution types is evaluated. Each of these areas is further described below in Section 2.A.4 in a discussion on the treatment of POSs used for computing time-dependent CDF and LERF.

2.A.3.1 Key Safety Functions

The key safety functions for LPSD PRA are consistent with those derived from a full power PRA. The key safety functions identified are as follows:

(a) reactivity control;
(b) RCS inventory control;
(c) decay heat removal;
(d) RCS integrity;
(e) containment integrity (including containment heat removal and containment pressure suppression).

2.A.3.2 Procedure Review

Plant operating procedures for shutdown and startup operations are initially reviewed in the context of an LPSD evolution involving refueling, often called a refueling outage. A refueling outage typically provides the widest range of LPSD plant conditions and activities of any of the historically observed LPSD evolution types. It is also typically the only planned and scheduled LPSD evolution. The actions described in the various steps in the procedures are examined to determine if any important safety related changes in the plant could result in changes in any of the following. These items are selected for consideration in determining the plant-specific systems used to fulfill the key safety functions listed above:

(a) operating modes or operational conditions as defined in plant Technical Specifications;
(b) RCS configurations such as vented or not vented, whether temporary RCS penetrations are installed, their differential pressure capability, the presence of vessel internals (which in some plants changes the decay heat removal mechanism from natural circulation cooling to forced circulation using the RHR system), and decay heat removal mechanisms such as steaming or residual heat removal;
(c) range of RCS parameters, e.g., the thermal-hydraulic conditions of the RCS, including power level or decay heat level, average reactor coolant temperatures, pressures, and water level;
(d) availability of systems monitoring safety parameters, especially RCS-level instrumentation;
(e) mode switch position (for BWRs);
(f) activities that may lead to changes in the above parameters, e.g., drain down, filling and venting, dilution, fuel movement, and/or cooldown;

- *(g)* the status of plant systems (e.g., the RPS) used for accident mitigation, including whether manually or automatically actuated, the status of power supplies, and their availability and capability for decay heat removal;
- *(h)* containment status, i.e., deinerted, intact, or open, and the status of individual containment penetrations (air locks, ventilation ducts, and pipes).

General guidelines used to differentiate the procedure steps important to be tracked for POS definition are as follows:

- *(a)* Changes in plant conditions (e.g., decay heat level) that change the numerator of the PRA success criteria (e.g., M out of N pumps for decay heat removal) or cause entire systems to be unavailable or ineffective (e.g., steam generator cooling) are generally the boundary lines in defining the POSs.
- *(b)* Major changes in plant conditions or the applicable procedures affecting the actuation of safety systems, such as whether manual or automatic actuation is available, and the times required for action are also considered as boundaries in defining POSs.
- *(c)* Changes in the denominator of the PRA success criteria (e.g., M out of N pumps) may but do not often constitute the boundaries in defining the POSs. Instead, these effects are incorporated as the maintenance configuration is established for each POS.
- *(d)* A change in the plant conditions that affects any of the key safety functions may result in the definition of a new POS. For example, when reactor decay heat removal shifts from secondary heat removal to the residual heat removal system, a new POS may be defined.
- *(e)* Specific POSs may be defined for plant conditions with the potential for accidents caused by LPSD evolution activities, e.g., fuel handling accidents during core unloading or containment overpressure testing that affect automatic safety injection actuation systems.
- *(f)* Activities that are procedure-based and initiated or completed by manual operation and that have the potential for a severe accident may also be defined as a distinct POS or may be grouped with a similar POS. For example, drain down to mid-loop in a PWR can be a unique POS or grouped with the mid-loop POS.

Even though most of the PRA elements and associated requirements are identical to a full power PRA, the development of LPSD models is approached as if the model is being developed as brand new. Considerable care and attention to detail are required to ensure that the LPSD model development does not overlook a change in plant/system/component response. For example, the low-pressure injection/recirculation system may be safety-actuated in a full power PRA model, but the same system may only be manually actuated during some POSs in an LPSD evolution. Manual actuation may change the system dependencies based on the pump protection circuitry (e.g., pump protective features such as seal water may be over-ridden by a safety signal at-power and therefore have no impact in the full power POS, but may trip the pump if lost during the applicable POSs in an LPSD evolution). Thus, the component protection schematics must be reviewed from the perspective of what is "normal" in the LPSD evolution POSs compared to "normal" in the full power PRA model.

In this procedure review step, both POS identification and grouping are inherently occurring as the procedural steps are mapped into a smaller number of plant states. In theory, each step in the procedure could be mapped to a unique plant state. However, grouping into a smaller set of POSs is typically conducted, largely based on the success criteria for mitigating systems.

POSs may cover time intervals in which thermal power, temperature, and/or pressure of the reactor coolant system are varying or the system-related conditions for heat transfer are changing. In the Surry LPSD PRA [6], the decay heat removal mechanisms during POSs involving such transitions were selected to be the same as in the quasi-steady state POS that preceded or followed the periods of transition. The representative time selected for evaluating the value of each plant condition that varies within a POS (e.g., RCS level) can be conservative for the entire POS so long as the contribution to CDF or LERF is not unrealistic. One way to ensure conservatism is to vary the representative time selected for the given plant condition as a function of the initiating event modeled, e.g., use a low RCS level for LOCAs and a high RCS level for overpressure initiators so that in each case, the values that result in shorter time windows allow for operator actions. While the combination of these two plant condition values may be possible only during a short duration of the POS or not at all, only one or the other of the two plant conditions typically governs the plant response for each initiator, i.e. this approach is conservative but not appreciably so.

It is important to ensure that the risk insights are not masked by this selection of the representative values for plant conditions within a POS. The POS analysis process is iterative with the development of subsequent LPSD tasks such that the initial definition of POS plant conditions may change. For example, as the success criteria and data are developed, it may be found that early in an outage, an alternate decay heat removal system may be insufficient for the complete duration of a particular POS due to the decay heat being initially higher than the capacity of the system. This would require a change in the defined POS interval and potentially a new POS covering the time interval for the changed success criteria.

A demand-based initiating event is linked to a specific activity as opposed to occurring randomly in time over the POS duration. For example, in a PWR, the activity for drain down to mid-loop has been associated with historical events related to over-draining while lowering the RCS level. This can be modeled as a separate POS associated with the drain down activity and not grouped with other POSs. The intent of separating periods involving demand-based initiating events from other POSs is to avoid having to approximate the demand-based initiating event as one that is time-based, effectively averaging the instant in time of the demand over an entire POS duration. If, instead, a POS with the same characteristics can represent both time-based and demand-based initiating events and the chosen PRA quantification tool can avoid the need to average the demand-based initiating event over the entire POS duration, a separate POS is not needed.

Some system alignments and component maintenance unavailabilities may be used as plant conditions defining a POS. For example, if planned maintenance occurs randomly within a POS time interval during different refueling outages, the POS definition need not use the start of such planned maintenance activities as a plant condition defining the POS. Instead, the probability of the planned maintenance could then be modeled as equally likely throughout the POS. On the other hand, if planned maintenance is more structured (e.g., with the protected train changing after the first half of the POS), then the start of such planned maintenance may appropriately be considered as a plant condition defining the affected POSs. In this more structured case, two POSs may be applied for the time interval, the first having the initially protected train always in planned maintenance, and the second POS having the other protected train always in planned maintenance, in accordance with plant policies.

For forced outages, the planned and unplanned test and maintenance activities early in the evolution closely approximate test and maintenance activities while at nominal full power. Such test and maintenance activities are generally assumed in the initial POSs of the LPSD evolution until such times that plant policies ensure that any degraded alignments are restored prior to proceeding with the outage progression.

2.A.3.3 Entry Times and POS Durations

POS duration data are developed using the requirements in the data analysis section. The applicable records are typically represented by the most recent data. However, future planned LPSD evolutions may differ from past practice, for example, by conducting a hot mid-loop. Another issue is that the most recent outage may consist of unusual activities that would not be expected in a typical outage, such as replacement of the reactor vessel head.

For time-averaged LPSD PRA models, decay heat levels are selected as one of the plant conditions used to define each POS. The level of decay heat is partially governed by the restrictions on plant transitions between different shutdown states. Decay heat levels are largely based on the historical records of preceding POS durations, as recorded in past LPSD evolutions.

Within the early portions of Modes 1 to 4 (e.g., PWR, before offloading fuel), for the purpose of defining system success criteria within the associated POSs, the decay heat level can be conservatively assumed to be the same as that immediately after plant trip. In Modes 5 and 6 (PWR), decay heat has limited influence on the system success criteria. Especially after refueling is complete (often termed the "late" part of the outage), the slow but continued reduction in decay heat levels generally does not change the mitigating system success criteria. This is true even though the reduced decay heat at such long times after shutdown can significantly increase the allowable time window for operator actions. Additionally, following refueling, a second decay heat curve is often used to account for the exchange of irradiated fuel assemblies with new ones, reducing the core decay heat further.

We see from the above discussion that the exact decay heat level has limited influence on the system success criteria for mitigating systems. Representative estimates of the decay heat level can instead be assumed. This is not to say that if an early and late POS are identical except for the decay heat level, just one POS representing both is defined. Rather, if significant in that the difference affects system success criteria, two different POSs are still to be defined, and when assigning the decay heat level, two different representative levels are then used. However, for the purpose of defining the times to boiling or times to core uncovery when defining the allowable windows for operator recovery, the exact decay heat levels from each time after shutdown can instead be used.

In this approach, the actual decay heat level at each time of quantification can still be accounted for. It is just that in the definition of system success criteria, selection of initiating events, and accident sequence development, care must be taken to ensure that the decay heat levels assumed for determining mitigation system success criteria are not overly conservative.

The trend toward shorter outages may mean that POSs are entered sooner after plant shutdown when decay heat levels are higher than might have been experienced in past outages. The higher decay heat may affect the success criteria of a system or component and may therefore require a new POS or a change in the characteristics of a POS, even if the actual plant outage procedures have not changed. The known plans for future outages may be in written form or may be extracted by way of personnel interviews.

For forced outages that have not been observed, there is likely no experience data from which to estimate the repair duration for the POS. Such durations will instead have to be estimated based on expert judgment.

2.A.3.4 Impacts of Varying LPSD Evolution Types

The set of plant conditions defining the POSs often allow the same POSs to be used in different LPSD evolution types. The Refueling Outage largely defines the set of POSs included in the LPSD PRA model. Other LPSD evolution types typically use a subset of the Refueling Outage POSs; however, the time spent in POSs occurring during other LPSD evolution types may (and probably will) be different than that for a Refueling Outage. These differences can therefore lead to different decay heat levels at POS entry for otherwise similar POSs to those defined for different LPSD evolutions.

2.A.4 Definition of POSs Used for Computing Time-Dependent CDF and LERF Risk Metrics

The above paragraphs refer to those plant conditions that must be considered in defining POSs when computing the time-averaged CDF and time-averaged large early release risk metrics for LPSD evolutions. For configuration risk management of specific LPSD evolutions and some other risk applications, the time-dependent CDF and LERF are instead computed as risk metrics. For configuration risk management, the time-dependent CDF and LERF are evaluated at many different times within the same POS (rather than using one quantification to represent the average over an entire POS interval), as defined in the preceding paragraphs.

The same POSs used to evaluate time-averaged risk metrics could also be useful for configuration risk management. One key difference is that the plant conditions chosen to define POSs solely to facilitate quantification for time-averaged CDF may be treated differently for configuration risk management models. Rather, at each time point needed for quantification within the POS interval, adjustments can be made to the configuration risk management models to reflect the changes that affect frequency quantification at each time. For configuration risk management applications, it is important that the plant conditions that define the POSs still facilitate the development of the remaining PRA elements, i.e., justification of success criteria, selection of initiating events, and development of accident sequences. Representative values for plant conditions may be assumed during model development for justification of success criteria, selection of initiating events, and development of accident sequences. Then, during time-dependent CDF quantification, these plant conditions can be varied consistent with the specific outage represented.

For example, the alignment conditions for the normally running and standby pumps and specification of the equipment that are out of service for test or maintenance are not plant conditions that need to be chosen to define a POS used to compute time-dependent CDF and LERF. These plant conditions may define the frequency of initiating events and the failure probabilities of mitigating systems, but would not affect success criteria, selection of initiating events to be included, or the development of the accident sequences. These alignments and maintenance conditions can instead be treated as time-dependent variables that are input to the solution of the LPSD evolution model at each specific point in time where these plant conditions are known.

Further, the status of systems related to containment integrity and activities affecting the availability of safety systems can instead also be accounted for in the quantification process rather than as plant conditions defining the POSs for configuration risk management.

In practice, when computing only time-dependent CDF and LERF, analysts generally prefer to limit the plant conditions needed to define POSs to those that distinguish the modes or operating conditions, similar to the way these distinctions appear in the plant technical specifications. The other plant conditions listed for time-averaged models are instead accounted for in the LPSD PRA models used for sequence quantification, which are then adjusted within each POS for evaluation at each time point. One caution is that the selection and frequency quantification of initiating event groups can vary with POS and, especially, that the frequency of the initiating event groups may vary with system alignment and maintenance conditions. To the extent that such alignments and maintenance conditions are allowed to vary within a POS, the applicable initiating event frequencies also need to vary.

We have seen how the plant conditions needed to characterize POSs can be reduced if only time-dependent CDF and LERF are to be computed rather than time-averaged risk metrics. However, for comparison, the other attributes identified as significant for defining POSs for time-averaged models must still be documented. When documenting the POSs for a time-dependent application, it is not necessary to explicitly list each POS and the specific values of the selected plant conditions in an exhaustive table of all POSs. For example, the user may choose to describe the selection of initiating events applicable to each POS in terms of a subset of plant conditions that totally define when they apply, i.e., RCS pressure and level conditions. Such explanations should cover all of the POS plant conditions listed in LPOS-A3.

Changes in supporting requirements for defining POSs for configuration risk management and other related applications requiring time-dependent risk metrics are described in Part 10.

Table 2-A-1 lists examples of plant conditions and their suggested treatment in an LPSD PRA model for a PWR for both time-averaged and time-dependent CDF and LERF calculations.

Table 2.A-1 Treatment of LPSD PRA POSs for Time-Dependent Models

	Treatment for Defining POSs	
POS-Affecting Plant Condition	**Time-Averaged CDF/LERF Models**	**Time-Dependent CDF/LERF Models**
Operating modes/operating conditions as defined by plant Technical Specifications, including reactivity status and mode switch position for BWRs	Used to define the POS	Used to define the POS
RCS configurations (e.g., vented or not vented, temporary RCS penetrations)	Used to define the POS	Used to define the POS
Range of RCS parameters (e.g., average coolant temperature/pressure/level)	Used to define the POS	*(a)* Representative values used to define the POS success criteria, initiating event selection, and accident sequence development *(b)* Time-dependent values used for HEPs during quantification

Table 2.A-1 Treatment of LPSD PRA POSs for Time-Dependent Models (Cont'd)

POS-Affecting Plant Condition	Treatment for Defining POSs	
	Time-Averaged CDF/LERF Models	**Time-Dependent CDF/LERF Models**
Time after shutdown, decay heat level	Used to define the POS	*(a)* Representative values used to define the POS success criteria, initiating event selection, and accident sequence development *(b)* Time-dependent values used for HEPs during quantification
Available RCS level instrumentation	Used to define the POS	Used to define the POS
Mode switch position (for BWRs)	Used to define the POS	Used to define the POS
Activities that may lead to changes in the above parameters, e.g., drain downs, filling and venting, dilution, fuel movement, and/or cooldown	Used to define the POS	Used to define the POS
Status of containment (including status penetrations, e.g., air locks/ventilation and ducts/pipes)	Used to define the POS	Time-dependent modeling of containment equipment alignments and outages during quantification
Capabilities of operating and mitigating systems, including RPS and those for decay heat removal	Used to define the POS	Used to define the POS
Availability/redundancy of operating and mitigating systems including RPS and those for decay heat removal	May be used to define the POS or assumed all available to define the POS	*(a)* Assumed all available to define the POS success criteria, initiating event selection, and accident sequence development *(b)* Time-dependent modeling of equipment alignments and outages during quantification

Part 3 Requirements for Internal Events LPSD PRA

3.1 Overview of Internal Events LPSD PRA Requirements

3.1.1 LPSD PRA Scope

This section establishes technical requirements for a Level 1 and large early release frequency (LERF) analysis of internal events (excluding floods and fires within the plant) while at low power or shutdown conditions. Consistent with the definitions in Section 1.2, internal floods are considered separately, as presented in Part 4. Most of the technical requirements for the analysis of internal events of this standard are included by reference from the ASME/ANS PRA Standard for full power conditions (Part 2 of ASME/ANS RA-Sa-2009 [1]), except as modified.

3.1.2 Coordination with Other Parts of This Standard

The requirements in this section are in addition to and based on the technical requirements developed for the identification of plant operating states in Part 2.

This section is intended to be used together with Parts 1 and 2 of this standard. Many of the technical requirements here in Part 3 are fundamental requirements for performing a PRA for any hazard group and are therefore relevant to Parts 4 through 10 of this standard. They are incorporated by reference in those requirements that address the development of the plant response to the damage states created by the hazard groups addressed in Parts 4 through 10. Their specific allocation to Part 3 is partially a historical artifact of the way this standard and Reference [1] were developed. The full power internal events requirements were developed first, and those of the remaining hazard groups were developed later. However, it is also a reflection of the fact that a fundamental understanding of the plant response to a reasonably complete set of initiating events (as defined in Section 3.2.1) provides the foundation for modeling the impact of various hazards described in Parts 4 through 10. The starting points for Part 4 (Internal Flood analysis), Part 5 (Seismic Events), Part 7 (High Winds), Part 8 (External Floods), and Part 9 (Other External Hazards) are the models developed for internal events. Hence, even though Part 3 is given a title associated with the internal hazard group, it is understood that the requirements in this section are applicable to all the hazard groups within the scope of the LPSD PRA.

3.1.3 Internal Events LPSD Scope

The scope of internal events covered in this section includes those events originating within the plant boundary. However, internal floods are covered in Part 4, and loss of offsite power, by convention, is considered an internal event.

3.2 Internal Events LPSD PRA Technical Elements and Requirements

The requirements of this section plus those from the POS analysis defined in Part 2 are organized by the following nine technical elements comprising a Level 1/LERF LPSD PRA for internal events (with their abbreviations):

(a) Plant Operating State Analysis (LPOS);
(b) Initiating Events Analysis (LIE);
(c) Accident Sequence Analysis (LAS);
(d) Success Criteria (LSC);

- *(e)* Systems Analysis (LSY);
- *(f)* Human Reliability Analysis (LHR);
- *(g)* Data Analysis (LDA);
- *(h)* Quantification (LQU);
- *(i)* LERF Analysis (LLE).

Tables of HLRs and SRs for the last eight LPSD PRA elements for internal events are provided in Subsections 3.2.1 through 3.2.8. The SRs are numbered and labeled to identify the HLR that is supported. For each Capability Category, the SRs define the minimum requirements necessary to meet that Capability Category. In these tables, some action statements apply to only one Capability Category, and some extend across two or three Capability Categories. When an action spans multiple categories, it applies equally to each Capability Category. When necessary, the differentiation between Capability Categories is made in other associated SRs; two examples are stated below. The interpretation of a Supporting Requirement whose action statement spans multiple categories is stated in Table 1-1.3-3. Some action statements span Capability Categories II and III because the authors were unable to specify a distinguishing requirement for Capability Category III at this time. It is intended that, by meeting all the SRs under a given HLR, an LPSD PRA will meet that HLR.

Examples of how the requirements for Capability Categories are differentiated:

LIE-A2 requires initiating events and event categories that can challenge the plant to be identified. The scope of identifying the events is the same for all Capability Categories. However, the treatment of the identified events does vary in scope and detail between Capability Categories, as seen in LAS-A9.

LHR-F1 is a general action statement about the way a human failure event is included in the LPSD PRA model, while LHR-F2 distinguishes different levels of analysis for the subsequent quantification.

Boldface is used to highlight the differences among the requirements in the three Capability Categories. Underlining is used to identify the differences in requirements for LPSD versus those for full power conditions described in [1].

3.2.1 Initiating Event Analysis (LIE)

Objectives: The objectives of the initiating event analysis are to identify and quantify events in each POS or groups of POSs that could lead to core damage in such a way that:

- *(a)* events that challenge normal plant operation and that require successful mitigation to prevent core damage are included;
- *(b)* initiating events are grouped according to the mitigation requirements to facilitate the efficient modeling of plant response;
- *(c)* frequencies of the initiating event groups are quantified.

Table 3.2.1-1 High Level Requirements for Internal Initiating Events Analysis (LIE)

Designator	Requirement
HLR-LIE-A	The initiating event analysis shall provide a reasonably complete identification of initiating events for all POSs retained for analysis.
HLR-LIE-B	The initiating event analysis shall group the initiating events within a POS so that events in the same group have similar mitigation requirements (i.e., the requirements for most events in the group are less restrictive than the limiting mitigation requirements for the group) to facilitate an efficient but realistic estimation of CDF.
HLR-LIE-C	The initiating event analysis shall estimate the annual frequency of each initiating event or initiating event group for each POS.
HLR-LIE-D	Documentation of the initiating event analysis shall be consistent with the applicable supporting requirements.

Table 3.2.1-2(a) Supporting Requirements for HLR-LIE-A

The initiating event analysis shall provide a reasonably complete identification of initiating events for all POSs retained for analysis (HLR-LIE-A).

Index No. LIE-A	**Capability Category I**	**Capability Category II**	**Capability Category III**
LIE-A1	IDENTIFY those initiating events that challenge normal plant operation and that require successful mitigation to prevent core damage using a structured, systematic process for identifying initiating events that accounts for plant-specific features for each POS or group of POSs. For example, such a systematic approach may employ master logic diagrams, heat balance fault trees, or failure modes and effects analysis (FMEA). Existing lists of known initiators are also commonly employed as a starting point [see Note (1)].		

Table 3.2.1-2(a) Supporting Requirements for HLR-LIE-A (Cont'd)

<table>
<tr><th>Index No. LIE-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td>LIE-A2</td><td colspan="3">INCLUDE in the spectrum of internal-event challenges considered at least the following general categories of initiating events [see Note (2)]:
(a) Transients. INCLUDE among the transients both equipment and human induced events that disrupt the plant and leave the primary system pressure boundary intact
(b) LOCAs. INCLUDE in the LOCA category both equipment and human induced events that disrupt the plant by causing a breach in the core coolant system with a resulting loss of core coolant inventory. DELINEATE the LOCA initiators into at least the following categories using a defined rationale for the differentiation [see Note (3)]. Examples of LOCA types include:
(1) small LOCAs (e.g., reactor coolant pump seal LOCAs, small pipe breaks)
(2) medium LOCAs (e.g., stuck open safety or relief valves)
(3) large LOCAs (e.g., inadvertent ADS, component ruptures)
(4) excessive LOCAs (LOCAs that cannot be mitigated by any combination of engineered systems, e.g., reactor pressure vessel rupture)
(5) LOCAs outside containment [e.g., primary system pipe breaks outside containment (BWRS)]
(6) diversion of flow LOCAs
(7) LOCAs in typically connected systems (inside containment)
(8) maintenance-induced LOCAs
(9) cold overpressure-induced LOCAs
(c) SGTRs: INCLUDE spontaneous rupture of a steam generator tube (PWRS)
(d) ISLOCAs: INCLUDE postulated events in systems interfacing with the reactor coolant system that could fail or be operated in such a manner as to result in an uncontrolled loss of core coolant outside the containment [e.g., interfacing systems LOCAs (ISLOCAs)]
(e) Special initiators (e.g., support systems failures, instrument line breaks) [see Note (4)]
(f) Reactivity control accidents [see Note (5)]
(g) Other categories of initiating events caused by at-initiator human failure events [see Note (6)]</td></tr>
<tr><td>LIE-A3</td><td colspan="3">REVIEW the plant-specific initiating event experience of all initiators during all POSs to ensure that the list of challenges accounts for plant experience. See also LIE-A7.</td></tr>
<tr><td>LIE-A4</td><td colspan="2">REVIEW generic analyses for all POSs for similar plants to assess whether the list of challenges included in the model accounts for industry experience and to identify initiating events involving at-initiator human failures that impact later operator mitigation actions.</td><td>REVIEW generic analyses and operating experience for all POSs for similar plants to assess whether the list of challenges included in the model accounts for industry experience and to identify initiating events involving at-initiator human failures that impact later operator mitigation actions.</td></tr>
</table>

Table 3.2.1-2(a) Supporting Requirements for HLR-LIE-A (Cont'd)

Index No. LIE-A	Capability Category I	Capability Category II	Capability Category III
LIE-A5	PERFORM a systematic evaluation of each system including support systems in each POS to assess the possibility of an initiating event occurring due to a failure of the system. **PERFORM a qualitative review of system impacts to identify potential system initiating events**.	PERFORM a systematic evaluation of each system including support systems in each POS to assess the possibility of an initiating event occurring due to a failure of the system. **USE a structured approach [such as a system-by-system review of initiating event potential, an FMEA (failure modes and effects analysis), or another systematic process] to assess and document the possibility of an initiating event resulting from individual systems or train failures**.	PERFORM a systematic evaluation of each system including support systems in each POS to assess the possibility of an initiating event occurring due to a failure of the system. **DEVELOP a detailed analysis of system interfaces. PERFORM an FMEA (failure modes and effects analysis)** to assess and document the possibility of an initiating event resulting from individual systems or train failures.
LIE-A6	When performing the systematic evaluation required in LIE-A5, INCLUDE initiating events resulting from multiple failures in each POS if the equipment failures result from a common cause [see Note (6)].	When performing the systematic evaluation required in LIE-A5, INCLUDE initiating events resulting from multiple failures in each POS if the equipment failures result from a common cause **and from routine system alignments** [see Note (6)].	When performing the systematic evaluation required in LIE-A5, INCLUDE initiating events resulting from multiple failures in each POS, **including equipment failures resulting from random and common causes and from routine system alignments** [see Note (6)].
LIE-A7	In the identification of the initiating events, INCLUDE: *(a)* events that have occurred during POSs other than the one being examined, unless it is determined that an event is not applicable to that POS *(b)* events that include a manual scram occurring during a controlled shutdown prior to reaching shutdown conditions, unless it is determined that an event is not applicable to the POS being examined [see Note (6)]		
LIE-A8	Same as IE-A8 in ASME/ANS RA-Sa-2009 [1]. No requirement for interviews.	**INTERVIEW plant personnel (e.g., operations, maintenance, engineering, safety analysis) to determine if potential initiating events have been overlooked for any POS** [see Note (6)].	

Table 3.2.1-2(a) Supporting Requirements for HLR-LIE-A (Cont'd)

Index No. LIE-A	Capability Category I	Capability Category II	Capability Category III
LIE-A9	Same as IE-A9 in ASME/ANS RA-Sa-2009 [1]. No requirement for precursor review.	REVIEW plant-specific operating experience for initiating event precursors in each POS for the purpose of identifying additional initiating events. **For example, plant-specific experience with intake structure clogging might indicate that loss of intake structures should be identified as a potential initiating event** [see Note (6)].	REVIEW plant-specific **and industry** operating experience for initiating event precursors in each POS for the purpose of identifying additional initiating events [see Note (6)].
LIE-A9a	No requirement for reviewing temporary maintenance alignments.	**In searching for initiating events, INCLUDE temporary alignments during routine maintenance that could either influence the likelihood that failures cause an initiating event for any POS, increase the severity of previously identified initiating events, or create a new initiating event for each POS as a result of the temporary alignment** [see Note (7)].	
LIE-A10	Same as IE-A10 in ASME/ANS RA-Sa-2009 [1].		

NOTES:

(1) Both equipment failures and at-initiator human failure events can challenge plant operation and require successful mitigation. Supporting requirements for the identification and quantification of at-initiator human failure events are provided in Section 3.2.5. References [5] and [6] provide example categorizations of initiating events for shutdown conditions, e.g., LOCA types (6) – (9) in item (b) of LIE-A2. Many initiating events for full power conditions will also apply to POSs with the RCS at high pressure. Special emphasis is placed on reviews of LPSD evolution activities (e.g., reducing water level to mid-loop for PWRs and hydro testing for BWRs) and maintenance activities (including plant realignments in preparation for maintenance) during shutdown POSs to identify initiating events unique to these plant conditions.

(2) Same as ASME/ANS RA-Sa-2009 [1] with LPSD specific examples added. Loss of coolant events:
  - *(a)* The need to include different types of LOCAs will be POS-dependent; e.g., if the vessel head is off, drain down events may be more dominant than pipe break LOCAs.
  - *(b)* Small, medium, and large LOCAs may also be defined within each of LOCA types 5 ~ 9. The use of LOCA types 5 ~ 9 is to facilitate identification of LOCAs. These LOCAs may have characteristics similar to ISLOCAs depending upon the final location of the water. However, the term "ISLOCA" in item (d) is reserved for events that involve passive boundary failures (see definition in Section 1.2).

(3) These special initiators may result in either a transient or a LOCA type of sequence. Examples include support systems failures, instrument line breaks, and spurious actuations of systems or equipment.

(4) Examples: addition of unborated water or events following a misloaded fuel assembly.

(5) ASME /ANS PRA Standard [1] requirement changed to clarify the need to identify events that could happen during any selected POS.
(6) Initiating events caused by at-initiator human failure events are particularly common for events during shutdown. See Section 3.2.5 for requirements related to identifying at-initiator human failure events).
(7) Routine but temporary alignments are common and may be important during shutdown. To the extent that these events are caused by at-initiator human failure events, they are also identified by satisfying the requirements of Section 3.2.5.

Table 3.2.1-2(b) Supporting Requirements for HLR-LIE-B

The initiating event analysis shall group the initiating events within a POS so that events in the same group have similar mitigation requirements (i.e., the requirements for most events in the group are less restrictive than the limiting mitigation requirements defined for the group) to facilitate an efficient but realistic estimation of CDF (HLR-LIE-B).

Index No. LIE-B	Capability Category I	Capability Category II	Capability Category III
LIE-B1	GROUP initiating events into groups to facilitate definition of accident sequences in the Accident Sequence Analysis element (Subsection 3.2.2) and to facilitate quantification in the Quantification element (Subsection 3.2.7).		
LIE-B2	Same as IE-B2 in ASME/ANS RA-Sa-2009 [1].		
LIE-B3	Same as IE-B3 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as IE-B3 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as IE-B3 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].
LIE-B4	Same as IE-B4 in ASME/ANS RA-Sa-2009 [1].		
LIE-B5	Same as IE-B5 in ASME/ANS RA-Sa-2009 [1].		
LIE-B6	ENSURE that any grouping of time-based initiating events together with demand-based initiating events properly considers the frequency of each.		

NOTE:
(1) During LPSD evolutions, a variety of POSs are entered. An initiating event grouping valid for one POS may not be appropriate for another. Plant operational practices may provide bounding or worst-case impacts on an initiating event grouping. The requirements related to the grouping of initiating events caused by at-initiator human failure events are presented in Section 3.2.5.

Table 3.2.1-2(c) Supporting Requirements for HLR-LIE-C

The initiating event analysis shall estimate the annual frequency of each initiating event or initiating event group for each POS (HLR-LIE-C).

<table>
<tr><th>Index No.
LIE-C</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td>LIE-C1</td><td colspan="3">CALCULATE the initiating event frequency for each applicable POS accounting for relevant generic and plant-specific data unless it is justified that there are adequate plant-specific data to characterize the parameter value and its uncertainty (see also LIE-C13 for requirements for rare and extremely rare events) [see Note (1)].</td></tr>
<tr><td>LIE-C2</td><td colspan="3">Same as IE-C2 in ASME/ANS RA-Sa-2009 [1].</td></tr>
<tr><td>LIE-C3</td><td colspan="3">CREDIT recovery actions [those implied in LIE-C6(c)] and those implied and discussed in LIE-C8, as appropriate. JUSTIFY each such credit (as evidenced such as through procedures or training) [see Note (8)].</td></tr>
<tr><td>LIE-C4</td><td colspan="3">Same as IE-C4 in ASME/ANS RA-Sa-2009 [1].</td></tr>
<tr><td>LIE-C5</td><td colspan="3">CALCULATE initiating event frequencies on a per calendar year basis. Specifically, for each POS, INCLUDE in the initiating event frequency analysis the fraction of time the plant is in each POS in an average year, as appropriate. For demand-based initiating events, account for the frequency in an average year that each POS is entered. ACCOUNT for differences between historical POS durations and frequencies over the period of POS occurrences in the historical records and those POS durations and frequencies in planned future plant operation that could be different from historical values [see Note (2)].</td></tr>
<tr><td>LIE-C6</td><td colspan="3">USE as screening criteria no higher than the following characteristics (or more stringent characteristics as devised by the analyst) to eliminate initiating events or groups from further evaluation:
(a) the frequency of the event or group, weighted by the sum of all applicable POS frequencies and POS durations, is less than 1×10^{-7} per calendar year, and the event does not involve either an ISLOCA, containment bypass, reactor vessel rupture, or an initiating event with the reactor coolant system vented and containment unisolable; or
(b) the frequency of the event or group weighted by the sum of all applicable POS frequencies and POS durations is less than 1×10^{-6} per calendar year for time-based initiating events or per POS frequency-weighted-challenge if demand-based, and core damage could not occur unless at least two trains of mitigating systems are failed independent of the initiator; or
(c) the resulting reactor shutdown is not an immediate occurrence; that is, the event does not require the plant to go to shutdown conditions until sufficient time has expired during which the initiating event conditions, with a high degree of certainty (based on supporting calculations), are detected and corrected before normal plant operation is curtailed (either administratively or automatically)
If either criterion (a) or (b) above is used, then CONFIRM that the value specified in the criterion meets the applicable requirements in Data Analysis (3.2.6) and Level 1 Quantification (3.2.7) [see Note (3)].</td></tr>
</table>

Table 3.2.1-2(c) Supporting Requirements for HLR-LIE-C (Cont'd)

Index No. LIE-C	Capability Category I	Capability Category II	Capability Category III
LIE-C6a	Specific POS and initiating event combinations may be screened out from further analysis using bounding analyses. ENSURE that: *(a)* The quantitative screening process does not screen the highest risk POSs or initiating events	Specific POS and initiating event combinations may be screened out from further analysis using bounding analyses. ENSURE that: ***(a)*** The quantitative screening process does not screen the highest risk POSs or initiating events; and ***(b)*** **the sum of the CDF contributions for all screened-out POS and initiating event combinations is <10% of the estimated total CDF for unscreened events; and** ***(c)*** **the sum of the LERF contributions for all screened-out POS and initiating event combinations is <10% of the estimated total LERF for unscreened events**	Specific POS and initiating event combinations may be screened out from further analysis using bounding analyses. ENSURE that: ***(a)*** The quantitative screening process does not screen the highest POSs or initiating events; and ***(b)*** the sum of the CDF contributions for all screened-out POS and initiating event combinations is <**1%** of the estimated total CDF for unscreened events; and *(c)* the sum of the LERF contributions for all screened-out POS and initiating event combinations is <1% of the estimated total LERF for unscreened events
LIE-C7	Same as IE-C7 in ASME/ANS RA-Sa-2009 [1]. No requirement for time trend analysis.		Same as IE-C7 in ASME/ANS RA-Sa-2009 [1].
LIE-C8	Some initiating events are amenable to fault-tree modeling as the appropriate way to quantify them. These initiating events, usually support system failure events, are highly dependent upon plant-specific design features. If fault-tree modeling is used for initiating events, USE the applicable systems-analysis requirements for fault-tree modeling found in the Systems Analysis Section (Section 3.2.4) [see Note (4)].		
LIE-C9	Same as IE-C9 in ASME/ANS RA-Sa-2009 [1].		
LIE-C9a	If HRA is used for initiating events (i.e., at-initiator HFE), QUANTIFY the initiating event frequency (as opposed to the probability of the human error). MODIFY, as necessary, the HRA computational methods that are used so that the top event quantification produces a failure frequency rather than a top event probability, as normally computed. USE the applicable requirements in the HRA Section 3.2.5 [see Note (5)].		

Table 3.2.1-2(c) Supporting Requirements for HLR-LIE-C (Cont'd)

Index No. LIE-C	Capability Category I	Capability Category II	Capability Category III
LIE-C10	Same as IE-C10 in ASME/ANS RA-Sa-2009 [1].		
LIE-C11	If fault-tree modeling or HRA is used for initiating events, USE plant-specific information in the assessment and quantification of recovery actions where available, consistent with the applicable requirements in the Human Reliability Analysis Section (Section 3.2.5).		
LIE-C12	Same as IE-C12 in ASME/ANS RA-Sa-2009 [1].		
LIE-C13	Same as IE-C13 in ASME/ANS RA-Sa-2009 [1] [see Note (6)].		Same as IE-C13 in ASME/ANS RA-Sa-2009 [1] [see Note (6)].
LIE-C14	Same as IE-C14 in ASME/ANS RA-Sa-2009 [1] [see Note (7)].		Same as IE-C14 in ASME/ANS RA-Sa-2009 [1] [see Note (7)].
LIE-C15	Same as IE-C15 in ASME/ANS RA-Sa-2009 [1].		

NOTES:

(1) A useful reference for initiating event frequencies during shutdown is EPRI 1021176 [8]. HRA techniques may be needed to quantify some at-initiator human failure events (see Section 3.2.5).

(2) Footnote (1) to Table 2-2.1-4(c) in Reference [1] states that the appropriate units for initiating events are events per calendar year, commonly expressed as events per reactor year, where a reactor year is one full calendar year of experience for one reactor. The reader is referred to that footnote for additional examples. Appendix 2-B in this standard discusses the calculation of risk metrics more generally. A change to the interval between refueling evolutions would be one reason to expect LPSD evolutions planned for future operation to be different from the historical records. So for LPSD PRA, this requirement is applied equally to all Capability Categories. It is not necessary to include all potential future planned LPSD evolutions. Those LPSD evolutions for which definitive plans are in place are to be considered. The applicability of the LPSD PRA for other future evolutions must be determined on an evolution specific basis. If the PRA is being used for some purpose other than calculating time-averaged risk, then it may not be necessary to account for the fraction of time the plant is in a particular POS, e.g., for configuration risk management applications (see Section 1.3.7).

(3) Just as with Reference [1], the numerical screening criteria are appropriate for a time-averaged CDF or LERF calculation. When assessing the initiator frequencies for screening, the sum of the fractions of time of applicable POSs is to be included in the assessment. If the *LPSD PRA* is to be used for other types of analyses (e.g., for configuration risk management applications requiring time-dependent risk metrics, see Section 1.3.7), then it is possible that different numerical criteria might need to be developed. Development and defense of such criteria would be a unique obligation of such an analysis.
Part (c) of IE-C6 in [1] does not apply to shutdown conditions but does apply to low power conditions.
For evaluation of a specific evolution, screening on initiating event frequency alone, without adjusting by the fraction of time in a POS, may be necessary to avoid inappropriate loss of the risk contribution of POSs with high conditional core damage probabilities.

(4) When fault trees are used to quantify support system initiating events, it is important to account for whether the failure being represented will occur during the POS under consideration. A procedural

event tree, where the top events represent operator actions within the governing LPSD evolution procedures [9], may then be useful.

(5) When HRA techniques are also required to quantify the fault trees, see the supporting requirements for quantification of at-initiator human failure event frequencies in Section 3.2.5.

(6) HRA techniques may also be an appropriate approach to quantifying at-initiator human failure events. See the requirements for quantifying at-initiator human failure events resulting from at-initiator activities in Section 3.2.5.

(7) Reference [1] discussion applies during low power and hot standby conditions and is not applicable during cold shutdown or refueling conditions.

(8) Reference [8] describes numerous loss of decay heat removal events and their associated recovery actions, which may be useful to mitigate potential initiators.

Table 3.2.1-2(d) Supporting Requirements for HLR-LIE-D

Documentation of the initiating event analysis shall be consistent with the applicable supporting requirements (HLR-LIE-D).

Index No. LIE-D	Capability Category I	Capability Category II	Capability Category III
LIE-D1	Same as IE-D1 in ASME/ANS RA-Sa-2009 [1].		
LIE-D2	Same as IE-D2 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].		
LIE-D3	DOCUMENT the sources of uncertainty and related assumptions (as identified in LQU-E1 and LQU-E2) associated with the initiating event analysis.		

NOTE:

(1) For initiating events resulting from at-initiator human failure events, the requirements in Section 3.2.5 apply.

3.2.2 Accident Sequence Analysis (LAS)

The objectives and high level requirements of the accident sequence element for LPSD conditions are the same as those identified in the ASME/ANS PRA Standard (ASME/ANS RA-Sa-2009 [1]) with the addition of one new objective and shall be accomplished for each POS.

3.2.2.1 Objectives

The objectives of the accident sequence element are to ensure that the response of the plant's systems and operators to an initiating event is reflected in the assessment of CDF and LERF in such a way that:

(a) Significant operator actions, mitigation systems, and phenomena that can alter sequences are appropriately included in the accident sequence model event tree structure and sequence definition;
(b) Plant-specific dependencies are reflected in the accident sequence structure;
(c) Success criteria are available to support the individual function successes, mission times, and time windows for operator actions for each critical safety function modeled in the accident sequences;
(d) End states are clearly defined to be core damage or successful mitigation with capability to support the Level 1 to Level 2 interface;
(e) The accident sequences are defined for the selected set of initiating events, POSs (or groups of POSs), and times that a POS (or group of POSs) can occur.

Table 3.2.2-1 High Level Requirements for Accident Sequence Analysis (LAS)

Designator	Requirement
HLR-LAS-A	The accident sequence analysis shall describe the plant-specific scenarios that can lead to core damage following each modeled initiating event. These scenarios shall address system responses and operator actions, including recovery actions that support the key safety functions necessary to prevent core damage.
HLR-LAS-B	Dependencies that can impact the ability of the mitigating systems to operate and function shall be addressed.
HLR-LAS-C	Documentation of the Accident Sequence analysis shall be consistent with the applicable supporting requirements.

Table 3.2.2-2(a) Supporting Requirements for HLR-LAS-A

The accident sequence analysis shall describe the plant-specific scenarios that can lead to core damage following each modeled initiating event. These scenarios shall address system responses and operator actions including recovery actions that support the key safety functions necessary to prevent core damage (HLR-LAS-A).

Index No. LAS-A	**Capability Category I**	**Capability Category II**	**Capability Category III**
LAS-A1	USE a method for accident sequence analysis that: *(a)* for each POS explicitly models the appropriate combinations of system responses and operator actions that affect the key safety functions for each modeled initiating event [see Note (1)] *(b)* includes a graphical representation of the accident sequences in an "event tree structure" or equivalent, such that the accident sequence progression is displayed *(c)* provides a framework to support sequence quantification		
LAS-A2	Same as AS-A2 in ASME/ANS RA-Sa-2009 [1].		
LAS-A3	Same as AS-A3 in ASME/ANS RA-Sa-2009 [1].		
LAS-A4	Same as AS-A4 in ASME/ANS RA-Sa-2009 [1].		
LAS-A5	DEFINE the accident sequence model in a manner that is consistent with the plant-specific system design, EOPs, abnormal procedures, <u>shutdown operating procedures,</u> and plant transient response <u>[see Note (2)].</u>		
LAS-A6	Same as AS-A6 in ASME/ANS RA-Sa-2009 [1].		
LAS-A7	Same as AS-A7 in ASME/ANS RA-Sa-2009 [1].		Same as AS-A7 in ASME/ANS RA-Sa-2009 [1].
LAS-A8	Same as AS-A8 in ASME/ANS RA-Sa-2009 [1] <u>[see Note (3)].</u>		
LAS-A9	Same as AS-A9 in ASME/ANS RA-Sa-2009 [1].	Same as AS-A9 in ASME/ANS RA-Sa-2009 [1].	Same as AS-A9 in ASME/ANS RA-Sa-2009 [1].
LAS-A10	Same as AS-A10 in ASME/ANS RA-Sa-2009 [1].	Same as AS-A10 in ASME/ANS RA-Sa-2009 [1].	Same as AS-A10 in ASME/ANS RA-Sa-2009 [1].
LAS-A11	Same as AS-A11 in ASME/ANS RA-Sa-2009 [1].		

NOTES:
(1) The accident sequence analysis is to be valid for the range of plant conditions within the POS.
(2) Procedures for use during shutdown contain a significant amount of detail and caution not normally included in normal operating procedures. For LPSD, boiling in the core with sufficient inventory makeup represents a stable, long-term, steady state condition.

Table 3.2.2-2(b) Supporting Requirements for HLR-LAS-B

Dependencies that can impact the ability of the mitigating systems to operate and function shall be addressed (HLR-LAS-B).

Index No. LAS-B	Capability Category I	Capability Category II	Capability Category III
LAS-B1	Same as AS-B1 in ASME/ANS RA-Sa-2009 [1] [see Notes (1) and (2)].		
LAS-B2	IDENTIFY the dependence of modeled mitigating systems on the success or failure of preceding systems, functions, and human actions. INCLUDE the impact on accident progression, either in the accident sequence models or in the system models. For example, *(a)* turbine-driven system dependency on SORV, depressurization, and containment heat removal (suppression pool cooling) *(b)* low-pressure system injection success dependent on need for RPV depressurization *(c)* system dependencies on containment conditions (e.g., deinertion, pressure capability, sump clogging) [see Note (3)]		
LAS-B3	For each accident sequence, IDENTIFY the phenomenological conditions created by the accident progression including those caused by changing plant conditions within a POS. Phenomenological impacts include generation of harsh environments affecting temperature, pressure, debris, water levels, humidity, etc. that could impact the success of the system or function under consideration [e.g., loss of pump net positive suction head (NPSH), clogging of flow paths]. INCLUDE the impact of the accident progression phenomena, either in the accident sequence models or in the system models. During shutdown, the effects of loss of primary coolant inventory can affect the available and credited systems. As part of accident sequence development for loss of inventory events, IDENTIFY the location and size of postulated inventory losses. INCLUDE the impact of the postulated loss of inventory either in the accident sequence models or in the system models [see Note (4)].		
LAS-B4	Same as AS-B4 in ASME/ANS RA-Sa-2009 [1].		
LAS-B5	Same as AS-B5 in ASME/ANS RA-Sa-2009 [1].		
LAS-B6	Same as AS-B6 in ASME/ANS RA-Sa-2009 [1] [see Note (5)].		
LAS-B7	Same as AS-B7 in ASME/ANS RA-Sa-2009 [1] [see Note (6)].		

NOTES:
(1) During LPSD, the dependence between operator-induced initiating events and recovery events may be especially important.

(2) During LPSD, for POSs with the containment open, the ability to re-establish containment integrity by closing the containment entrances may be significantly affected by the initiating event, e.g., loss of offsite power.
(3) In some cases, operators are directed to control the rate of feed to match boil-off. Success of this action has two ramifications: (1) it may avoid the need to go to recirculation; and (2) it adds heat to the containment, which may require containment heat removal systems to operate. Failure to control flow (i.e., over feeding) leads to a need for recirculation but may not require additional heat removal capability beyond the recirculation system.
(4) For example, systems that might not be available at the start of a sequence due to the POS could become available as plant conditions change. RCIC is initially unavailable during Cold Shutdown due to the lack of steam, but it may become available as the RCS heats up and pressurizes. Examples of phenomenological conditions that could affect accident progression are the viability of recirculation from the containment or the potential impact of RCS boiling on the ability to close the containment.
(5) Shutdown-specific maintenance activities and system alignments may be performed routinely. During LPSD, two key examples of time-phased dependencies are: (1) initiation of PWR Gravity Injection before RCS boiling (boiling may negate the elevation head needed for gravity injection if the RCS is vented via a high-elevation vent); and (2) recovery of RHR function before RCS boiling (boiling may require RCS fill and venting of RHR pumps).

Table 3.2.2-2(c) Supporting Requirements for HLR-LAS-C

Documentation of the accident sequence analysis shall be consistent with the applicable supporting requirements (HLR-LAS-C).

Index No. LAS-C	Capability Category I	Capability Category II	Capability Category III
LAS-C1	Same as AS-C1 in ASME/ANS RA-Sa-2009 [1].		
LAS-C2	Same as AS-C2 in ASME/ANS RA-Sa-2009 [1].		
LAS-C3	Same as AS-C3.in ASME/ANS RA-Sa-2009 [1].		

3.2.3 Success Criteria (LSC)

The objectives and high level requirements of the Success Criteria Analysis for LPSD conditions are the same as those identified in the ASME/ANS PRA Standard (ASME/ANS RA-Sa-2009 [1]) and shall be accomplished for each POS.

3.2.3.1 Objectives

The objectives of the success criteria element are to define the plant-specific measures of success and failure that support the other technical elements of the PRA in such a way that

(a) overall success criteria are defined (i.e., core damage and large early release);
(b) success criteria are defined for critical safety functions, supporting systems, structures, components, and operator actions necessary to support accident sequence development;
(c) the methods and approaches have a firm technical basis;
(d) the resulting success criteria are referenced to the specific deterministic calculations.

Table 3.2.3-1 High Level Requirements for Success Criteria (LSC)

Designator	Requirement
HLR-LSC-A	The overall success criteria for the PRA and the system, structure, component, and human action success criteria used in the LPSD PRA shall be defined and referenced and shall be consistent with the features, procedures, and operating philosophy of the plant.
HLR-LSC-B	The thermal/hydraulic, structural, and other supporting engineering bases shall be capable of providing success criteria and event timing sufficient for quantification of CDF and LERF, determination of the relative impact of success criteria on SSC and human actions, and the impact of uncertainty on this determination.
HLR-LSC-C	Documentation of success criteria shall be consistent with the applicable supporting requirements.

Table 3.2.3-2(a) Supporting Requirements for HLR-LSC-A

The overall success criteria for the PRA and the system, structure, component, and human action success criteria used in the LPSD PRA shall be defined and referenced and shall be consistent with the features, procedures, and operating philosophy of the plant (HLR-LSC-A).

Index No. LSC-A	Capability Category I	Capability Category II	Capability Category III
LSC-A1	Same as SC-A1 in ASME/ANS RA-Sa-2009 [1].		
LSC-A2	Same as SC-A2 in ASME/ANS RA-Sa-2009 [1].	Same as SC-A2 in ASME/ANS RA-Sa-2009 [1].	
LSC-A2a	VERIFY that the plant parameters used in determining core damage (in LSC-A2) are appropriate for all plant operating states [see Note (1)].		
LSC-A3	Same as SC-A3 in ASME/ANS RA-Sa-2009 [1].		
LSC-A4	Same as SC-A4 in ASME/ANS RA-Sa-2009 [1].		
LSC-A5	Same as SC-A5 ASME/ANS RA-Sa-2009 [1].	Same as SC-A5 in ASME/ANS RA-Sa-2009 [1].	
LSC-A6	Same as SC-A6 in ASME/ANS RA-Sa-2009 [1].		

NOTE:
(1) The examples of core damage plant parameters in LSC-A2 may not be suitable for shutdown conditions. Specifically, the example of "collapsed liquid level below top of active fuel for a prolonged period" may be too conservative for plant states with the primary system depressurized and vented.

Table 3.2.3-2(b) Supporting Requirements for HLR-LSC-B

The thermal/hydraulic, structural, and other supporting engineering bases shall be capable of providing success criteria and event timing sufficient for quantification of CDF, determination of the relative impact of success criteria on the importance of the SSCs and human actions, and the impact of uncertainty on this determination (HLR-LSC-B).

Index No. LSC-B	**Capability Category I**	**Capability Category II**	**Capability Category III**
LSC-B1	USE appropriate **conservative** generic analyses/evaluations that are applicable to the plant. **For LPSD POSs, generic evaluations of decay heat using general power correlations are sufficient.**	USE appropriate generic analyses/evaluations that are applicable to the plant **for thermal/hydraulic, structural, and other supporting engineering bases in support of success criteria requiring detailed computer modeling** (see SC-B4). USE evolution-specific decay heat calculations for LPSD POSs. **JUSTIFY that the use of conservative, plant specific/or generic analysis is applicable to the plant and does not affect the determination of which combinations of systems and trains of systems are required to respond to an initiating event.**	**USE realistic plant-specific models for thermal/hydraulic, structural, and other supporting engineering bases in support of success criteria requiring detailed computer modeling (see LSC-B4)**. USE evolution-specific decay heat calculations for LPSD POSs.
LSC-B2	Same as SC-B2 in ASME/ANS RA-Sa-2009 [1].	Same as SC-B2 in ASME/ANS RA-Sa-2009 [1].	
LSC-B3	When defining success criteria, USE thermal/hydraulic, structural, or other analyses/evaluations appropriate to the POS definition and characterization as well as the event being analyzed and accounting for a level of detail consistent with the initiating event grouping (HLR-LIE-B) and accident sequence modeling (HLR-LAS-A and HLR-LAS-B). INCLUDE the effect of changes in decay heat level (HLR-LPOS-A) [see Note (1)].		
LSC-B4	Same as SC-B4 in ASME/ANS RA-Sa-2009 [1].		
LSC-B5	Same as SC-B5 in ASME/ANS RA-Sa-2009 [1].		

NOTE:
(1) Full power success criteria are not always bounding for LPSD conditions.

Table 3.2.3-2(c) Supporting Requirements for HLR-LSC-C

Documentation of success criteria shall be consistent with the applicable supporting requirements (HLR-LSC-C).

Index No. LSC-C	Capability Category I	Capability Category II	Capability Category III
LSC-C1	Same as SC-C1 in ASME/ANS RA-Sa-2009 [1].		
LSC-C2	Same as SC-C2 in ASME/ANS RA-Sa-2009 [1].		
LSC-C3	Same as SC-C3 in ASME/ANS RA-Sa-2009 [1].		

3.2.4 Systems Analysis (LSY)

The objectives and high level requirements of the Systems Analysis for LPSD conditions are the same as those identified in the ASME/ANS PRA Standard (ASME/ANS RA-Sa-2009 [1]) and shall be accomplished for each POS.

3.2.4.1 Objectives

The objectives of the systems analysis element are to identify and quantify the causes of failure for each plant system represented in the initiating event analysis and accident sequence analysis in such a way that

(a) system-level success criteria, mission times, time windows for operator actions, and assumptions provide the basis for the system logic models as reflected in the model, and a reasonably complete set of system failure and unavailability modes for each system is represented;
(b) human errors and operator actions that could influence the system unavailability or the system's contribution to accident sequences are identified for development as part of the HRA element;
(c) different initial system alignments are evaluated to the extent needed for CDF and LERF determination;
(d) intersystem dependencies and intra-system dependencies including functional, human, phenomenological, and common-cause failures that could influence system unavailability or the system's contribution to accident sequence frequencies are identified and accounted for.

Table 3.2.4-1 High Level Requirements for Systems Analysis (LSY)

Designator	Requirement
HLR-LSY-A	The systems analysis shall provide a reasonably complete treatment of the causes of system failure and unavailability modes represented in the initiating events analysis and sequence definition.
HLR-LSY-B	The systems analysis shall provide a reasonably complete treatment of common cause failures and intersystem and intra-system dependencies.
HLR-LSY-C	Documentation of the systems analysis shall be consistent with the applicable supporting requirements.

Table 3.2.4-2(a) Supporting Requirements for HLR-LSY-A

The systems analysis shall provide a reasonably complete treatment of the causes of system failure and unavailability modes represented in the initiating events analysis and sequence definition (HLR-LSY-A).

Index No. LSY-A	Capability Category I	Capability Category II	Capability Category III
LSY-A1	Same as SY-A1 in ASME/ANS RA-Sa-2009 [1].		
LSY-A2	Same as SY-A2 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].		
LSY-A3	REVIEW plant information sources to define or establish *(a)* system components and boundaries *(b)* dependencies on other systems *(c)* instrumentation and control requirements *(d)* testing and maintenance requirements and practices *(e)* operating limitations such as those imposed by Technical Specifications *(f)* component operability and design limits *(g)* procedures for the operation of the system during normal and accident conditions *(h)* system configuration during normal and accident conditions *(i)* for LPSD states, REVIEW past evolutions to determine unique system operating states (e.g., temporary power or cooling) that should be included in the sequence models		
LSY-A4	Same as SY-A4 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].	Same as SY-A4 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].	
LSY-A5	Same as SY-A5 in ASME/ANS RA-Sa-2009 [1] [see Note (3)].		
LSY-A6	Same as SY-A6 in ASME/ANS RA-Sa-2009 [1].		
LSY-A7	Same as SY-A7 in ASME/ANS RA-Sa-2009 [1].		Same as SY-A7 in ASME/ANS RA-Sa-2009 [1].
LSY-A8	Same as SY-A8 in ASME/ANS RA-Sa-2009 [1].		
LSY-A9	Same as SY-A9 in ASME/ANS RA-Sa-2009 [1].		
LSY-A10	INCLUDE the effect of variable success criteria (i.e., success criteria that change as a function of plant status) into the system modeling. Example causes of variable system success criteria are *(a)* different accident scenarios. Different success criteria are required for some systems to mitigate different accident scenarios (e.g., the number of pumps required to operate in some systems is dependent upon the modeled initiating event) *(b)* dependence on other components. Success criteria for some systems are also dependent on the success of another component in the system (e.g., operation of additional pumps in some cooling water systems is required if noncritical loads are not isolated) *(c)* time dependence. Success criteria for some systems are time-dependent (e.g., two pumps are required to provide the needed flow early following an accident initiator, but only one is required for mitigation later following the accident) *(d)* sharing of a system between units. Success criteria may be affected when both units are challenged by the same initiating event (e.g., LOOP) *(e)* varying decay heat levels during LPSD. Changing decay heat with time after shutdown and after fuel reload may affect system success criteria *(f)* variations in plant operating states. Varying plant operating states affect the time to core damage and the time available for system/component recovery		

Table 3.2.4-2(a) Supporting Requirements for HLR-LSY-A (Cont'd)

Index No. LSY-A	Capability Category I	Capability Category II	Capability Category III
LSY-A11	Same as SY-A11 in ASME/ANS RA-Sa-2009 [1].		
LSY-A12	Same as SY-A12 in ASME/ANS RA-Sa-2009 [1].		
LSY-A13	Same as SY-A13 in ASME/ANS RA-Sa-2009 [1] <u>[see Note (4)].</u>		
LSY-A14	Same as SY-A14 in ASME/ANS RA-Sa-2009 [1].		
LSY-A15	Same as SY-A15 in ASME/ANS RA-Sa-2009 [1].		
LSY-A16	Same as SY-A16 in ASME/ANS RA-Sa-2009 [1]		Same as SY-A16 in ASME/ANS RA-Sa-2009 [1].
LSY-A17	In the system model, INCLUDE HFEs that are expected during the operation of the system or component or that are accounted for in the final quantification of accident sequences unless they are already included explicitly as events in the accident sequence models. These HFEs are referred to as post-initiator human actions [see also Human Reliability Analysis (3-2.5) and Accident Sequence Analysis (3-2.2)]. <u>During LPSD conditions, INCLUDE any additional human failure events (HFEs) expected due to the different POSs.</u>		
LSY-A18	INCLUDE in either the system model or accident sequence modeling those conditions that cause the system to isolate or trip or those conditions that, once exceeded, cause the system to fail; alternatively, DEMONSTRATE that their exclusion does not impact the results. For example, conditions that isolate or trip a system include *(a)* system-related parameters such as a high temperature within the system *(b)* external parameters used to protect the system from other failures (e.g., the low-flow trip of a residual heat removal pump of a PWR) *(c)* adverse environmental conditions (see LSY-A22)		
LSY-A19	In the systems model, unless screened out, INCLUDE out-of-service unavailability for components in the system model in a manner consistent with the actual practices and history of the plant for removing equipment from service. *(a)* INCLUDE *(1)* unavailability caused by testing when a component or system train is reconfigured from its required accident mitigating position such that the component cannot function as required *(2)* maintenance events at the train level when procedures require isolating the entire train for maintenance *(3)* maintenance events at a sub-train level (i.e., between tagout boundaries such as a functional equipment group) when directed by procedures *(b)* Examples of out-of-service unavailability to be modeled are as follows: *(1)* train outages during a work window for preventive/corrective maintenance *(2)* a functional equipment group (FEG) removed from service for preventive/corrective maintenance *(3)* a relief valve taken out of service *(4)* Equipment removed from service during a preceding POS *(c)* <u>Examples of out-of-service unavailability to be modeled during shutdown conditions are as follows:</u> (1) <u>equipment intentionally taken out of service due to plant conditions (e.g., high-pressure injection (PWR) with low reactor vessel pressure, automatic actuation of safety equipment)</u> (2) <u>equipment that will not function given plant conditions (e.g., steam-driven pumps at low reactor temperatures)</u> (3) <u>planned maintenance configurations and test alignments during the shutdown [see Note (5)]</u>		

Table 3.2.4-2(a) Supporting Requirements for HLR-LSY-A (Cont'd)

Index No. LSY-A	Capability Category I	Capability Category II	Capability Category III
LSY-A20	Same as SY-A20 in ASME/ANS RA-Sa-2009 [1].		
LSY-A21	IDENTIFY system conditions that cause a loss of desired system function (e.g., excessive heat loads, excessive electrical loads, excessive humidity, etc. and, during LPSD, low SG pressure, low RCS level, or low RCS pressure).		
LSY-A22	Same as SY-A22 in ASME/ANS RA-Sa-2009 [1] [see Note (6)].	Same as SY-A22 in ASME/ANS RA-Sa-2009 [1] [see Note (6)].	Same as SY-A22 in ASME/ANS RA-Sa-2009 [1] [see Note (6)].
LSY-A23	Same as SY-A23 in ASME/ANS RA-Sa-2009 [1].		
LSY-A24	Same as SY-A24 in ASME/ANS RA-Sa-2009 [1] [see Note (7)].		

NOTES:
(1) For LPSD states, look for evolution-specific planning guides, temporary system alignments, shutdown operating procedures, etc.
(2) Some systems and alignments applicable to shutdown conditions may not have been modeled in the full power PRA.
(3) Many systems are re-aligned, tagged out, have their automatic functions disabled, etc. in the process of going into an outage.
(4) Unusual system alignments and infrequent operations such as drain-down increase the potential for flow diversion pathways during shutdown conditions.
(5) The capability to remove differing sets of SSCs for maintenance and testing is a unique characteristic of shutdown conditions. In some cases, due to the changes in maintenance configurations, additional POSs may need to be defined.
(6) During shutdown, cavitation of a shutdown cooling/residual heat removal pump is possible due to changes in vessel level. For Capability Category II or Capability Category III, credit for pump operability may be allowed if supported by plant abnormal procedures and engineering or vendor evaluations.
(7) In some shutdown cases where relatively long times are available before core damage, more credit for restoration of equipment could be feasible than for full power models. EPRI TR-113051 [10], and EPRI 1021176 [8] provide information and analysis that may support equipment recovery.

Table 3.2.4-2(b) Supporting Requirements for HLR-LSY-B

The systems analysis shall provide a reasonably complete treatment of common cause failures and intersystem and intra-system dependencies (HLR-LSY-B).

Index No. LSY-B	Capability Category I	Capability Category II	Capability Category III
LSY-B1	Same as SY-B1 in ASME/ANS RA-Sa-2009 [1].	Same as SY-B1 in ASME/ANS RA-Sa-2009 [1].	
LSY-B2	Same as SY-B2 in ASME/ANS RA-Sa-2009 [1]. No requirement to model inter-system common cause failures.		Same as SY-B2 in ASME/ANS RA-Sa-2009 [1].

Table 3.2.4-2(b) Supporting Requirements for HLR-LSY-B (Cont'd)

Index No. LSY-B	Capability Category I	Capability Category II	Capability Category III
LSY-B3	Same as SY-B3 in ASME/ANS RA-Sa-2009 [1].		
LSY-B4	Same as SY-B4 in ASME/ANS RA-Sa-2009 [1].		
LSY-B5	Same as SY-B5 in ASME/ANS RA-Sa-2009 [1].		
LSY-B6	Same as SY-B6 in ASME/ANS RA-Sa-2009 [1].		
LSY-B7	Same as SY-B7 in ASME/ANS RA-Sa-2009 [1].	Same as SY-B7 in ASME/ANS RA-Sa-2009 [1].	Same as SY-B7 in ASME/ANS RA-Sa-2009 [1].
LSY-B8	IDENTIFY spatial and environmental hazards that may impact multiple systems or redundant components in the same system and INCLUDE them in the system fault tree or the accident sequence evaluation. For each shutdown, IDENTIFY temporary conditions that may affect the ability of the modeled systems to respond to an initiating event, and INCLUDE the effect of the temporary condition on the operation of the system in the system model for the duration of the temporary condition. Example: Use results of plant walkdowns as a source of information regarding spatial/environmental hazards, for resolution of spatial/environmental issues, or evaluation of the impacts of such hazards. LPSD examples of these temporary conditions include the removal of flood, ventilation, or fire barriers or the installation and removal of scaffolding or temporary shielding [see Note (1)].		
LSY-B9	Same as SY-B9 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].		
LSY-B10	Same as SY-B10 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].	Same as SY-B10 in ASME/ANS RA-Sa-2009 [1] [see Note (3)].	
LSY-B11	Same as SY-B11 in ASME/ANS RA-Sa-2009 [1] [see Note (3)].		
LSY-B12	Same as SY-B12 in ASME/ANS RA-Sa-2009 [1].		
LSY-B13	Same as SY-B13 in ASME/ANS RA-Sa-2009 [1].		
LSY-B14	Same as SY-B14 in ASME/ANS RA-Sa-2009 [1] [see Note (4)].		
LSY-B15	Same as SY-B15 in ASME/ANS RA-Sa-2009 [1].		

NOTES:
(1) The removal of a flood barrier as part of a maintenance activity may affect the ability of a modeled system or component to successfully perform its function in the event of an internal or external flooding event. These conditions are not typically included in a full power PRA but are a consideration for modeling of shutdown conditions.
(2) For LPSD analyses, actuation signals sometimes vary by POS or might not be present.
(3) Inventories of air, cooling, and other services may be different in different POSs.
(4) During plant shutdown, unusual or temporary system alignments may create conditions whereby plant equipment is exposed to environments not considered for power operation.

Table 3.2.4-2(c) Supporting Requirements for HLR-LSY-C

Documentation of the systems analysis shall be consistent with the applicable supporting requirements (HLR-LSY-C).

Index No. LSY-C	Capability Category I	Capability Category II	Capability Category III
LSY-C1	Same as SY-C1 in ASME/ANS RA-Sa-2009 [1].		
LSY-C2	Same as SY-C2 in ASME/ANS RA-Sa-2009 [1].		
LSY-C3	Same as SY-C3 in ASME/ANS RA-Sa-2009 [1].		

3.2.5 Human Reliability Analysis (LHR)[9]

3.2.5.1 Objectives

The objective of the human reliability element of the LPSD PRA is to ensure that the impacts of plant personnel actions are reflected in the assessment of risk for each POS or group of POSs in such a way that

- *(a)* pre-initiating event activities, at-initiating event activities, and post-initiating event activities, including those modeled in support system initiating event fault trees, are addressed;
- *(b)* logic model elements are defined to represent the effect of such personnel actions on initiating events, system availability/unavailability, and accident sequence development;
- *(c)* plant-specific and scenario-specific factors are accounted for, including those factors that influence either what activities are of interest or human performance;
- *(d)* human performance issues are addressed in an integral way so that issues of dependency are captured.

The requirements for human-induced initiating events resulting from at-initiating event activities were not considered necessary for full power PRA in ASME/ANS RA-Sa-2009 [1]. This is primarily because for full power activities, it is assumed that human caused errors are included in the data for the more common initiating events and are included as response actions in fault trees representing support system initiators. Further, it is assumed that the dependencies between at-initiating event actions and post-initiating event actions for full power scenarios are not significant. However, for LPSD evolutions, significant contributions to risk may come from at-initiating event activities, e.g., over draining. In addition, the dependencies between at-initiating event actions and post-initiating event actions may be more significant that full power scenarios and thus need to be considered for shutdown conditions. For these reasons, high level and supporting requirements are also identified for such events.

9 Reference [11] provides useful background information for human reliability analysis: D. J. Wakefield, G. W. Parry, G. W. Hannaman, A. J. Spurgin, "Sharp 1 – Revised Systematic Human Action Reliability Procedure," EPRI Report TR-101711-T2, March, 1993.

Table 3.2.5-1 High Level Requirements for Human Reliability Analysis (LHR)

Designator	Requirement
Pre-Initiator HRA	
HLR-LHR-A	A systematic process shall be used to identify those specific routine activities in each POS that, if not completed correctly, may impact the availability of equipment necessary to perform system function modeling in the LPSD PRA.
HLR-LHR-B	Screening of activities that need not be addressed explicitly in the model shall be based on an assessment of how plant-specific operational practices limit the likelihood of errors in such activities.
HLR-LHR-C	For each activity that is not screened out, an appropriate human failure event (HFE) shall be defined for each applicable POS to characterize the impact of the failure as an unavailability of a component, system, or function modeled in the LPSD PRA.
HLR-LHR-D	The assessment of the probabilities of the pre-initiator human failure events shall be performed by using a systematic process that addresses the plant-specific and activity-specific influences on human performance.
Post-Initiator HRA	
HLR-LHR-E	A systematic review of the relevant procedures and past operational events shall be used to identify the set of operator responses required for each of the accident sequences
HLR-LHR-F	Human failure events shall be defined for each POS that represent the impact of not properly performing the required responses, consistent with the structure and level of detail of the accident sequences.
HLR-LHR-G	The assessment of the probabilities of the post-initiator HFEs shall be performed using a well-defined and self-consistent process that addresses the plant-specific and scenario-specific influences on human performance and addresses potential dependencies between human failure events in the same accident sequence.
HLR-LHR-H	Recovery actions (at the cut set or scenario level) shall be modeled only if it has been demonstrated that the action is plausible and feasible for those scenarios to which they are applied. Estimates of probabilities of failure shall address dependency on prior human failures in the scenario.

Table 3.2.5-1 High Level Requirements for Human Reliability Analysis (LHR) (Cont'd)

Designator	Requirement
At-Initiator HRA	
HLR-LHR-I	A systematic process shall be used to identify routine test activities, maintenance activities, and activities needed to execute LPSD evolutions for each POS that could result in initiating events if incorrectly carried out.
HLR-LHR-J	For each POS, the identified at-initiator human failure events shall be grouped so that events in the same group have similar mitigation requirements to facilitate an efficient but realistic estimation of CDF.
HLR-LHR-K	The assessment shall estimate the annual frequency of initiating events or initiating event groups made up of at-initiator human failure events.
HLR-LHR-L	Human failure events shall be defined to represent failure of a critical activity that leads to or contributes to an initiating event.
Pre-, At-, and Post-Initiator HRA	
HLR-LHR-M	Documentation of the human reliability analysis shall be consistent with the applicable supporting requirements (HLR-LHR-M).

Table 3.2.5-2(a) Supporting Requirements for HLR-LHR-A

Pre-Initiator HRA: A systematic process shall be used to identify those specific routine activities in each POS that, if not completed correctly, may impact the availability of equipment necessary to perform system function modeling in the LPSD PRA (HLR-LHR-A).

Index No. LHR-A	Capability Category I	Capability Category II	Capability Category III
LHR-A1	For equipment and POSs modeled in the *LPSD PRA*, IDENTIFY, through a review of procedures, plant practices and industry operating experience, LPSD evolution activities and test and maintenance activities that require realignment of equipment or a control system outside its normal operational or standby status [see Note (1)]. SELECT a representative schedule for each evolution type for a list of test and maintenance activities to consider.	For equipment and POSs modeled in the LPSD PRA, IDENTIFY, through a review of procedures, plant practices and industry operating experience, LPSD evolution activities and test and maintenance activities that require realignment of equipment or a control system outside its normal operational or standby status [see Note (1)]. SELECT the routinely implemented test and maintenance activities from several schedules for each evolution type to consider.	

Table 3.2.5-2(a) Supporting Requirements for HLR-LHR-A (Cont'd)

Index No. LHR-A	Capability Category I	Capability Category II	Capability Category III
LHR-A2	For equipment and POSs modeled in the LPSD PRA, IDENTIFY, through a review of procedures, and practices, and industry operating experience, those calibration activities that, if performed incorrectly, can have an adverse impact on the automatic initiation of standby safety equipment. SELECT a representative schedule for each evolution type for a list of calibration activities to consider.	For equipment and POSs modeled in the LPSD PRA, IDENTIFY, through a review of procedures, plant practices, and industry operating experience, those calibration activities that, if performed incorrectly, can have an adverse impact on the automatic initiation of standby safety equipment. SELECT several schedules for each evolution type for a list of calibration activities to consider.	
LHR-A2a	No requirement for evaluating impact on indications to operators.	**IDENTIFY, through a review of procedures, plant practices, and industry operating experience, those activities that, if performed incorrectly, can have an adverse impact on the RCS level indications relied on by the operators as cues for manual actuation.**	IDENTIFY, through a review of procedures, plant practices, and industry operating experience, those activities that, if performed incorrectly, can have an adverse impact on the **indications** relied on by the operators (see LHR-G3) as cues for manual actuation.
LHR-A3	IDENTIFY the work practices identified above (LHR-A1, LHR-A2, and LHR-A2a) that involve a mechanism that simultaneously affects equipment in either different trains of a redundant system or diverse systems or in multiple systems when there is only one train available in each system [e.g., use of common calibration equipment by the same crew on the same shift, a maintenance or test activity that requires realignment of an entire system (e.g., SLCS), or testing that affects multiple systems (e.g., ECCS testing, or load sequencer testing)].		

Table 3.2.5-2(b) Supporting Requirements for HLR-LHR-B

Pre-Initiator HRA: Screening of activities that need not be addressed explicitly in the model shall be based on an assessment of how plant-specific operational practices limit the likelihood of errors in such activities (HLR-LHR-B).

Index No. LHR-B	Capability Category I	Capability Category II	Capability Category III
LHR-B1	If screening is performed, ESTABLISH rules for screening **classes** of activities from further consideration and SCREEN OUT on a POS-by-POS basis. Example: Screen maintenance and test activities from further consideration only if **the plant practices are generally structured to include independent checking of restoration of equipment to standby or operational status on completion of the activity.**	If screening is performed, ESTABLISH rules for screening individual activities from further consideration and SCREEN OUT on a POS-by-POS basis. Example: Screen maintenance and test **activities** from further consideration only if *(a)* **equipment is automatically re-aligned on system demand; or** *(b)* **following maintenance activities, a post-maintenance functional test is performed that reveals misalignment; or** *(c)* **equipment position is indicated in the control room, status is routinely checked, and realignment can be affected from the control room; or** *(d)* **equipment status is required to be checked frequently (i.e., at least once a shift)**	
LHR-B2	DO NOT SCREEN OUT activities that could simultaneously have an impact on multiple trains of a redundant system, on diverse systems (LHR-A3), or on multiple systems within the same protected train (i.e., when it is the only train available).		
LHR-B3	DO NOT SCREEN OUT otherwise unscreened activities from applicability to subsequent POSs unless any related HFE would be detected by administrative controls before transitioning from the POS where the activity takes place to subsequent POSs where the HFE would impact risk.		

Table 3.2.5-2(c) Supporting Requirements for HLR-LHR-C

Pre-Initiator HRA: For each activity that is not screened out, an appropriate human failure event (HFE) shall be defined for the applicable POS to characterize the impact of the failure as an unavailability of a component, system, or function modeled in the LPSD PRA (HLR-LHR-C).

Index No. LHR-C	Capability Category I	Capability Category II	Capability Category III
LHR-C1	For each unscreened activity, DEFINE a human failure event (HFE) that represents the impact of the human failure at the appropriate level (i.e., function, system, train, or component affected).		
LHR-C1a	For each unscreened activity, IDENTIFY the average time to detection of the failure considering administrative practices and whether the detection time extends to subsequent POSs.		
LHR-C2	Same as HR-C2 in ASME/ANS RA-Sa-2009 [1].	Same as HR-C2 in ASME/ANS RA-Sa-2009 [1].	
LHR-C3	INCLUDE the impact of miscalibration on operator performance and as a mode of failure of the automatic initiation of standby systems.		

Table 3.2.5-2(d) Supporting Requirements for HLR-LHR-D

Pre-Initiator HRA: The assessment of the probabilities of the pre-initiator human failure events shall be performed by using a systematic process that addresses the plant-specific and activity-specific influences on human performance (HLR-LHR-D).

Index No. LHR-D	Capability Category I	Capability Category II	Capability Category III
LHR-D1	Same as HR-D1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].		
LHR-D2	USE **screening estimates** in the quantification of the pre-initiator HEPs.	**For significant basic events that are also HFEs, USE detailed assessments** in the quantification of pre-initiator HEPs. **USE screening values based on a simple model such as ASEP [12] in the quantification of the pre-initiator HEPs for non-significant basic events.** When bounding values are used, ENSURE they are based on limiting cases from models such as ASEP **[12].**	USE **detailed assessments** in the quantification of pre-initiator HEPs for **each system.**

Table 3.2.5-2(d) Supporting Requirements for HLR-LHR-D (Cont'd)

Index No. LHR-D	**Capability Category I**	**Capability Category I**	**Capability Category III**
LHR-D3	Same as HR-D3 in ASME/ANS RA-Sa-2009 [1]. No requirement for evaluating the quality of written procedures, administrative controls, or human-machine interface.	For each detailed human error probability assessment, INCLUDE in the evaluation process the following plant-specific relevant information: *(a)* the quality of written procedures (for performing tasks) and administrative controls (for independent review) *(b)* the quality of the human-machine interface, including both the equipment configuration, and instrumentation and control layout *(c)* familiarity of the work teams with the written procedures	
LHR-D4	Same as HR-D4 in ASME/ANS RA-Sa-2009 [1].		
LHR-D5	ESTIMATE the joint probability of those pre-initiator HFEs within the same POS, identified as having some degree of dependency (i.e., having some common elements in their causes,, such as performed by the same crew in the same time - frame).		ESTIMATE the joint probability of those pre-initiator HFEs identified as having some degree of dependency, **even if performed in different POSs** (i.e., having some common elements in their causes, such as performed by the same crew in the same time - frame).
LHR-D6	Same as HR-D6 in ASME/ANS RA-Sa-2009 [1].		
LHR-D7	Same as HR-D6 in ASME/ANS RA-Sa-2009 [1]. No requirement to check the reasonableness of the HEPs in light of the plant's experience.	**ENSURE the reasonableness of the HEPs in light of the plant's experience**	

Table 3.2.5-2(e) Supporting Requirements for HLR-LHR-E

Post-Initiator HRA: A systematic review of the relevant procedures and past operational events shall be used to identify the set of operator responses required for each of the accident sequences (HLR-LHR-E).

Index No. LHR-E	Capability Category I	Capability Category II	Capability Category III
LHR-E1	When identifying the key human response actions REVIEW *(a)* the plant-specific emergency operating procedures and other relevant procedures (e.g., AOPs, annunciator response procedures) in the context of the accident scenarios and applicable POSs *(b)* system operation such that an understanding of how the system(s) function(s) and the human interfaces with the system(s) are obtained *(c)* past operational events (both for the specific plant and in industry) to assist the analyst in identifying the kinds of activities that have resulted in operator recovery actions		
LHR-E2	Same as HR-E2 in ASME/ANS RA-Sa-2009 [1].		
LHR-E3	Same as HR-E3 in ASME/ANS RA-Sa-2009 [1].	Same as HR-E3 in ASME/ANS RA-Sa-2009 [1].	
LHR-E4	Same as HR-E4 in ASME/ANS RA-Sa-2009 [1].	Same as HR-E4 in ASME/ANS RA-Sa-2009 [1].	

Table 3.2.5-2(f) Supporting Requirements for HLR-LHR-F

Post-Initiator HRA: Human failure events shall be defined for each POS that represent the impact of not properly performing the required responses, consistent with the structure and level of detail of the accident sequences (HLR-LHR-F).

Index No. LHR-F	Capability Category I	Capability Category II	Capability Category III
LHR-F1	Same as HR-F1 in ASME/ANS RA-Sa-2009 [1].		Same as HR-F1 in ASME/ANS RA-Sa-2009 [1].
LHR-F2	Same as HR-F2 in ASME/ANS RA-Sa-2009 [1].	Same as HR-F2 in ASME/ANS RA-Sa-2009 [1].	Same as HR-F2 in ASME/ANS RA-Sa-2009 [1].
LHR-F3	GROUP the same HFEs in different POSs across those POSs **only when** the HFE impacts and boundary conditions for the limiting POS are used.	GROUP the same HFEs in different POSs **for those POSs only when the HFE impacts and boundary conditions are the same, or if the HFEs are not risk significant, and the HFE impacts and boundary conditions of the limiting POS for the group are used to represent the group**.	GROUP the same HFEs in different POSs for those POSs **only when** the HFE impacts and boundary conditions are the same**. HFEs with the same impacts but with different boundary conditions in different POSs may not be grouped.**

Table 3.2.5-2(g) Supporting Requirements for HLR-LHR-G

Post-Initiator HRA: The assessment of the probabilities of the post-initiator HFEs shall be performed using a well-defined and self-consistent process that addresses the plant-specific and scenario-specific influences on human performance and addresses potential dependencies between human failure events in the same accident sequence (HLR-LHR-G).

Index No. LHR-G	Capability Category I	Capability Category II	Capability Category III
LHR-G1	Same as HR-G1 in ASME/ANS RA-Sa-2009 [1].	Same as HR-G1 in ASME/ANS RA-Sa-2009 [1].	Same as HR-G1 in ASME/ANS RA-Sa-2009 [1].
LHR-G2	Same as HR-G2 in ASME/ANS RA-Sa-2009 [1].		
LHR-G3	Same as HR-G3 in ASME/ANS RA-Sa-2009 [1].	**When estimating HEPs, EVALUATE the impact of the following plant-specific and scenario-specific performance shaping factors:** *(a)* **quality [type (classroom or simulator) and frequency] of the operator training or experience, including training performed just prior to complex evolutions** *(b)* **quality of the written procedures and administrative controls for the applicable POSs** *(c)* **availability of instrumentation needed to take corrective actions (see also LHR-C3 and LHR-D7)** *(d)* **degree of clarity of cues/indications** *(e)* **human-machine interface** *(f)* time available and time required to complete the response *(g)* complexity of the required response *(h)* **environment (e.g., lighting, heat, radiation) under which the operator is working** *(i)* **accessibility of the equipment requiring manipulation** *(j)* **necessity, adequacy, and availability of special tools, parts, clothing, etc.** *(k)* **distractions caused by parallel tests and maintenance activities and LPSD evolution tasks**	
LHR-G3a	No requirement to consider the reliability of RCS level indications.	**When estimating HEPs, EVALUATE the impact of RCS level indication availability needed to take corrective actions consistent with LHR-A2a.**	When estimating HEPs, EVALUATE the impact of **indication** availability needed to take corrective actions consistent with LHR-A2a.

Table 3.2.5-2(g) Supporting Requirements for HLR-LHR-G (Cont'd)

<table>
<tr><th>Index No. LHR-G</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td>LHR-G4</td><td>For each applicable POS, BASE the time available to complete actions on applicable generic studies (e.g., thermal/hydraulic analysis for similar plants). SPECIFY the point in time at which operators are expected to receive relevant indications.</td><td>For each applicable POS, BASE the time available to complete actions on appropriate realistic generic thermal/hydraulic analyses or simulation from similar plants (e.g., plant of similar design and operation). SPECIFY the point in time at which operators are expected to receive relevant indications.</td><td>For each applicable POS, BASE the time available to complete actions on plant-specific thermal/hydraulic analysis or simulations. SPECIFY the point in time at which operators are expected to receive relevant indications.</td></tr>
<tr><td>LHR-G5</td><td>Same as HR-G5 in ASME/ANS RA-Sa-2009 [1].</td><td>Same as HR-G5 in ASME/ANS RA-Sa-2009 [1].</td><td>Same as HR-G5 in ASME/ANS RA-Sa-2009 [1].</td></tr>
<tr><td>LHR-G6</td><td colspan="3">Same as HR-G6 in ASME/ANS RA-Sa-2009 [1].</td></tr>
<tr><td>LHR-G7</td><td colspan="3">For multiple human actions in the same accident sequence or cut set (i.e., including pre-initiator, at-initiator, and post-initiator HFEs including recovery actions as per LHR-H3) identified in accordance with Supporting Requirement LQU-C1, EVALUATE the degree of dependence and calculate a joint human error probability that reflects the dependence for each POS, as applicable. INCLUDE the influence of success or failure in preceding human actions and system performance on the human event under consideration, including as a minimum:
(a) time required to complete all actions in relation to the time available to perform the actions
(b) factors that could lead to dependence (e.g., common instrumentation, common procedures, increased stress, command and control of local activities, etc.)
(c) availability of resources (e.g., personnel) [see Note 1]</td></tr>
<tr><td>LHR-G8</td><td colspan="3">Same as HR-G8 in ASME/ANS RA-Sa-2009 [1].</td></tr>
</table>

NOTE:

(1) The state of the art in HRA is such that the assessment of dependency is largely based on the analyst's judgment. While it is expected that there will be a progressively more detailed treatment of dependency when moving from Capability Categories I to III, the distinction is not made at the level of this SR. Instead, it is expected to follow from the increase in the level of detail in the analysis of HFEs in going from Capability Categories I to III.

Table 3.2.5-2(h) Supporting Requirements for HLR-LHR-H

Post-Initiator HRA: Recovery actions at the cut set or scenario level shall be modeled only if it has been demonstrated that the action is plausible and feasible for those scenarios to which they are applied. Estimates of probabilities of failure shall address dependency on prior human failures in the scenario (HLR-LHR-H) [see Note (1)].

Index No. LHR-H	Capability Category I	Capability Category II	Capability Category III
LHR-H1	Same as HR-H1 in ASME/ANS RA-Sa-2009 [1].	Same as HR-H1 in ASME/ANS RA-Sa-2009 [1].	Same as HR-H1 in ASME/ANS RA-Sa-2009 [1].
LHR-H2	INCLUDE operator recovery actions only if, on a plant-specific basis: *(a)* a procedure is available, and operator training has included the action as part of crew's training, or justification for the omission for one or both is provided (e.g., justified because recovery is feasible, and there is much more time available than required for recovery) *(b)* "cues" (e.g., alarms) that alert the operator to the recovery action provided procedure, training, or skill of the craft exist *(c)* attention is given to the relevant performance shaping factors provided in LHR-G3 *(d)* there is sufficient manpower to perform the action		
LHR-H3	Same as HR-H3 in ASME/ANS RA-Sa-2009 [1].		

NOTE:
(1) Recovery actions are actions taken in addition to those normally identified in the review of emergency, abnormal, and system operation procedures, which would normally be addressed in LHR-E through LHR-G. They are included to allow credit for recovery from failures in cut sets or scenarios when failure to take credit would distort the insights from the risk analysis. The potential for recovery (e.g., manually opening a valve that failed to open automatically) may well differ between scenarios, POSs, or cut sets. In this context, recovery is associated with a work-around but does not include repair, which is addressed in LSY-A22 and LDA-C14.

Table 3.2.5-2(i) Supporting Requirements for HLR-LHR-I

At-Initiator HRA: A systematic process shall be used to identify routine test activities, maintenance activities, and activities needed to execute LPSD evolutions for each POS that could result in initiating events if incorrectly carried out (HLR-LHR-I).

Index No. LHR-I	**Capability Category I**	**Capability Category II**	**Capability Category III**
LHR-I1	REVIEW generic analyses for all POSs for similar plants to assess whether the list of initiating events caused by at-initiator HFEs included in the model accounts for industry experience. In particular, IDENTIFY any cases where at-initiator human failure events impact later human responses [see Note (1)].	REVIEW **operating experience** for all POSs for the modeled plant and for similar plants, including generic analyses of similar plants, to assess whether the list of initiating events caused by at-initiator HFEs included in the model accounts for industry experience. In particular, IDENTIFY any cases where at-initiator human failure events impact later human responses [see Note (1)].	
LHR-I2	For equipment and POSs modeled in the *LPSD PRA*, INCLUDE in the modeling of support system initiating fault trees (see LIE-C8) the contribution of HFEs during test, maintenance, and other LPSD evolution leading to the initiating event, or PROVIDE the basis for exclusion.		
LHR-I3	INCLUDE the identified at-initiator human failure events as separate initiators from the associated hardware failures if adverse dependencies between the at-initiator human failure event and post-initiator human failures are identified (see HLR-G7).		INCLUDE the identified at-initiator human failure events as separate initiators from the associated hardware failures.

NOTE:
(1) A useful reference for identifying initiating events during shutdown is EPRI 1021176 [8].

Table 3.2.5-2(j) Supporting Requirements for HLR-LHR-J

At-Initiator HRA: For each POS, the identified at-initiator human failure events shall be grouped so that events in the same group have similar mitigation requirements to facilitate an efficient but realistic estimation of CDF (HLR-LHR-J).

Index No. LHR-J	**Capability Category I**	**Capability Category II**	**Capability Category III**
LHR-J1	For each POS, GROUP at-initiator human failure events into initiating event groups to facilitate definition of accident sequences (Subsection 3.2.2) and to facilitate sequence quantification (Subsection 3.2.7).		
LHR-J2	GROUP at-initiator human failure events that are applicable to the same POSs only when the following can be assured: *(a)* events can be considered similar in terms of plant response, success criteria, timing, and the effect on the operability and performance of operators and relevant mitigating systems; OR *(b)* events can be subsumed into a group and bounded by the worst case impacts within the "new" group	GROUP at-initiator human failure events that are applicable to the same POSs only when the following can be assured: *(a)* events can be considered similar in terms of plant response, success criteria, timing, and the effect on the operability and performance of operators and relevant mitigating systems; OR *(b)* events can be subsumed into a group and bounded by the worst case impacts within the "new" group **DO NOT SUBSUME events into a group unless** **(1) the impacts are comparable to or less than those of the remaining events in that group; AND** **(2) it is demonstrated that such grouping does not impact significant accident sequences**	GROUP at-initiator human failure events that are applicable to the same POSs only when the following can be assured: *(a)* events can be considered similar in terms of plant response, success criteria, timing, and the effect on the operability and performance of operators and relevant mitigating systems; OR *(b)* events can be subsumed into a group and bounded by the worst case impacts within the "new" group **DO NOT SUBSUME events into a group unless the impacts are comparable to those of the remaining events in that group.**
LHR-J3	GROUP separately from other initiating events those events with different plant response (i.e., those with different success criteria) impacts or those that could have more severe radionuclide release potential (e.g., based on the time after shutdown that the event occurs and containment closure status).		

Table 3.2.5-2(j) Supporting Requirements for HLR-LHR-J (Cont'd)

Index No. LHR-J	Capability Category I	Capability Category II	Capability Category III
LHR-J4	DO NOT GROUP at-initiator human failure events together with hardware failures that otherwise would meet the requirements of LHR-J2, so as to allow proper accounting of dependencies between human failure events.		
LHR-J5	For multi-unit sites with shared systems, DO NOT SUBSUME multi-unit at-initiator human failure events into initiating event groups if they impact mitigation capability differently.		

Table 3.2.5-2(k) Supporting Requirements for HLR-LHR-K

At-Initiator HRA: The assessment shall estimate the annual frequency of initiating events or initiating event groups made up of at-initiator human failure events (HLR-LHR-K) [see Note (1)].

Index No. LHR-K	Capability Category I	Capability Category II	Capability Category III
LHR-K1	For at-initiator human failure events, ESTIMATE the HEPs conditional on the occurrence of the activity using a systematic process consistent with the requirements of LHR-D, LHR-F, and LHR-G, as appropriate, or using expert judgment (see Section 1.4.3).		
LHR-K1a	For at-initiator human failure events, ESTIMATE the frequency of the associated activity.		
LHR-K2	No requirement to consider the impact of reliability of RCS level indications on HEPs.	**When estimating HEPs, EVALUATE the impact of RCS-level indication availability for success of the activity consistent with LHR-A2a.**	**When estimating HEPs, EVALUATE the impact of indication availability for success of the activity consistent with LHR-A2a.**
LHR-K3	For at-initiator HFEs associated with test and maintenance activities and LPSD evolution activities, USE screening estimates in the quantification of the HEPs conditional on the occurrence of the activity.	**For significant basic events that are also HFEs associated with test and maintenance activities and LPSD evolution activities, USE detailed assessments in the quantification of HEPs conditional on the occurrence of the associated activity. USE screening values based on a simple model such as ASEP [12] in the quantification of HEPs for non-significant basic events that are also HFEs involving test or maintenance.**	**For at-initiator HFEs associated with test and maintenance activities and LPSD evolution activities, USE detailed assessments in the quantification of HEPs conditional on the occurrence of the associated activity.**

Table 3.2.5-2(k) Supporting Requirements for HLR-LHR-K (Cont'd)

Index No. LHR-K	Capability Category I	Capability Category II	Capability Category III
LHR-K4	ESTIMATE the joint HEP of those at-initiator HFEs if multiple HFEs are needed to cause the initiating event per the requirements of LHR-G7 (see LHR-I3).		
LHR-K5	CALCULATE initiating event frequencies for at-initiator human failure events for each applicable POS on a per calendar year basis considering the frequency of the activities being performed and the HEPs for the HFE and any opportunities for recovery. Specifically, for each applicable POS, INCLUDE in the initiating event frequency analysis for the frequency in an average year that each POS is entered and hence how frequently each such at-initiator activity is challenged.		
LHR-K6	As screening criteria for at-initiator HFE-caused initiating events, USE no higher than the following characteristics to eliminate initiating events or initiating event groups from further evaluation: *(a)* the frequency of the event summed over the times of all applicable POSs is less than 1×10^{-7} per reactor year (/yr.), and the event does not involve either an ISLOCA, containment bypass, reactor vessel rupture, or an initiating event with the reactor coolant system vented and containment unisolated; *(b)* the frequency of the event summed over the times of all applicable POSs is less than 1×10^{-6} /yr., and core damage could not occur unless at least two trains of mitigating systems are failed independent of the initiator; or *(c)* for POSs at low power conditions, the resulting reactor shutdown is not an immediate occurrence; that is, the event does not require the plant to go to shutdown conditions until sufficient time has expired during which the initiating event conditions, with a high degree of certainty (based on supporting calculations), are detected and corrected before normal plant operation is curtailed (either administratively or automatically) [See Note (2)].		
LHR-K7	ENSURE the consistency of the quantification for the at-initiator HEPs. REVIEW the HFEs, associated HEPs, and their final initiating event frequencies relative to each other to check their reasonableness given the procedures, operating practices, plant history, and experience.		
LHR-K8	CHARACTERIZE the uncertainty in the initiating event frequencies for at-initiator HFEs in a manner consistent with the quantification approach and CALCULATE mean values for use in the quantification of the LPSD PRA results.		

NOTES:

(1) A useful reference for initiating event frequencies during shutdown is EPRI 1021176 [8].

(2) It is important to account for whether the failure being represented can occur during the POS under consideration. A procedural event tree where the top events represent operator actions within the governing LPSD evolution procedures [9] may also be used.

Table 3.2.5-2(l) Supporting Requirements for HLR-LHR-L

At-Initiator HRA: Human failure events shall be defined to represent a failure of a critical activity that leads to or contributes to an initiating event (HLR-LHR-L).

Index No. LHR-L	**Capability Category I**	**Capability Category II**	**Capability Category III**
LHR-L1	DEFINE HFEs that represent the impact of the human failures at the function, system, train, or component level, as appropriate**. If the impact of the failures is similar or can be conservatively bounded, GROUP the failures to correctly perform several responses into a single HFE.**		DEFINE HFEs that represent the impact of the human failures at the function, system, train, or component level, as appropriate.
LHR-L2	GROUP HFEs for different POSs across those POSs if the boundary conditions for the limiting POS are used [see also the supporting requirements for HLR-LIE-B].	GROUP HFEs for different POSs **for those POSs where the HFE boundary conditions are the same or if the HFEs with the same activity are not risk significant, and the boundary conditions of the limiting POS for the group is used to represent the group [see also the supporting requirements for HLR-LIE-B].**	GROUP HFEs for different POSs for those POSs where the HFE boundary conditions are the same. HFEs with the same activity **but with different boundary conditions in different POSs may not be grouped** [see also supporting requirements for HLR-LIE-B].
LHR-L3	COMPLETE the definition of the HFEs by specifying, for each POS or group of POSs, *(a)* activity-specific timing of cues and time window for successful completion *(b)* activity-specific procedural guidance *(c)* the availability of cues and other indications for detection and evaluation of errors *(d)* the complexity of the activity task analysis is not required). ***(e)* frequency of performing the activity**	COMPLETE the definition of the HFEs by specifying, for each POS or group of POSs, *(a)* activity-specific timing of cues and time window for successful completion *(b)* activity-specific procedural guidance *(c)* the availability of cues and other indications for detection and evaluation of errors ***(d)* the specific high level tasks (e.g., train level) required to achieve the goal of the activity** ***(e)* frequency of performing the activity**	COMPLETE the definition of the HFEs by specifying, for each POS or group of POSs, *(a)* activity-specific timing of cues and time window for successful completion *(b)* activity-specific procedural guidance *(c)* the availability of cues and other indications for detection and evaluation of errors ***(d)* the specific detailed tasks (e.g., at the level of individual components such as pumps or valves)** required to achieve the goal of the activity ***(e)* frequency of performing the activity**

Table 3.2.5-2(m) Supporting Requirements for HLR-LHR-M

Pre-, At-, and Post-Initiator HRA: Documentation of the human reliability analysis shall be consistent with the applicable supporting requirements (HLR-LHR-M).

Index No. LHR-M	Capability Category I	Capability Category II	Capability Category III
LHR-M1	Same as HR-I1 in ASME/ANS RA-Sa-2009 [1].		
LHR-M2	DOCUMENT the processes used to identify, characterize, and quantify the pre-initiator, at-initiator, post-initiator, and recovery actions considered in the LPSD PRA, including the inputs, methods, and results. For example, this documentation typically includes [see Note (1)]: *(a)* HRA methodology and process used to identify pre-, at- , and post-initiator HFEs *(b)* qualitative screening rules and results of screening *(c)* factors used in the quantification of human action, how they were derived (their bases), and how they were incorporated into the quantification process *(d)* quantification of HEPs, including: *(1)* screening values and their bases *(2)* detailed HEP analyses with uncertainties and their bases *(3)* the method and treatment of dependencies for pre-, at-, and post-initiator actions *(4)* tables of pre-, at-, and post-initiator human failure events evaluated by model, POS, system, initiating event, and function *(5)* HEPs for recovery actions and their dependency on other HEPs		
LHR-M3	Same as HR-I3 in ASME/ANS RA-Sa-2009 [1].		

NOTE:
(1) A useful reference for identifying initiating events during shutdown is EPRI 1021176 [8].

3.2.6 Data Analysis (LDA)

The objectives and high level requirements of the Data Analysis for LPSD conditions are the same as those identified in ASME/ANS RA-Sa-2009 [1] and shall be accomplished for each POS.

3.2.6.1 Objectives

The objectives of the data analysis technical element are to provide estimates of the parameters used to determine the probabilities of the basic events representing equipment failures and unavailabilities modeled in the PRA in such a way that

(a) parameters, whether estimated on the basis of plant-specific or generic data, appropriately reflect the configuration and operation of the plant;
(b) component or system unavailabilities due to maintenance or repair are accounted for;
(c) uncertainties in the data are understood and appropriately accounted for.

A useful reference document for parameter estimation is NUREG/CR-6823 [13].

Table 3.2.6-1 High Level Requirements for Data Analysis (LDA)

Designator	Requirement
HLR-LDA-A	Each parameter shall be clearly defined in terms of the logic model, basic event boundary, and the model used to evaluate event probability.
HLR-LDA-B	Grouping components into a homogeneous population for parameter estimation shall consider the design, environmental, and service conditions of the components in the as-built and as-operated plant.
HLR-LDA-C	Generic parameter estimates shall be chosen, and collection of plant-specific data shall be consistent with the parameter definitions of HLR-LDA-A and the grouping rationale of HLR-LDA-B.
HLR-LDA-D	The parameter estimates shall be based on relevant generic industry or plant-specific evidence. Where feasible, generic and plant-specific evidence shall be integrated using acceptable methods to obtain plant-specific parameter estimates. Each parameter estimated shall be accompanied by a characterization of the uncertainty.
HLR-LDA-E	Documentation of data analysis shall be consistent with the applicable supporting requirements.

Table 3.2.6-2(a) Supporting Requirements for HLR-LDA-A

Each parameter shall be clearly defined in terms of the logic model, basic event boundary, and the model used to evaluate event probability (HLR-LDA-A).

Index No. LDA-A	Capability Category I	Capability Category II	Capability Category III
LDA-A1	Same as DA-A1 in ASME/ANS RA-Sa-2009 [1].		
LDA-A2	DEFINE SSC boundaries, failure modes, and success criteria applicable to the POS being evaluated in a manner consistent with corresponding basic event definitions in System Analysis (LSY-A5, LSY-A7, LSY-A8, and LSY-A9 through LSY-A14 and LSY-B4) for failure rates and common cause failure parameters and ESTABLISH boundaries of unavailability events applicable to the POS being evaluated in a manner consistent with corresponding definitions in System Analysis (LSY-A19).		
LDA-A3	Same as DA-A3 in ASME/ANS RA-Sa-2009 [1].		
LDA-A4	IDENTIFY the parameter to be estimated and the data required for estimation. Examples are as follows: *(a)* For failures on demand, the parameter is the probability of failure, and the data required are the number of failures given a number of demands; *(b)* For standby failures, operating failures, and initiating events, the parameter is the failure rate, and the data required are the number of failures in the total (standby or operating) time; *(c)* For unavailability due to test or maintenance, the parameter is the unavailability on demand, and the alternatives for the data required include: *(1)* the total time of unavailability OR a list of the maintenance events with their durations, together with the total time required to be available; OR *(2)* the number of maintenance or test acts, their average duration, and the total time required to be available. *(d)* For POS durations, the parameter is the duration for each POS, and the data required are the durations for past evolutions; *(e)* For POS frequencies, the parameter is POSs per evolution, and the data required are the number of evolutions during the calendar year.		

Table 3.2.6-2(b) Supporting Requirements for HLR-LDA-B

Grouping components into a homogeneous population for parameter estimation shall consider the design, environmental, and service conditions of the components in the as-built and as-operated plant (HLR-LDA-B).

Index No. LDA-B	Capability Category I	Capability Category II	Capability Category III
LDA-B1	Same as DA-B1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as DA-B1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as DA-B1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].
LDA-B2	Same as DA-B2 in ASME/ANS RA-Sa-2009 [1].	Same as DA-B2 in ASME/ANS RA-Sa-2009 [1].	Same as DA-B2 in ASME/ANS RA-Sa-2009 [1].

NOTE:
(1) One source that provides a range of statistical tests to complement engineering characteristics for grouping data is the *Handbook of Parameter Estimation for Probabilistic Risk Assessment*, NUREG/CR-6823 [13].

Table 3.2.6-2(c) Supporting Requirements for HLR-LDA-C

Generic parameter estimates shall be chosen and plant-specific data shall be collected in accordance with the parameter definitions of HLR-LDA-A and the grouping rationale of HLR-LDA-B (HLR-LDA-C).

Index No. LDA-C	Capability Category I	Capability Category II	Capability Category III
LDA-C1	USE generic parameter estimates appropriate for the POS from recognized sources. ENSURE that the parameter definitions and boundary conditions are consistent with those established in response to LDA-A1 to LDA-A4 (for example, some sources include the breaker within the pump boundary, whereas others do not). DO NOT INCLUDE generic data for unavailability due to test, maintenance, and repair unless it can be established that the data are consistent with the POS test and maintenance philosophies for the subject plant. JUSTIFY the use of common parameter estimates in multiple POSs [see Note (1)].	USE generic parameter estimates appropriate for the POS from recognized sources. ENSURE that the parameter definitions and boundary conditions are consistent with those established in response to LDA-A1 to LDA-A4 (for example, some sources include the breaker within the pump boundary, whereas others do not). DO NOT INCLUDE generic data for unavailability due to test, maintenance, and repair unless it can be established that the data are consistent with the POS test and maintenance philosophies for the subject plant. JUSTIFY the use of common parameter estimates in multiple POSs [see Note (1)].	USE generic parameter estimates appropriate for the POS from recognized sources. ENSURE that the parameter definitions and boundary conditions are consistent with those established in response to LDA-A1 to LDA-A4 (for example, some sources include the breaker within the pump boundary, whereas others do not). DO NOT INCLUDE generic data for unavailability due to test, maintenance, and repair unless it can be established that the data are consistent with the POS test and maintenance philosophies for the subject plant. JUSTIFY the use of common parameter estimates in multiple POSs [see Note (1)].
LDA-C2	COLLECT plant-specific data applicable to the POS being evaluated for the basic event/parameter grouping corresponding to that defined by requirements LDA-A1, LDA-A3, LDA-A4, LDA-B1, and LDA-B2 [see Note (2)].	COLLECT plant-specific data applicable to the POS being evaluated for the basic event/parameter grouping corresponding to that defined by requirements LDA-A1, LDA-A3, LDA-A4, LDA-B1, and LDA-B2 [see Note (2)].	COLLECT plant-specific data applicable to the POS being evaluated for the basic event/parameter grouping corresponding to that defined by requirements LDA-A1, LDA-A3, LDA-A4, LDA-B1, and LDA-B2 [see Note (2)].
LDA-C3	COLLECT plant-specific data in a manner consistent with uniformity in design, operational practices, and experience applicable to the POS being evaluated or any other POSs in which the equipment performance is similar. JUSTIFY the rationale for screening or disregarding plant-specific data (e.g., plant design modifications, changes in operating practices) [see Note (3)].	COLLECT plant-specific data in a manner consistent with uniformity in design, operational practices, and experience applicable to the POS being evaluated or any other POSs in which the equipment performance is similar. JUSTIFY the rationale for screening or disregarding plant-specific data (e.g., plant design modifications, changes in operating practices) [see Note (3)].	COLLECT plant-specific data in a manner consistent with uniformity in design, operational practices, and experience applicable to the POS being evaluated or any other POSs in which the equipment performance is similar. JUSTIFY the rationale for screening or disregarding plant-specific data (e.g., plant design modifications, changes in operating practices) [see Note (3)].
LDA-C4	Same as DA-C4 in ASME/ANS RA-Sa-2009 [1].	Same as DA-C4 in ASME/ANS RA-Sa-2009 [1].	Same as DA-C4 in ASME/ANS RA-Sa-2009 [1].
LDA-C5	Same as DA-C5 in ASME/ANS RA-Sa-2009 [1].	Same as DA-C5 in ASME/ANS RA-Sa-2009 [1].	Same as DA-C5 in ASME/ANS RA-Sa-2009 [1].

Table 3.2.6-2(c) Supporting Requirements for HLR-LDA-C (Cont'd)

Index No. LDA-C	Capability Category I	Capability Category II	Capability Category III
LDA-C6	ESTIMATE the number of plant-specific demands on standby components applicable to a specific POS (or group of POSs in which equipment performance is similar) on the basis of the number of *(a)* surveillance tests *(b)* maintenance tests *(c)* surveillance tests or maintenance on other components *(d)* operational demands DO NOT COUNT additional demands from post-maintenance testing that is part of a successful renewal [see Note (4)].		
LDA-C7	ESTIMATE the number of surveillance tests and planned maintenance activities based **on plant requirements** for the POS being evaluated [see Note (5)].	BASE the number of surveillance tests on **plant surveillance requirements and actual practice** for the POS being evaluated. BASE number of planned maintenance activities on **plant maintenance plans and actual practice** for the POS being evaluated. **BASE the number of unplanned maintenance activities on actual plant experience** for the POS being evaluated [see Note (5)].	
LDA-C8	When required, ESTIMATE the time that components were configured in their standby status for the POS being evaluated [see Note (6)].	When required, **USE plant-specific operational records to determine** the time that components were configured in their standby status for the POS being evaluated [see Note (6)].	
LDA-C9	ESTIMATE operational time from surveillance test practices for standby components and from actual operational data for the POS being evaluated [see Note (7)].		ESTIMATE operational time from surveillance test **records** for standby components and from actual operational data for the POS being evaluated [see Note (7)].
LDA-C10	Same as DA-C10 in ASME/ANS RA-Sa-2009 [1].	Same as DA-C10 in ASME/ANS RA-Sa-2009 [1].	Same as DA-C10 in ASME/ANS RA-Sa-2009 [1].
LDA-C11	Same as DA-C11 in ASME/ANS RA-Sa-2009 [1].		
LDA-C12	Same as DA-C12 in ASME/ANS RA-Sa-2009 [1].		

Table 3.2.6-2(c) Supporting Requirements for HLR-LDA-C (Cont'd)

Index No. LDA-C	Capability Category I	Capability Category II	Capability Category III
LDA-C13	ESTIMATE the duration of the actual time that the equipment was unavailable for each test and maintenance activity. Using these duration estimates and estimates from LDA-C7, CALCULATE the test and maintenance unavailabilities for each LPSD POS. Special attention should be paid to the case of a multi-plant site with shared systems, when the Technical Specifications (TS) requirements can be different depending on the status of both plants. Accurate modeling generally leads to a particular allocation of outage data among basic events to take this mode dependence into account. In the case that reliable estimates of the start and finish times of periods of unavailability are not available, **provide conservative estimates** [see Note (8)].	ESTIMATE the duration of the actual time that the equipment was unavailable for each test and maintenance activity. Using these duration estimates and estimates from LDA-C7, CALCULATE the test and maintenance unavailabilities for the LPSD POS. Special attention should be paid to the case of a multi-plant site with shared systems, when the Technical Specifications (TS) requirements can be different depending on the status of both plants. Accurate modeling generally leads to a particular allocation of outage data among basic events to take this mode dependence into account. In the case that reliable estimates of the start and finish times are not available, **INTERVIEW the plant maintenance and operations personnel to generate estimates of ranges for the unavailable time per maintenance act for components, trains, or systems for which the unavailabilities are significant basic events** [see Note (8)].	
LDA-C14	Same as DA-C14 in ASME/ANS RA-Sa-2009 [1] [see Note (9)].		
LDA-C15	For each SSC for which repair is to be modeled (see LSY-A22), IDENTIFY instances of plant-specific or applicable industry experience, and for each repair, COLLECT the associated repair time on a POS-by-POS basis with the repair time being the period from identification of the component failure until the component is returned to service [see Note (10)].		
LDA-C16	Same as DA-C16 in ASME/ANS RA-Sa-2009 [1] [see Note (11)].		
LDA-C17	COLLECT plant-specific evolution timeline data, accounting for POS start time and duration and test and maintenance configurations for each LPSD evolution (see also LPOS-C1, C2) [see Note 12].		
LDA-C18	PROVIDE a basis for the use of the same generic parameter estimates for groups of POSs.		
LDA-C19	When required, ESTIMATE the number of evolutions per calendar year, accounting for the specific evolution type (see LPOS-C1).		

NOTES:

(1) Examples of parameter estimates and associated sources include:
- *(a)* component failure rates and probabilities: NUREG/CR-4639 [14], NUREG/CR-4550 [15], NUREG-1715 [16], and NUREG/CR-6928 [17];
- *(b)* common cause failures: NUREG/CR-5497 [18] and NUREG/CR-6268 [19];
- *(c)* AC off-site power recovery: NUREG/CR-5496 [20], NUREG/CR-5032 [21], and NUREG/CR-6890 [22];
- *(d)* component recovery.

See NUREG/CR-6823 [13] for listing of additional data sources.

(2) This may include data from the specific POS and any other POSs in which the equipment performance would be expected to be similar. Use of the same data in multiple POSs requires justification. Generally, equipment failure data are no different during shutdown than during operations. However, several factors are important when considering using normal failure data. The following factors may affect all parameter estimates, not just equipment failure rates:
- *(a)* Long evolutions with equipment far outside normal operating conditions and test practice can affect successful performance;
- *(b)* Systems analysis models can account for different test and operating practice during the evolution.

Parameter estimates may be affected by special configurations (RCS and maintenance) that occur during LPSD.

(3) Use of the same data in multiple POSs requires justification. Caution is required because changes in outage practice are occurring. Refueling occurs less often, outages are getting shorter, some forced outages are less frequent, and outage planning is improving. The use of historical data may no longer be relevant. The analyst must account for new plans as well as knowledge of past problems. Generalized Bayesian methods and expert elicitation techniques may be needed. NUREG/CR-6823 [13] provides some useful "how to" guidance for such situations.

(4) The counts may need to be specialized to LPSD conditions and even to specific shutdown maintenance conditions. Use of the same data in multiple POSs requires justification.

(5) The counts may need to be specialized to LPSD conditions and even to specific shutdown maintenance.

(6) The time components configured in their standby status may need to be specialized to LPSD conditions and even to specific shutdown maintenance.

(7) The time may need to be specialized to LPSD conditions and even to specific shutdown maintenance.

(8) Same as ASME/ANS Standard RA-Sa-2009 [1] except as modified to account for LPSD conditions.

(9) The times may need to be specialized to LPSD conditions and even to specific shutdown maintenance conditions. Note that out of service unavailability data are very different for shutdown conditions, primarily because:
- *(a)* Equipment unavailabilities are correlated by planned maintenance configurations;
- *(b)* Equipment repair is more a function of outage schedule and outage management than actual time required completing repair; and
- *(c)* Outage times may be much longer than nominal full power [i.e., there may be no limiting condition of operation (LCO), and outage management considerations may defer restoration to service; thus, data for outage time is often to be based on policy and outage practice rather than past experience (full power data are irrelevant to such cases)].

(10) Note that repair data can be very different for shutdown conditions, primarily because:
- *(a)* Equipment repair is more a function of outage schedule and outage management than actual time required completing repair;
- *(b)* Outage times may be much longer than nominal full power [i.e., there may be no LCO, and outage management considerations may defer restoration to service; thus, data for outage time

can often be based on policy and outage practice rather than past experience (full power data are irrelevant to such cases)];

(c) Cognizance of outage planning considerations is essential.

(11) Note that other planned maintenance activities can have a major impact on recovery of off-site power outage, and POS-specific corrections may be required.

(12) Data collection may include the use of expert elicitation, as described in Section 1-4.3 of ASME/ANS RA-Sa-2009 [1]. Uncertainty information can be developed from timelines of previous outages combined with expert elicitation. All indications are that such data are very plant-specific and vary with time, especially in recent years. Data may be collected and assembled differently for time-averaged CDF or LERF calculations and outage-specific assessments.

Table 3.2.6-2(d) Supporting Requirements for HLR-LDA-D

The parameter estimates shall be based on relevant generic industry and plant-specific evidence. Where feasible, generic and plant-specific evidence shall be integrated using acceptable methods to obtain plant-specific parameter estimates. Each parameter estimate shall be accompanied by a characterization of the uncertainty (HLR-LDA-D).

Index No. LDA-D	Capability Category I	Capability Category II	Capability Category III
LDA-D1	**ESTIMATE plant-specific parameters for basic events and POSs, modeling the unique design or operational features, if available, or use generic information modified as discussed in LDA-D2; USE generic information for the remaining events.**	ESTIMATE realistic parameters **for significant basic events and significant POSs** based on relevant generic and plant-specific evidence unless it is justified that there are adequate plant-specific data to characterize the parameter value and its uncertainty. When it is necessary to combine evidence from generic and plant-specific data, USE a Bayes update process or equivalent statistical process that assigns appropriate weight to the statistical significance of the generic and plant-specific evidence and provides an appropriate characterization of uncertainty. SELECT prior distributions as either non-informative or representative of variability in industry data. **CALCULATE parameter estimates for the remaining events and POSs using generic industry data.**	ESTIMATE realistic parameters based on relevant generic and plant-specific evidence unless it is justified that there are adequate plant-specific data to characterize the parameter value and its uncertainty. When it is necessary to combine evidence from generic and plant-specific data, USE a Bayes update process or equivalent statistical process that assigns appropriate weight to the statistical significance of the generic and plant-specific evidence and provides an appropriate characterization of uncertainty. SELECT prior distributions as either non-informative or representative of variability in industry data.
LDA-D2	Same as DA-D2 in ASME/ANS RA-Sa-2009 [1].		

Table 3.2.6-2(d) Supporting Requirements for HLR-LDA-D (Cont'd)

Index No. LDA-D	Capability Category I	Capability Category II	Capability Category III
LDA-D3	**PROVIDE a characterization (e.g., qualitative discussion) of the uncertainty intervals for the estimates of those parameters used for estimating the probabilities of the significant basic events and significant POSs.**	PROVIDE a **mean value of and a statistical representation of the uncertainty intervals for the parameter estimates of significant basic events and significant POSs. Acceptable systematic methods include Bayesian updating, frequentist method, or expert judgment.**	PROVIDE a mean value of and a statistical representation of the uncertainty intervals for the parameter estimates. Acceptable systematic methods include Bayesian updating, frequentist method, or expert judgment.
LDA-D4	Same as DA-D4 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as DA-D4 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	
LDA-D5	Same as DA-D5 in ASME/ANS RA-Sa-2009 [1].	Same as DA-D5 in ASME/ANS RA-Sa-2009 [1].	Same as DA-D5 in ASME/ANS RA-Sa-2009 [1].
LDA-D6	Same as DA-D6 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].	Same as DA-D6 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].	Same as DA-D6 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].
LDA-D7	Same as DA-D7 in ASME/ANS RA-Sa-2009 [1].		
LDA-D8	Same as DA-D8 in ASME/ANS RA-Sa-2009 [1].	Same as DA-D8 in ASME/ANS RA-Sa-2009 [1].	Same as DA-D8 in ASME/ANS RA-Sa-2009 [1].

NOTES:

(1) NUREG/CR-6823, "Handbook of Parameter Estimation for Probabilistic Risk Assessment," [13] provides guidance.

(2) Note that equipment common cause failure (CCF) data are a difficult area for LPSD conditions. Many of the underlying causes of CCF can be affected by physical activities during outages, changes in plant conditions, and outside personnel having access to plant equipment. Full power CCF data may be applicable to the POS and maintenance activities during each phase of LPSD. However, adjustments are often necessary. Cognizance of the many controls the plant has in place to keep workers from interacting with the "protected train" helps ensure that CCF probabilities are realistic.

Table 3.2.6-2(e) Supporting Requirements for HLR-LDA-E

Documentation of the data analysis shall be consistent with the applicable supporting requirements (HLR-LDA-E).

Index No. LDA-E	Capability Category I	Capability Category II	Capability Category III
LDA-E1	Same as DA-E1 in ASME/ANS RA-Sa-2009 [1].		
LDA-E2	DOCUMENT the processes used for data parameter definition, grouping, and collection, including parameter selection and estimation and the inputs, methods, and results. For example, this documentation typically includes [see Note (1)]: *(a)* system and component boundaries used to establish component failure probabilities *(b)* the model used to evaluate each basic event probability *(c)* sources for generic parameter estimates *(d)* the plant-specific and POS-specific sources of data including those used for POS durations *(e)* the time periods for which plant-specific data were gathered and justification of any censoring of the data for specific LPSD conditions *(f)* justification for exclusion of any data *(g)* the basis for the estimates of common cause failure probabilities, including justification for screening or mapping of generic and plant-specific data *(h)* the rationale for any distributions used as priors for Bayesian updates, where applicable *(i)* parameter estimation including the characterization of uncertainty, as appropriate *(j)* justification for use of full power or other POS data *(k)* the rationale for using generic parameter estimates for multiple POSs		
LDA-E3	DOCUMENT the sources of model uncertainty and related assumptions (as identified in LQU-E1 and LQU-E2) associated with the data analysis.		

NOTE:

(1) The documentation requirements ensure there is a record of how the special conditions that exist during LPSD are accounted for in the analysis. They provide a picture of the POS-by-POS differences in the data and parameter estimation.

3.2.7 Quantification (LQU)

The objectives and high level requirements of the Quantification technical element for LPSD conditions are the same as those identified in [1] and shall be accomplished for each POS or group of POSs. These requirements apply to the quantification of both Internal Events and all other hazard groups.

3.2.7.1 Objectives

The objectives of the quantification element are to provide an estimate of CDF (and to support the quantification of LERF) based upon the plant-specific core damage scenarios in such a way that:

(a) The results reflect the design, operation, and maintenance of the plant;
(b) Significant contributors to CDF (and LERF) are identified such as POSs (or groups of POSs), initiating events, accident sequences, and basic events (equipment unavailability and human failure events);
(c) Dependencies are accounted for;
(d) Uncertainties are understood and appropriately quantified.

Table 3.2.7-1 High Level Requirements for LPSD PRA Quantification (LQU)

Designator	Requirement
HLR-LQU-A	The Level 1 quantification shall quantify CDF and shall support the quantification of LERF.
HLR-LQU-B	The quantification shall use appropriate models and codes and shall account for method-specific limitations and features.
HLR-LQU-C	Model quantification shall determine that all identified dependencies are addressed appropriately.
HLR-LQU-D	The quantification results shall be reviewed, and significant contributors to CDF (and LERF) such as LPSD evolutions, POSs, initiating events, accident sequences, and basic events (equipment unavailabilities and human failure events) shall be identified. The results shall be traceable to the inputs and assumptions made in the LPSD PRA.
HLR-LQU-E	Uncertainties in the LPSD PRA results shall be characterized. Sources of model uncertainty and related assumptions shall be identified, and their potential impact on the results understood.
HLR-LQU-F	Documentation of the quantification shall be consistent with the applicable supporting requirements.

Table 3.2.7-2(a) Supporting Requirements for Quantification HLR-LQU-A

The Level 1 quantification shall quantify core damage frequency and shall support the quantification of LERF (HLR-LQU-A).

Index No. LQU-A	Capability Category I	Capability Category II	Capability Category III
LQU-A1	INTEGRATE the accident sequences, system models, data, and HRA in the quantification process for each initiating event group, POS, and LPSD evolution modeled accounting for system dependencies to arrive at accident sequence frequencies.		INTEGRATE the accident sequences, system models, data, and HRA in the quantification process for each initiating event group, POS, and representative LPSD evolution accounting for system dependencies to arrive at accident sequence frequencies.
LQU-A2	Same as QU-A2 in ASME/ANS RA-Sa-2009 [1].		
LQU-A3	Same as QU-A3 in ASME/ANS RA-Sa-2009 [1]. *Point estimate CDF quantification is to be performed separately by POS or groups of POSs and then aggregated* [see Note (1)].	Same as QU-A3 in ASME/ANS RA-Sa-2009 [1]. *Point estimate CDF quantification is to be performed separately by POS or groups of POSs and then aggregated* [see Notes (1) and (2)].	Same as QU-A3 in ASME/ANS RA-Sa-2009 [1]. *Point estimate CDF quantification is to be performed separately by POS or groups of POSs and then aggregated* [see Notes (1) and (2)].
LQU-A4	Same as QU-A4 in ASME/ANS RA-Sa-2009 [1].		
LQU-A5	Same as QU-A5 in ASME/ANS RA-Sa-2009 [1].		

NOTES:

(1) See Appendix 3.A.

(2) When the probabilities of a number of basic events are estimated using the same parameter data, the probabilities of the events will be identical. When an uncertainty analysis is performed using a Monte Carlo sampling approach, the same sample value is to be used for each basic event probability using the same parameter since the state of knowledge about the parameter value is the same for each event. This is called the state of knowledge correlation, and it results in a mean value for the joint probability that is larger than the product of the mean values of the event probabilities. This result is most important for cut sets that contain multiple basic events whose probabilities are based on the same data, particularly when the uncertainty on the parameter value is large. It has been found to be significant in cut sets contributing to ISLOCA frequency that involve rupture of multiple valves, for example [23].

Table 3.2.7-2(b) Supporting Requirements for Quantification HLR-LQU-B

The quantification shall use appropriate models and codes and shall account for method-specific limitations and features (HLR-LQU-B).

Index No. LQU-B	Capability Category I	Capability Category II	Capability Category III
LQU-B1	Same as QU-B1 in ASME/ANS RA-Sa-2009 [1].		
LQU-B2	Same as QU-B2 in ASME/ANS RA-Sa-2009 [1].		
LQU-B3	Same as QU-B3 in ASME/ANS RA-Sa-2009 [1].		
LQU-B4	Same as QU-B4 in ASME/ANS RA-Sa-2009 [1].		
LQU-B5	Same as QU-B5 in ASME/ANS RA-Sa-2009 [1].		
LQU-B6	Same as QU-B6 in ASME/ANS RA-Sa-2009 [1].		
LQU-B7	Same as QU-B7 in ASME/ANS RA-Sa-2009 [1].		
LQU-B8	Same as QU-B8 in ASME/ANS RA-Sa-2009 [1].		
LQU-B9	Same as QU-B9 in ASME/ANS RA-Sa-2009 [1].		
LQU-B10	Same as QU-B10 in ASME/ANS RA-Sa-2009 [1].		

Table 3.2.7-2(c) Supporting Requirements for Quantification HLR-LQU-C

Model quantification shall determine that all identified dependencies are addressed appropriately (HLR-LQU-C).

Index No. LQU-C	Capability Category I	Capability Category II	Capability Category III
LQU-C1	Same as QU-C1 in ASME/ANS RA-Sa-2009 [1].		
LQU-C2	Same as QU-C2 in ASME/ANS RA-Sa-2009 [1].		
LQU-C3	Same as QU-C3 in ASME/ANS RA-Sa-2009 [1].		

Table 3.2.7-2(d) Supporting Requirements for Quantification HLR-LQU-D

The quantification results shall be reviewed, and significant contributors to CDF (and LERF) such as LPSD evolutions, POSs, initiating events, accident sequences, and basic events (equipment unavailabilities and human failure events) shall be identified. The results shall be traceable to the inputs and assumptions made in the LPSD PRA (HLR-LQU-D).

Index No. LQU-D	Capability Category I	Capability Category II	Capability Category III
LQU-D1	Same as QU-D1 in ASME/ANS RA-Sa-2009 [1].		
LQU-D2	Same as QU-D2 in ASME/ANS RA-Sa-2009 [1].		
LQU-D3	Same as QU-D3 in ASME/ANS RA-Sa-2009 [1].		
LQU-D4	Same as QU-D4 in ASME/ANS RA-Sa-2009 [1]. No requirements to compare results to those from similar plants.	Same as QU-D4 in ASME/ANS RA-Sa-2009 [1].	
LQU-D5	Same as QU-D5 in ASME/ANS RA-Sa-2009 [1].		
LQU-D6	IDENTIFY significant contributors to CDF such as LPSD evolutions, POSs, initiating events, accident sequences, equipment failures, common cause failures, and operator errors.	IDENTIFY significant contributors to CDF such as LPSD evolutions, POSs, initiating events, accident sequences, equipment failures, common cause failures, and operator errors. **INCLUDE SSCs and operator actions that contribute to initiating event frequencies and event mitigation.**	
LQU-D7	Same as QU-D7 in ASME/ANS RA-Sa-2009 [1].		

Table 3.2.7-2(e) Supporting Requirements for Quantification HLR-LQU-E

Uncertainties in the LPSD PRA results shall be characterized. Sources of model uncertainty and key assumptions shall be identified, and their potential impact on the results understood (HLR-LQU-E).

Index No. LQU-E	Capability Category I	Capability Category II	Capability Category III
LQU-E1	Same as QU-E1 in ASME PRA Standard (ASME/ANS RA-Sa-2009 [1]).		
LQU-E2	Same as QU-E2 in ASME/ANS PRA Standard (ASME/ANS RA-Sa-2009 [1]).		Same as QU-E2 in ASME/ANS PRA Standard (ASME/ANS RA-Sa-2009 [1]).
LQU-E3	ESTIMATE the uncertainty interval of the CDF results aggregated over all POSs. Provide a basis for the estimate consistent with the characterization of parameter uncertainties (LPOS-C1, LPOS-C2, LPOS-C3, LDA-D3, LHR-D6, LHR-G8, and LIE-C15).	ESTIMATE the uncertainty interval of the CDF results aggregated over all POSs. **ESTIMATE the uncertainty intervals associated with parameter uncertainties (LDA-D3, LHR-D6, LHR-G8, LHR-K7, and LIE-C15), taking into account the "state-of-knowledge" correlation.**	**PROPAGATE parameter uncertainties (LDA-D3, LHR-D6, LHR-G8, LHR-K7, and LIE-C15) and those model uncertainties explicitly characterized by a probability distribution using the Monte Carlo approach or other comparable means. PROPAGATE uncertainties in such a way that the "state-of-knowledge" correlation between event probabilities is taken into account to obtain the uncertainty interval of the CDF results aggregated over all POSs.**
LQU-E4	Same as QU-E4 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].		

NOTE:
(1) For specific applications, key assumptions and parameters are to be examined both individually and in logical combinations.

Table 3.2.7-2(f) Supporting Requirements for Quantification HLR-LQU-F

Documentation of the quantification shall be consistent with the applicable supporting requirements (HLR-LQU-F).

Index No. LQU-F	Capability Category I	Capability Category II	Capability Category III
LQU-F1	Same as QU-F1 in ASME/ANS RA-Sa-2009 [1].		
LQU-F2	DOCUMENT the model integration process including any recovery analysis and the results of the quantification including uncertainty and sensitivity analyses. For example, documentation typically includes: *(a)* records of the process/results when adding non-recovery terms as part of the final quantification *(b)* records of the cut set review process *(c)* a general description of the quantification process including accounting for systems successes, the truncation values used, and how recovery and post-initiator HFEs are applied *(d)* the process and results for establishing the truncation screening values for final quantification demonstrating that convergence towards a stable result was achieved *(e)* the total plant CDF and contributions from the different LPSD evolutions, POSs, initiating events, and accident classes *(f)* the accident sequences and their contributing cut sets *(g)* equipment or human actions that are the key factors in causing the accidents to be non-dominant *(h)* the results of all sensitivity studies *(i)* the uncertainty distribution for the total CDF *(j)* importance measure results *(k)* a list of mutually exclusive events eliminated from the resulting cut sets and their bases for elimination *(l)* asymmetries in quantitative modeling to provide application users the necessary understanding regarding why such asymmetries are present in the model *(m)* the process used to illustrate that the computer code(s) used to perform the quantification will yield correct results		
LQU-F3	DOCUMENT the significant contributors (such as LPSD evolutions, POSs, initiating events, accident sequences, and basic events) to CDF in the LPSD PRA results summary.	DOCUMENT the significant contributors (such as LPSD evolutions, POSs, initiating events, accident sequences, and basic events) to CDF in the LPSD PRA results summary. DESCRIBE in detail **the significant accident sequences or functional failure groups.**	
LQU-F4	Same as QU-F4 in ASME/ANS RA-Sa-2009 [1].		
LQU-F5	Same as QU-F5 in ASME/ANS RA-Sa-2009 [1].		
LQU-F6	Same as QU-F6 in ASME/ANS RA-Sa-2009 [1].		

3.2.8 LERF Analysis (LLE)

3.2.8.1 Introduction

Consistent with ASME/ANS RA-Sa-2009 [1], this standard includes technical requirements related to a limited Level 2 analysis sufficient to evaluate the large early release frequency (LERF). The basic definition for LERF in this standard is identical to that for full power PRAs in ASME/ANS RA-Sa-2009 [1].

The approach to developing any quantitative LPSD PRA typically uses as its starting point the full power, internal events PRA model. Some additional analysis elements are needed to perform an LPSD PRA, as the HLRs and SRs below demonstrate. Some "trimming" of the full power, internal events model may also be appropriate to eliminate parts of it not relevant to the LPSD analysis. There are also unique elements that are not covered in a full power PRA, including the initial conditions and success criteria.

The analysis of the LERF endpoint for LPSD PRAs proceeds in a somewhat different fashion than for full power PRAs. The emphasis is more on containment isolation status than on containment structural failure (although the latter remains important) since there may be POSs where the containment has an equipment hatch removed or other large openings to permit maintenance activities. Also, the dissipated decay heat during shutdown results in a reduced source term when compared to full power (although the radiological impact of the source term decreases at a slower rate that the decay heat does). Thus, while the definition of LERF is the same as at full power, the determination of "large" includes considerations additional to those at full power.

The concept of "early" in the definition of LERF is identical to that in a full power PRA. In neither case does it refer to a specific point in time after the initiating event; rather, it refers to the time of release compared to the time required for effective offsite protective actions, e.g., evacuation and sheltering. Therefore, in determining whether a potential accident sequence falls into the LERF category, it is necessary to consider the timing of the accident as it develops to the point at which reactor parameters would trigger evacuation, the time required for evacuation, and the time of the release.

The objectives and HLRs of the LERF analysis for LPSD conditions are the same as those identified in ASME/ANS RA-Sa-2009 [1] and shall be accomplished for each POS or group of POSs.

3.2.8.2 Objectives

The objectives of the LERF analysis technical element are to identify and quantify the contributors to large early releases based upon the plant-specific core damage scenarios in such a way that:

- *(a)* The methodology is clear and consistent with the Level 1 evaluation and creates an adequate transition from Level 1;
- *(b)* Operator actions, mitigation systems, and phenomena that can alter sequences are appropriately included in the LERF event tree structure and sequence definition;
- *(c)* Dependencies are reflected in the accident sequence model structure, if necessary;
- *(d)* Success criteria are available to support the individual function successes, mission times, and time windows for operator actions and equipment recovery for each critical safety function modeled in the accident sequences;
- *(e)* End states are clearly defined to be LERF or non-LERF.

NOTE: In a number of cases, the LERF supporting requirements include reference to applicable requirements in other sections of the standard, e.g., for LAS, LSC, LSY, LHR, LDA, and LQU. The requirements in other sections of this standard were primarily written in the context of CDF. Where applicable to LERF, these requirements are to be interpreted in the context of LERF. New requirements that are only applicable to LERF are identified in this section.

Table 3.2.8-1 High Level Requirements for LERF Analysis (HLR-LLE)

Designator	Requirement
HLR-LLE-A	Core damage sequences shall be grouped into plant damage states based on their accident progression attributes.
HLR-LLE-B	The accident progression analyses shall include an evaluation of the contributors (e.g., phenomena, equipment failures, human actions) to a large early release.
HLR-LLE-C	The accident progression analysis shall include identification of those sequences that would result in a large early release.
HLR-LLE-D	The accident progression analyses shall include an evaluation of the containment structural capability for those containment challenges that would result in a large early release.
HLR-LLE-E	The frequency of different containment failure modes leading to a large early release shall be quantified and aggregated.
HLR-LLE-F	The quantification results shall be reviewed, and significant contributors to LERF such as plant damage states, containment challenges, and failure modes shall be identified. Sources of model uncertainty and related assumptions shall be identified, and their potential impact on the results understood.
HLR-LLE-G	The documentation of the LERF analysis shall be consistent with the applicable supporting requirements.

Some requirements below reference ASME/ANS RA-Sa-2009 [1], which includes references to NUREG/CR-6595. This reference has been updated as NUREG/CR-6595, Rev. 1, “An Approach for Estimating the Frequencies of Various Containment Failure Modes and Bypass Events,” October 2004 [24], which is the applicable reference for this section.

Table 3.2.8-2(a) Supporting Requirements for HLR-LLE-A

Core damage sequences shall be grouped into plant damage states based on their accident progression attributes (HLR-LLE-A).

Index No. LLE-A	Capability Category I	Capability Category II	Capability Category III
LLE-A1	IDENTIFY those physical characteristics at the time of core damage that can influence LERF. Examples include *(a)* RCS pressure (high RCS pressure can result in high-pressure melt ejection) *(b)* status of emergency core coolant systems (failure in injection can result in a dry cavity and extensive Core Concrete Interaction) *(c)* status of containment isolation (failure of isolation can result in an unscrubbed release) *(d)* status of containment heat removal *(e)* containment integrity (e.g., vented, bypassed, or failed) *(f)* steam generator pressure and water level (PWRs) *(g)* status of containment inerting (BWRs) *(h)* time after shutdown *(i)* POS before and after refueling *(j)* applicability of emergency response plans and procedures vs. POS to determine the potential for evacuation or other protective actions [See Note (1)]		
LLE-A2	Same as LE-A2 in ASME/ANS RA-Sa-2009 [1].		
LLE-A3	Same as LE-A3 in ASME/ANS RA-Sa-2009 [1].		
LLE-A4	Same as LE-A4 in ASME/ANS RA-Sa-2009 [1].		
LLE-A5	Same as LE-A5 in ASME/ANS RA-Sa-2009 [1].		

NOTE:
(1) Some examples may not apply to all POSs; e.g., high RCS pressure is not possible with the reactor vented, the containment may be open at the time of core damage, etc.

Table 3.2.8-2(b) Supporting Requirements for HLR-LLE-B

The accident progression analysis shall include an evaluation of the contributors (e.g., phenomena, equipment failures, human actions) to a large early release (HLR-LLE-B).

Index No. LLE-B	Capability Category I	Capability Category II	Capability Category III
LLE-B1	IDENTIFY LERF contributors from the set identified in Table 3.2.8-3. **An acceptable approach for identifying contributors that could influence LERF for the various containment types is contained in NUREG/CR-6595 [24].** INCLUDE, as appropriate, unique plant issues as determined by expert judgment and/or engineering analyses [see Note (1)].	IDENTIFY LERF contributors from the set identified in Table 3.2.8-3. INCLUDE, as appropriate, unique plant issues as determined by expert judgment and/or engineering analyses [see Note (1)].	**INCLUDE LERF contributors sufficient to support development of realistic accident progression sequences. ADDRESS those contributors identified by IDCOR and NUREG-1150 [25] and those in Table 3.2.8-3.** INCLUDE, as appropriate, unique plant issues as determined by expert judgment and/or engineering analyses [see Note (1)].
LLE-B2	Same as LE-B2 in ASME/ANS RA-Sa-2009 [1].	Same as LE-B2 in ASME/ANS RA-Sa-2009 [1].	Same as LE-B2 in ASME/ANS RA-Sa-2009 [1].
LLE-B3	Same as LE-B3 in ASME/ANS RA-Sa-2009 [1].		

NOTE:
(1) Note that some of the potential LERF contributors in Table 3.2.8-3 will not contribute to a specific POS if the physical conditions of the POS or the POS's time evolution do not permit the relevant condition to occur.

Table 3.2.8-2(c) Supporting Requirements for HLR-LLE-C

The accident progression analysis shall include identification of those sequences that would result in a large early release (HLR-LLE-C).

Index No. LLE-C	Capability Category I	Capability Category II	Capability Category III
LLE-C1	Same as LE-C1 in ASME/ANS RA-Sa-2009 [1].	DEVELOP accident sequences to a level of detail to account for the potential contributors identified in LLE-B1 and analyzed in LLE-B2. **COMPARE the containment challenges analyzed in LLE-B with the containment structural capability analyzed in LLE-D and identify accident progressions that have the potential for large early release. <u>JUSTIFY any generic or plant-specific calculations used to evaluate source terms for accident progressions that have the potential for large early release.</u>**	DEVELOP accident sequences to a level of detail to account for the potential contributors identified in LLE-B1 and analyzed in LLE-B2. **COMPARE the containment challenges analyzed in LLE-B with the containment structural capability analyzed in LLE-D and identify accident progressions that have the potential for large early release. CALCULATE <u>plant-specific</u> source terms for accident progressions that have the potential for large early releases.**
LLE-C1a	**<u>No requirement.</u>**	**<u>IDENTIFY LER sequences from the results of the accident progression analysis and source term analysis of HLR LLE-C1 by comparing the sequence source terms with release fractions chosen to define LER. JUSTIFY the release fractions chosen to define LER. The criteria in Appendix A of NUREG/CR-6595, Rev. 1 [24] for LER provide an acceptable basis during transition from full power operation to shutdown operation. For shutdown operation, ACCOUNT FOR the impact of radionuclide decay on the potential source term. For transition from shutdown operation to full power operation, ANALYZE for core changes during the outage.</u>**	

Table 3.2.8-2(c) Supporting Requirements HLR-LLE-C (Cont'd)

Index No. LLE-C	Capability Category I	Capability Category II	Capability Category III
LLE-C1b	SCREEN OUT accident sequences that cannot result in a large early release based on one of the following criteria: Criterion 1: The available radionuclide inventory can be demonstrated to be insufficient to result in a large early release for the scenario analyzed. Criterion 2: The time available for protective actions (e.g., evacuation and sheltering) before release to the environment in the scenario analyzed can be demonstrated to be sufficient to allow effective protective actions to be carried out [see Note (1)].		
LLE-C2	Same as LE-C2 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C2 in ASME/ANS RA-Sa-2009 [1].	
LLE-C3	Same as LE-C3 in ASME/ANS RA-Sa-2009 [1]. No requirement to address repair.	REVIEW significant accident progression sequences resulting in a large early release to determine if repair of equipment can be credited. JUSTIFY credit given for repair [i.e., ensure that plant conditions do not preclude repair failure probability (see LSY-A24, LDA-C15, and LDA-D8)]. AC power recovery based on generic data applicable to the plant is acceptable.	
LLE-C4	Same as LE-C4 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C4 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C4 in ASME/ANS RA-Sa-2009 [1].
LLE-C5	Same as LE-C5 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C5 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C5 in ASME/ANS RA-Sa-2009 [1].
LLE-C6	Same as LE-C6 in ASME/ANS RA-Sa-2009 [1].		
LLE-C7	Same as LE-C7 in ASME/ANS RA-Sa-2009 [1].		
LLE-C8	Same as LE-C8 in ASME/ANS RA-Sa-2009 [1].		
LLE-C9	Same as LE-C9 in ASME/ANS RA-Sa-2009 [1].		
LLE-C10	Same as LE-C10 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C10 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C10 in ASME/ANS RA-Sa-2009 [1].
LLE-C11	Same as LE-C11 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C11 in ASME/ANS RA-Sa-2009 [1].	
LLE-C12	Same as LE-C12 in ASME/ANS RA-Sa-2009 [1]. No requirement.	Same as LE-C12 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C12 in ASME/ANS RA-Sa-2009 [1].
LLE-C13	Same as LE-C13 in ASME/ANS RA-Sa-2009 [1].	Same as LE-C13 in ASME/ANS RA-Sa-2009 [1].	

NOTE:
(1) These screening criteria may be applied to individual core damage sequences as well as entire plant damage states (PDSs) or POSs provided the criteria can be shown to apply to the entire PDS or POS. This requirement is related to and builds on LLE-C1.

Table 3.2.8-2(d) Supporting Requirements for HLR-LLE-D

The accident progression analyses shall include an evaluation of the containment structural capability for those containment challenges that would result in a large early release (HLR-LLE-D).

Index No. LLE-D	Capability Category I	Capability Category II	Capability Category III
LLE-D1	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].
LLE-D2	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].
LLE-D3	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1] [see Notes (1) and (3)].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1] [see Notes (1) and (3)].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1] [see Notes (1) and (3)].
LLE-D4	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1].
LLE-D5	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1].
LLE-D6	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1].	Same as LE-D1 in ASME/ANS RA-Sa-2009 [1].

Table 3.2.8-2(d) Supporting Requirements for HLR-LLE-D (Cont'd)

Index No. LLE-D	Capability Category I	Capability Category II	Capability Category III
LLE-D7	PERFORM containment isolation analysis in a **conservative** manner. INCLUDE consideration of operator actions required to establish containment closure and time available and time required for closure, and of both the failure of containment isolation systems to perform properly, and the status of safety systems that do not have automatic isolation [see Notes (4) and (5)].	PERFORM containment isolation analysis in a **realistic** manner **for the significant accident progression sequences resulting in a large early release. USE conservative or a combination of conservative or realistic treatment for the non-significant accident progression sequences resulting in a large early release.** INCLUDE consideration of operator actions required to establish containment closure and time available and time required for closure considering the time evacuation is declared and the time of RCS boiling, and of both the failure of containment isolation systems to perform properly, and the status of safety systems that do not have automatic isolation [see Notes (4) and (5)].	PERFORM containment isolation analysis in a realistic manner. INCLUDE consideration of operator actions required to establish containment closure and time available and time required for closure considering the time evacuation is declared and the time of RCS boiling, and of both the failure of containment isolation systems to perform properly, and the status of safety systems that do not have automatic isolation [see Notes (4) and (5)].

NOTES:

(1) The containment may be open or have a reduced pressure capability during shutdown. The calculation of containment capacity will be associated with the capacity of temporary closures for certain POSs.

(2) Not used.

(3) Containment failures below ground level may not be a large early release even if the timing is early. Such failures may arise as a result of failures in the basemat region.

(4) This requirement is the same as LE-D7 in ASME/ANS RA-Sa-2009 [1] except for the addition of the need to consider operator action and closure time for containment status during shutdown POSs.

(5) The closure time following RCS boiling with an open RCS may depend on environmental impacts such as fog, noise, humidity, temperature, and radiation or on the presence of obstructions in the way of the closure path.

Table 3.2.8-2(e) Supporting Requirements for HLR-LLE-E

The frequency of different containment failure modes leading to a large early release shall be quantified and aggregated (HLR-LLE-E).

Index No. LLE-E	Capability Category I	Capability Category II	Capability Category III
LLE-E1	Same as LE-E1 in ASME/ANS RA-Sa-2009 [1].		
LLE-E2	Same as LE-E2 in ASME/ANS RA-Sa-2009 [1].	Same as LE-E2 in ASME/ANS RA-Sa-2009 [1].	Same as LE-E2 in ASME/ANS RA-Sa-2009 [1].
LLE-E3	Same as LE-E3 in ASME/ANS RA-Sa-2009 [1].	INCLUDE as LERF contributors potential large early release (LER) sequences identified from the results of the accident progression analysis of LLE-C except those LER sequences justified as non-LERF contributors in LLE-C1a and LLE-C1b.	Same as LE-E3 in ASME/ANS RA-Sa-2009 [1].
LLE-E4	QUANTIFY LERF in a manner consistent with the applicable requirements in Tables 3-2.7-2(a), 3-2.7-2(b), and 3-2.7-2(c) except now for LERF.		

Table 3.2.8-2(f) Supporting Requirements for HLR-LLE-F

The quantification results shall be reviewed, and significant contributors to LERF such as plant damage states, containment challenges, and failure modes shall be identified. Sources of model uncertainty and related assumptions shall be identified, and their potential impact on the results understood (HLR-LLE-F).

Index No. LLE-F	Capability Category I	Capability Category II	Capability Category III
LLE-F1	Same as LE-F1 in ASME/ANS RA-Sa-2009 [1].	**PERFORM a quantitative evaluation of the relative contribution to LERF from plant damage states and significant LERF contributors from Table 3.2.8-3.**	
LLE-F2	Same as LE-F2 in ASME/ANS RA-Sa-2009 [1].		
LLE-F3	IDENTIFY and CHARACTERIZE the LERF sources of model uncertainty and related assumptions in a manner consistent with the applicable requirements of Tables 3-2.7-2(d) and 3-2.7-2(e) except now for LERF.		

Table 3.2.8-2(g) Supporting Requirements for HLR-LLE-G

The documentation of the LERF analysis shall be consistent with the applicable supporting requirements (HLR-LLE-G).

Index No. LLE-G	Capability Category I	Capability Category II	Capability Category III
LLE-G1	Same as LE-G1 in ASME/ANS RA-Sa-2009 [1].		
LLE-G2	Same as LE-G2 in ASME/ANS RA-Sa-2009 [1].		
LLE-G3	Same as LE-G3 in ASME/ANS RA-Sa-2009 [1].		
LLE-G4	Same as LE-G4 in ASME/ANS RA-Sa-2009 [1].		
LLE-G5	Same as LE-G5 in ASME/ANS RA-Sa-2009 [1].		
LLE-G6	Same as LE-G6 in ASME/ANS RA-Sa-2009 [1].		
LLE-G7	DOCUMENT the screened-out core damage sequences, plant damage states, and POSs, and include the technical justification.		

Table 3.2.8-3 Containment Failure or Bypass Events to Be Considered as LERF Contributors

	Containment Design				
Contributor	**Large Dry & Subatmospheric**	**Ice Condenser**	**BWR Mark I**	**BWR Mark II**	**BWR Mark III**
Containment isolation failure	x	x	x	x	x [see Note (1)]
Containment Bypass					
(a) ISLOCA	x	x	x	x	x
(b) SGTR	x	x	. . .	. . .	. . .
(c) Induced SGTR	x	x	. . .	. . .	. . .
(d) Induced ISLOCA	x	x	. . .	x	x
(e) Isolation condenser tube rupture	. . .	. . .	x (if applicable)	x (if applicable)	. . .
Energetic containment failures					
(a) HPME	x	x	x	x	x
(b) Hydrogen combustion	. . .	x	x [see Note (2)]	x [see Note (2)]	x
RPV vertical displacement due to blowdown forces [see Note (3)]	x	x	. . .	. . .	. . .
Core debris impingement [see Note (4)]	x	x	x		
Steam explosion [see Note (5)]	x	x	x	X	x
Shell melt-through	. . .	. . .	x (if applicable)	x (if applicable)	. . .
Pressure suppression bypass [see Note (6)]	. . .	x	x	X	x
RPV and/or containment venting	x (if applicable)	x (if applicable)	x	X	x
Vacuum breaker failure	. . .	. . .	x	X	x

Table 3.2.8-3 Containment Failure or Bypass Events to Be Considered as LERF Contributors (Cont'd)

	Containment Design				
Contributor	**Large Dry & Subatmospheric**	**Ice Condenser**	**BWR Mark I**	**BWR Mark II**	**BWR Mark III**
Hydrodynamic loads under severe accident conditions	. . .	. . .	x	X	x
Over-pressure failure due to increases in quasi-static pressure (i.e., steam and non-condensable gas content) combined with increased atmosphere temperature	x	x	x	X	x
Mechanical and electrical penetration failure	x	x	x	X	x
Leakage at hatches (includes leakage past degraded seals)	x	x	x	X	x

GENERAL NOTE: Combinations of contributors are to also be considered where appropriate.

NOTES:
(1) Drywell (DW) isolation failure.
(2) Combustion within the containment might be precluded during at-power operation when the primary containment is inerted.
(3) This failure mode is caused by the upward reaction forces accompanying RPV lower head failure at high pressure. Displacement of the RPV and attached piping can cause damage to piping penetrations and other containment structures.
(4) Refers to direct contact between molten core debris and a thin-walled (steel) containment shell.
(5) Steam explosion challenges are generally of low probability.
(6) Ice bed bypass for ice condensers (PWRs) and suppression pool bypass for BWRs.

3.3 Peer Review for Internal Events LPSD PRA

3.3.1 Purpose

This section provides requirements for peer review of a Level 1 and LERF Internal Events LPSD PRA.

NEI-00-02 [26] provides an example of an acceptable review methodology for full power conditions. However, the differences between the SRs of the Technical Requirements section of each respective section of this standard and the supporting requirements of Appendix B of NEI-00-02 shall be evaluated. This evaluation shall be documented.

NEI-05-04 [27] provides another example of an acceptable review methodology. NEI-05-04 references the Technical Requirements of Part 2 of [1].

3.3.2 Peer Review Team Composition and Personnel Qualifications

In addition to the general requirements in Section 1.6, the peer-review team shall have combined experience in the areas of systems engineering, plant operations, fault and event tree modeling, thermal hydraulic analysis, data analysis, HRA, and severe accident phenomenology. The team members assigned to review the HRA and LERF Analysis shall have experience specific to these areas and be capable of recognizing the impact of plant-specific features on the analysis.

3.3.3 Review of PRA Elements to Confirm the Methodology

3.3.3.1 Initiating Event Analysis (LIE)

The entire initiating event analysis shall be reviewed.

3.3.3.2 Accident Sequence Analysis (LAS)

A review shall be performed on selected accident sequences. The portion of the accident sequences selected for review typically includes:

(a) accident sequence model for a loss of RHR cooling while at reduced inventory;
(b) the accident sequence model containing LOOP/Station Blackout considerations;
(c) accident sequence model for a loss of a support system initiating event;
(d) LOCA accident sequence model, especially for human-induced LOCAs;
(e) ISLOCA accident sequence model;
(f) the SGTR accident sequence model (for PWRs only);
(g) reactivity insertions accident sequence model;
(h) cold overpressure-induced accident sequence model.

3.3.3.3 Success Criteria (LSC)

A review shall be performed on success criteria definitions and evaluations. The portion of the success criteria selected for review typically includes:

(a) the definition of core damage used in the success criteria evaluations and the supporting bases;
(b) the conditions corresponding to a safe, stable state;
(c) the core and containment response conditions used in defining LERF and supporting bases;

(d) the core and containment system success criteria used in the LPSD PRA for mitigating each modeled initiating event;
(e) the generic bases (including assumptions) used to establish the success criteria of systems credited in the LPSD PRA and the applicability to the modeled plant for each POS;
(f) the plant-specific bases (including assumptions) used to establish the system success criteria of systems for each POS credited in the LPSD PRA;
(g) calculations performed specifically for the LPSD PRA for each computer code used to establish core cooling or decay heat removal success criteria and accident sequence timing;
(h) calculations performed specifically for the LPSD PRA for each computer code used to establish support system success criteria (e.g., a room heat-up calculation used to establish room cooling requirements or a load shedding evaluation used to determine battery life during an SBO);
(i) expert judgments used in establishing success criteria used in the LPSD PRA.

3.3.3.4 Systems Analysis (LSY)

A review shall be performed on the systems analysis. The portion of system models selected for review typically includes a sample of the systems where failure contributes to significant sequences (CDF or LERF), including:

(a) different models reflecting different levels of analysis detail;
(b) front-line system for each mitigating function (e.g., reactivity control, coolant injection, and decay heat removal);
(c) each major type of support system (e.g., electrical power, cooling water, instrument air, and HVAC);
(d) complex systems with variable success criteria (e.g., a cooling water system requiring different numbers of pumps for success dependent upon whether non-safety loads are isolated).

3.3.3.5 Human Reliability Analysis (LHR)

A review shall be performed on the human reliability analysis. The portion of the HRA selected for review typically includes a sample of the human failure events whose failure contributes to significant sequences (CDF or LERF), including:

(a) the selection and implementation of any screening HEPs used in the PRA;
(b) post-accident HFEs and associated HEPs;
(c) pre-initiator HFEs and associated HEPs for both instrumentation miscalibration and failure of equipment;
(d) at-initiator human failure events and associated HEPs;
(e) HEPs for the same function but under the influence of different PSFs, including for different POSs;
(f) HEPs for dependent human actions, including dependencies of multiple HEPs in the same sequence;
(g) HEPs less than 1×10^{-4};
(h) HFEs and associated HEPs involving remote actions in harsh environments;
(i) the selection and identification of the HFEs associated with the HEPs for the above review topics.

3.3.3.6 Data Analysis (<u>LDA</u>)

A review shall be performed on the data analysis. The portion of the data analysis selected for review typically includes:

- *(a)* data values and associated component boundary definitions for component failure modes (including those with high importance values) contributing to the CDF or LERF calculated in the <u>LPSD</u> PRA;
- *(b)* common cause failure values;
- *(c)* the numerator and denominator for one data value for each major failure mode (e.g., failure to start, failure to run, and test and maintenance unavailabilities);
- *(d)* equipment repair and recovery data;
- *(e)* <u>the influence of POS on all of the above.</u>

3.3.3.7 Quantification (<u>LQU</u>)

Level 1 quantification results shall be reviewed. The portion of the Level I quantification process selected for review typically includes:

- *(a)* appropriateness of the computer codes used in the quantification;
- *(b)* the truncation values and process <u>to quantify each POS and aggregate;</u>
- *(c)* the recovery analysis;
- *(d)* model asymmetries and sensitivity studies;
- *(e)* the process for generating modules (if used);
- *(f)* logic flags (if used);
- *(g)* the solution of logic loops (if appropriate);
- *(h)* the summary and interpretation of results.

3.3.3.8 LERF Analysis (<u>LLE</u>)

The LERF analysis and the Level I/LERF interface process shall be reviewed.

The portion of Level 1 and LERF interface process selected for a detailed review typically includes:

- *(a)* accident characteristics chosen for carryover to LERF analysis (and for binning of PDSs if PDS methods were used);
- *(b)* interface mechanism used;
- *(c)* CDF carryover.

The portion of the LERF analysis selected for review typically includes:

- *(a)* the LERF analysis method;
- *(b)* demonstration that the phenomena that impact radionuclide release characterization of LERF have been appropriately considered <u>for each POS;</u>
- *(c)* human action and system success considering adverse conditions that would exist following core damage;
- *(d)* the sequence mapping;
- *(e)* evaluation of containment performance under severe accident conditions <u>including conditions when the equipment hatch is initially removed</u> or partially bolted;
- *(f)* the definition and bases for LERF;

(g) inclusion in the containment event tree of the function events necessary to achieve a safe stable containment end state;
(h) sensitivity analysis;
(i) the containment response calculations performed specifically for the LPSD PRA, for the significant sequences and plant damage states (if PDS methods are used), and for each POS.

3.3.3.9 POS Analysis (LPOS)

A review shall be performed on the POS analysis. The portion of the POS analysis selected for review typically includes a review of the structured, systematic process to identify and define POSs and a detailed review of a sample of POSs that contribute to significant sequences (CDF or LERF). The review would include:

(a) a review of the plant evolutions selected;
(b) the attributes used to define the set of POSs;
(c) the set of POSs and their attributes for each selected plant evolution, including decay heat levels, frequencies, and durations;
(d) the process of screening out and grouping POSs for analysis;
(e) a review to determine if the set of POSs supports the analysis of all hazard groups and that the POS grouping schemes do not mask significant contributors.

Appendix 3.A (Non-Mandatory) Risk Metric Calculation Methodology

3.A.1 Purpose

The purpose of this appendix is to describe a method that can be used to determine the combined risk produced by multiple POSs when the risk from each individual POS has been determined. This method can be applied when the risk from each POS is expressed using the same risk metric. The risk metric may, for example, be time-averaged core damage frequency or time-averaged large early release frequency. Here the time-averaged frequencies must account for the average fraction of time spent in each POS and, for some demand-based initiators, also account for the frequency per year at which such POSs are entered. There is not one "average" LPSD evolution. Rather, an average LPSD evolution of each LPSD evolution type is one whose POS durations in a reactor year are consistent with the data from plant operation over many years from all LPSD evolutions of that same type. LPSD evolution types are described in Part 2 and non-mandatory Appendix 2.A.

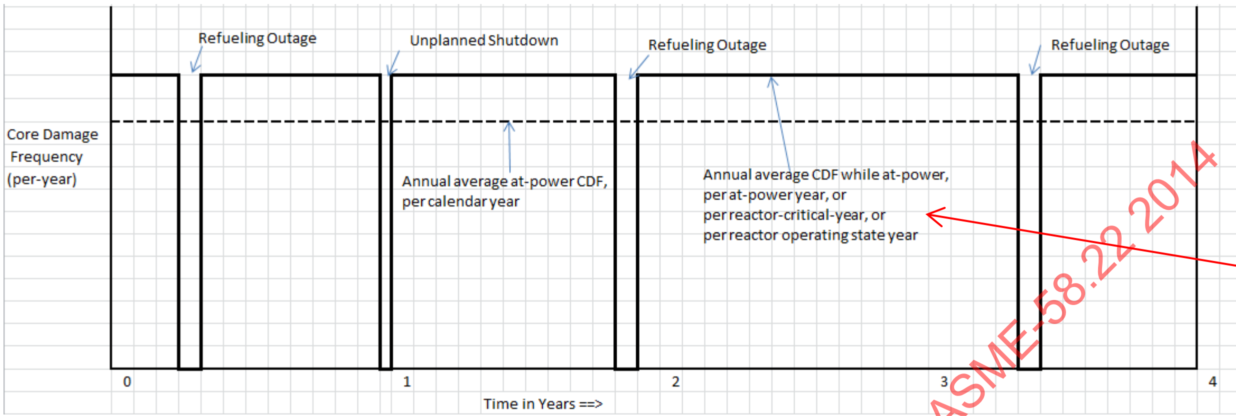
In assessing risk from full power operation, Reference [1] defines a year variously to mean a "reactor year" (i.e., a calendar year in the operating life of one reactor regardless of power level, which can be thought of as an average year with respect to the plant availability) or a "reactor operating state year" (i.e., an equivalent calendar year of operation assuming the plant is always in a particular POS). This standard requires the calculation of initiating event frequencies on a "per calendar year" basis for use in computing the time-averaged CDF or LERF (see Table 3.2.1-4) consistent with [1].

For full power PRAs, this distinction (between reactor year, which was defined equivalently to a calendar year in [1], and reactor operating state year) is not always made since the plant is typically operating for a large fraction of a year. However, for conformance with Supporting Requirement LIE-C5 in [1], the plant availability factor must be included, even for at-power conditions. The resulting CDF is an unconditional CDF for a calendar year in the sense that it can be added to the unconditional CDF for each of the other POSs to obtain the total CDF for the plant summed over all POSs for all LPSD evolution types.

This appendix discusses the use of risk metrics to represent risk specifically when multiple POSs are involved, as is the case with LPSD evolutions. It is important to clearly distinguish the units of risk metrics since POSs can have short durations. Thus, the CDF for a "calendar year" and the CDF for a "reactor-operating-state-year" (i.e., one year with the plant conditions meeting the definition of the POS) will be quite different. The implications of this are illustrated in the following section using CDF as the example risk metric; however, the concepts apply equally to LERF or any other risk metric.

3.A.2 Terms Used in Describing Risk Profiles

Figure 3.A-1 illustrates an example risk profile for CDF for at-power conditions.



Throughout this section we refer to CDF as the risk measure, although the discussion is equally valid for large early release frequency or alternative risk measures. The examples shown in this section are for PWRs, but the insights illustrated are applicable to BWRs.

During any calendar year, there can be plant outages in which the plant is shutdown and therefore not contributing to at-power risk. These outages generally fall into two categories, planned refueling outages and unplanned outages. In Figure 3.A-1, three regularly scheduled refueling outages are shown within a four calendar-year period. Also illustrated is a single unplanned shutdown that could occur at any time, but for this illustration takes place only in the first of the four years shown. For time-averaged CDF during at-power conditions, CDF is averaged over the entire period that the reactor is at-power (not just over one specific year or the four years illustrated, but rather over all the years for which data is available). The CDF shown by the horizontal part of the solid line in Figure 3.A-1 is also referred to as CDF per at-power year, CDF per reactor critical year, or CDF per reactor operating state year.

The risk while at-power is shown as the horizontal line. For this initial discussion, we neglect for now the fact that this risk also varies as equipment is taken out of service while the plant is at-power. As a result, it is shown as a constant value for the periods while the plant is at-power. Of course, the at-power risk drops to zero during plant shutdowns. The proportion of the CDF from both at-power and shutdown periods can be averaged to give the annual average CDF per calendar year from at-power conditions only, as represented by the dashed line in Figure 3.A-1. This can be conceptually achieved by scaling down the annual average CDF while at-power by the proportion of the calendar year that the plant is actually at-power, on average, i.e., by excluding the periods that the reactor is shutdown.

In practice, an indirect method is used to accomplish the above. Time-averaged at-power CDF models first determine the average frequency per calendar year for each initiating event and, these initiating event frequencies are then used directly in evaluating the core damage sequence frequencies for at-power conditions. The sequence frequencies are then totaled to give the annual average CDF per calendar year. Please refer to the footnote to Table 2.2.1-4(c) of reference [1] for a discussion of the approach for different types of initiating events. Once the annual average, at-power CDF per calendar-year (i.e., the dashed line) is known, the annual average CDF while at-power, as represented by the solid horizontal line in Figure 3.A-1, can be easily computed by dividing the dashed line frequency by the fraction of time the reactor is, on average, at-power.

For annual average at-power CDF per calendar year, the models generally consider a single POS that corresponds to the nominal conditions for the reactor at-power. The CDFs from periods of time when the reactor is shutdown are excluded. Test and maintenance conditions that are allowed at-power are averaged over time for the single POS by assuming they may occur randomly at any time at-power, although some models do link together planned maintenance and test events, such as when a rolling maintenance schedule is regularly implemented. Only one annual averaged CDF is evaluated for this single POS and is applicable whenever the reactor is at-power.

Figure 3.A-2 illustrates an example time-varying risk profile for CDF for one week while at-power.

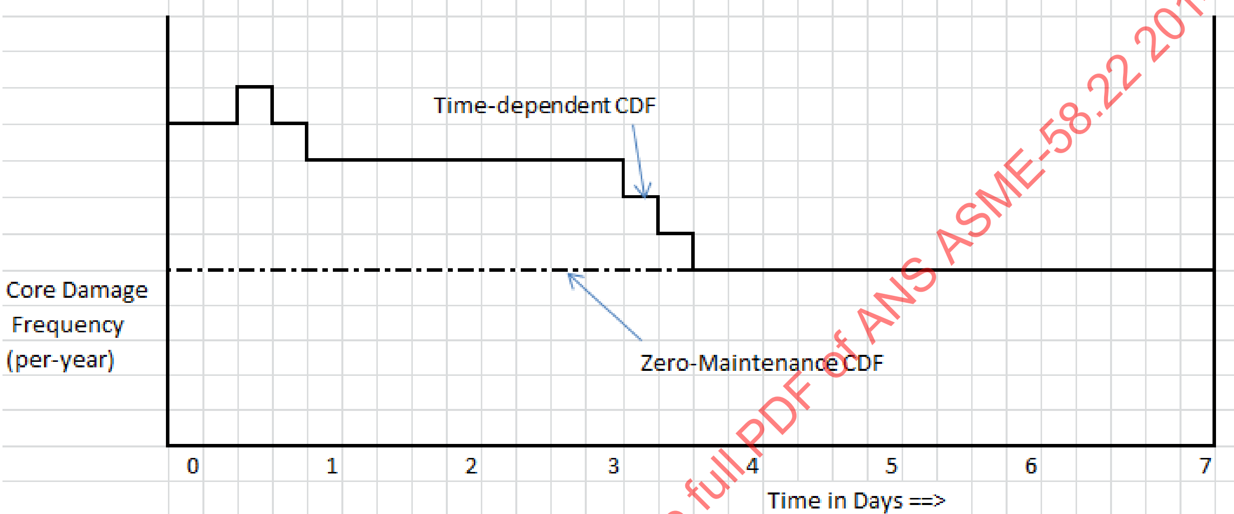


Figure 3.A-2 Time-Dependent CDF profile for At-Power

For this profile, specific maintenance and test events are evaluated as they occur on the timeline rather than occurring probabilistically throughout the period, as in Figure 3.A-1. We see that planned maintenance occurs in the first part of the week, but that all equipment is restored to service by day four. The events used in the time-averaged model to represent the probabilistic occurrence of maintenance and test alignments are removed from the evaluation. Such calculations are performed to support configuration risk management. Separate CDF evaluations are performed for each set of plant conditions of specific equipment alignments and equipment outage maintenance and tests. We refer to the different states of planned maintenance and tests in this standard as plant configurations. Each plant configuration represents the same plant conditions that define the at-power POS (e.g., RCS conditions, success criteria) but differ in that specific equipment alignments and equipment outages are evaluated as they occur in time, thereby defining a new plant configuration. A separate CDF evaluation is performed for each plant configuration resulting in the time-dependent staircase plot of CDF shown. If the plant configuration includes no test or maintenance conditions, then its associated CDF is expected to be lower than the solid line shown in Figure 3.A-1 since taking equipment out of service for test or maintenance generally increases the CDF. Such a plot is often called the time-dependent CDF for the period of time evaluated. It is also sometimes called the instantaneous CDF, but we avoid that term in this standard.

Since the time-dependent profile in Figure 3.A-2 is for at-power risk, the time-dependent CDF would drop to zero during outages. If the time-dependent CDF for at-power conditions is averaged over one year, the result is said to be the average at-power CDF for that year only. If several such plots are averaged over many years, the end result is expected to approximate the annual average at-power CDF per calendar year shown as the dashed line in Figure 3.A-1.

Now consider the evaluation of CDF for the conditions during shutdown. Figure 3.A-3 illustrates the POS-dependent average CDF for a typical refueling shutdown that starts when the reactor is tripped and ends with a restoration to power after 35 days. Early and later periods at mid-loop operation, which have relatively high risk, are separated by many days of low risk during refueling operations while at flooded up conditions and many days at very low risk when the entire core is offloaded to the spent fuel pool.

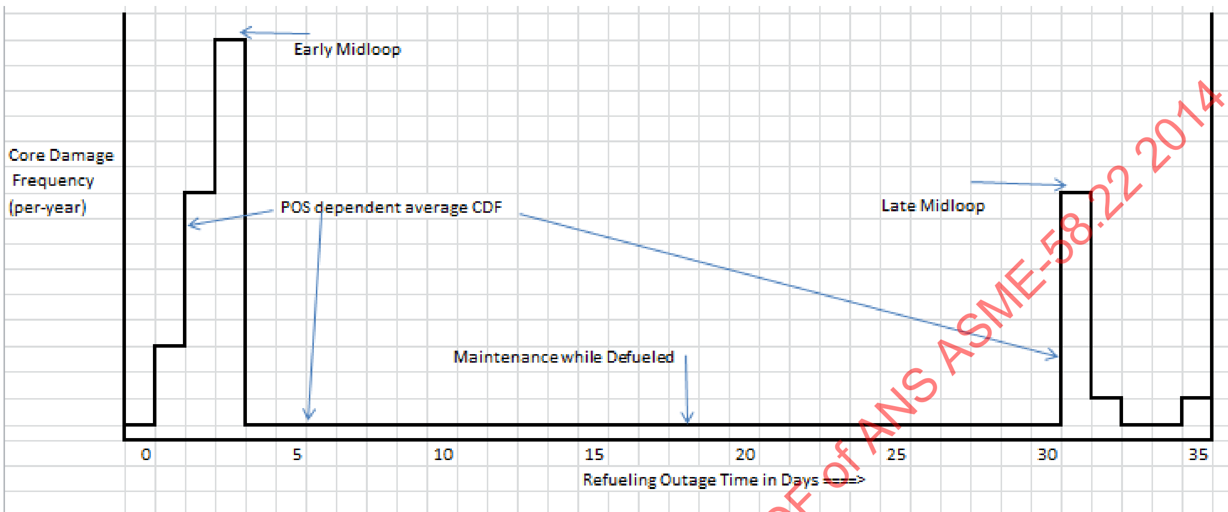


Figure 3.A-3 CDF per POS year for Average Refueling Evolution

Each break in the staircase plot of Figure 3.A-3 corresponds to an average CDF estimate for a different POS, where all POSs together represent the entire refueling plant evolution. A single average CDF is computed for each POS, just as the solid curve in Figure 3.A-1 is for the single at-power POS. The plot in Figure 3.A-3 is again a time-averaged CDF in the sense that unplanned equipment tests and maintenance activities permitted within each POS are probabilistically averaged over each individual POS; i.e., effectively, the conditions within a POS are assumed constant. The duration of each POS is also the average over the historical data for similar refueling outage conditions for that POS. For shutdown, the different core damage frequencies are referred to as the time-averaged CDF per POS year, i.e., the probability of core damage if the POS duration lasted a full year. While the time-averaged CDF of all POSs for the refueling outage shown in Figure 3.A-3 together present a CDF time-profile, we avoid calling this plot the time-dependent CDF for the refueling outage because it only consists of the average CDF of each POS and not the CDF of individual plant configurations within each POS, i.e., where the time-dependent profile is more finely divided.

The time-averaged core damage probability for the entire refueling outage can be obtained by weighting the POS-dependent CDF evaluated for a POS year by the average duration of each POS and summing over all POSs in the refueling outage. This sum yields the average core damage probability per refueling outage. To obtain the contribution of plant refueling evolutions to time-averaged CDF per calendar year, we then only need multiply the time-averaged core damage probability for an average refueling outage by the frequency of refueling outages per calendar year to obtain the time-averaged CDF from refueling outages per calendar year. This result is analogous to the frequency of the dashed line in Figure 3.A-1 for the contribution of the at-power POS to time-averaged CDF per calendar year.

The contributions to time-averaged CDF per calendar year of other types of LPSD evolutions are developed in the same way as described above for refueling outages. The time-averaged CDF per POS year is first developed for each POS in the LPSD evolution. The contribution of each POS is weighted by the average POS duration and summed, and the resulting time-averaged core damage probability per LPSD evolution occurrence is then weighted by the frequency of the LPSD evolution per calendar year.

Figure 3.A-4 illustrates an example time-dependent risk profile for CDF for a portion of the refueling outage.

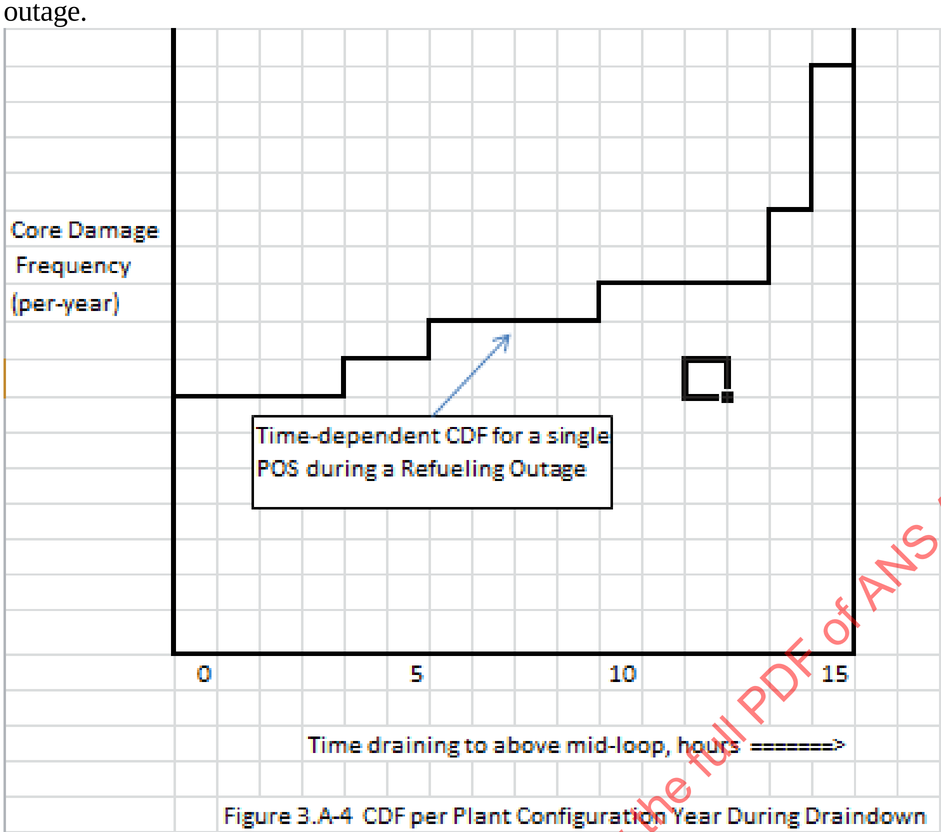


Figure 3.A-4 CDF per Plant Configuration Year During Draindown

For illustration, we select the time interval when the RCS is initially solid and vented until the RCS is drained to just above mid-loop conditions. We assume this time interval corresponds to a single POS in the time-averaged model. As with the approach to risk management for at-power conditions, for LPSD evolutions, additional plant conditions are considered, resulting in a number of plant configurations within the single POS. These plant configurations are then each evaluated for CDF; e.g., the added conditions may be varying RCS levels or times after shutdown. Instead of a specific operator response time for the entire POS duration, a refined set of plant configurations within this POS (e.g., for different times during the drain down) may then be used to more accurately account for the time available for those operator actions that may be important for this POS. The CDF for plant configurations closer to the completion of the drain down, when the time available to respond to a loss of RHR would be shorter, may then be elevated. Again, a separate CDF evaluation is performed for each plant configuration, resulting in the time-dependent staircase plot of CDF shown in Figure 3.A-4. Each frequency result in the time-dependent profile represents the CDF for a plant configuration for a duration of one year. Such a plot is often called the time-dependent CDF profile for the period of time evaluated. Such a profile is not averaged because separate plant configurations are instead used to represent changing system alignments and equipment out of service times for the specific LPSD evolution.

Similar plots of CDF for successive plant configurations within a POS may be evaluated for each POS of an LPSD evolution. By weighting the time-dependent CDF per plant configuration year by each plant configuration's actual duration, one obtains the probability of core damage for the specific LPSD evolution modeled. A time-averaged CDF for the type of LPSD evolution modeled (e.g., for refueling outages) could be developed once the frequency of such LPSD evolutions was established and a representative set evaluated. If several such LPSD evolutions are averaged over many years, the end result is expected to approximate the annual average CDF per calendar year for the type of LPSD evolution evaluated.

3.A.3 CDF per Calendar Year for Low Power and Shutdown Conditions

The CDF per calendar year for each POS is obtained by summing the time-averaged frequencies of each core damage sequence that may initiate while in that POS. The core damage sequence frequencies are in turn made up of the product of each sequence's initiator frequency and the conditional probabilities of plant equipment and operator responses that lead to the final consequence state. The plant response probabilities are dimensionless, whereas the initiator frequencies must be evaluated in annual average events per calendar year.

There are two general types of initiators: time-based (n) and demand based (m).

The time-based initiator frequencies are proportional to the duration of time spent in the corresponding POS of a given evolution type. The equation for the initiator portion of the sequence frequency is

$$\Lambda_{n,j,i} = f_{EVO(j)} \times P_{\mathrm{POS}(i,j)} \times t_{\mathrm{POS}(i,j)} \times \lambda_{hr,n,j,i}, \qquad \text{A.1}$$

where:

$\Lambda_{n,j,i}$ = frequency of time-based initiator n during evolution type j while in POS i expressed in units of annual average events per calendar year;

$f_{EVO(j)}$ = frequency of evolution type j in evolutions per calendar year;

$P_{\mathrm{POS}(i,j)}$ = probability of entering POS i given evolution type j;

$t_{\mathrm{POS}(i,j)}$ = average duration of POS i for evolution type j in hours; and

$\lambda_{hr,n,j,i}$ = initiator n frequency per hour of exposure while in evolution j and POS i.

The product, $f_{EVO(j)} \times P_{\mathrm{POS}(i,j)} \times t_{\mathrm{POS}(i,j)}$, is the average annual hours of exposure to the initiator n during POS i in evolution type j per calendar year.

The quantity $P_{\mathrm{POS}(i,j)}$ is either 1.0 or 0.0 depending on whether the evolution type j includes POS i.

Note that $t_{\mathrm{POS}(i,j)}$ can also be expressed as

$$t_{\mathrm{POS}(i,j)} = t_{EVO(j)} \times f_{\mathrm{POS}(i,j)} = t_{EVO(j)} \times (t_{\mathrm{POS}(i,j)}/\Sigma_i\, t_{\mathrm{POS}(i,j)}),$$

where the sum is over all POSs i that are part of evolution type j, and:

$t_{\mathrm{POS}(i,j)}$ = average duration of POS i for evolution type j in hours;

$t_{EVO(j)}$ = average duration of entire evolution j; and

$f_{\mathrm{POS}(i,j)}$ = fraction of time spent in POS i during evolution j.

The form used for $t_{\mathrm{POS}(i,j)}$ depends on how the evolution POS duration data are collected or estimated by experts and interpreted.

Demand-based initiator (m) frequencies are not proportional to the duration of time spent in the corresponding POS i, but rather to the frequency of each POS i and the number of challenges in POS i. For demand-based initiators, the equation for the initiator portion of the sequence frequency is then

$$\Lambda_{m,j,i} = f_{EVO(j)} \times P_{\mathrm{POS}(i,j)} \times N_{d,m} \times Q_{d,m,j,i}, \qquad \text{A.2}$$

where:

$\Lambda_{m,j,i}$ = frequency of demand-based initiator m during evolution type j in POS i expressed in units of annual average events per calendar year;

$Q_{d,m,j,i}$ = initiator m occurrence probability per demand for evolution type j and POS i;

$f_{EVO(j)}$ = frequency of evolution type j in evolutions per calendar year;

$P_{\mathrm{POS}(i,j)}$ = probability of POS i given evolution type j; and

$N_{d,m}$ = number of challenges to demand-based initiator m during POS(i,j).

The product $f_{EVO(j)} \times P_{\mathrm{POS}(i,j)} \times N_{d,m}$ is the annual average of challenges to the initiator m during *POS i* in evolution type j per calendar year.

The quantity $P_{\mathrm{POS}(i,j)}$ is either 1.0 or 0.0 depending on whether the evolution type j includes POS i.

Often, the number $N_{d,m}$ is equal to 1.0. It is possible, however, that a single POS would involve more than one demand-based challenge, e.g., when more than one drain down is planned in the same POS. Of course, it would be better practice to subdivide such a POS so that each drain-down activity was in a separate POS.

The initiator frequencies expressed in Eqs. A.1 and A.2 are then multiplied with the individual plant response probabilities (which are dimensionless) conditional on the occurrence of the initiator to quantify the frequencies of the associated sequences resulting in core damage or other consequence end states as determined by the risk metric. The resulting core damage sequence frequencies are then also expressed in time-averaged core damage events per calendar year.

Since the POSs and evolution types are defined exclusively, the sum of the core damage sequence frequencies for each POS i and evolution type j then leads to the total time-averaged CDF per calendar year from low power and shutdown conditions. These totals can then be combined with the time-averaged CDF from full power events, which are also exclusive of the low power and shutdown POSs (see below), by a straight summation.

For the time-averaged CDF for a specific POS i in evolution type j, the formula for the sum of such sequence frequencies is

$$\mathrm{CDF}\ (i,j) \ = \ \Sigma_n \{\Lambda_{n,j,i} \times \Sigma_x\ (\mathrm{SEQ}(x,n,j,i))\} + \ \Sigma_m \{\Lambda_{m,j,i} \times \Sigma_y\ (\mathrm{SEQ}\ (y,m,j,i))\},$$

where:

(a) the sums are over all core damage sequences x and y for each initiator n or m, where the initiators are either time-based or demand based;

(b) SEQ(x,n,j,i) are the conditional probabilities of core damage for each sequence x given time-based initiator $\Lambda_{n,j,i}$ for the same evolution j and POS i; and

(c) SEQ(y,m,j,i) are the conditional probabilities of core damage for each sequence y given demand-based initiator $\Lambda_{m,j,i}$ for the same evolution j and POS i.

The total time-averaged CDF for all low power and shutdown conditions is then obtained by summing over all POSs i for each evolution j:

$$CDF_{LPSD} = \Sigma_j \Sigma_i [CDF(i,j)]$$

3.A.4 Time-Averaged CDF per Calendar Year for Full Power Conditions

For full power conditions, there is no LPSD evolution; thus, the Initiator Frequency Eqs. A.1 and A.2 must be modified.

The time-based initiator frequencies are proportional to the duration of time spent at full power, $t_{full\ power}$. The equation for the initiator portion of the sequence frequency is

$$\Lambda_n = t_{full\ power} \times \lambda_{hr,n} = 8766\ (hr/yr) \times A \times \lambda_{hr,n}, \qquad A.3$$

where:

Λ_n = frequency of time-based initiator n while at full power expressed in units of time-averaged events per calendar year;

A = plant average availability fraction; and

$\lambda_{hr,n}$ = initiator n frequency per hour of exposure while at full power.

The product, 8766 (hr/yr) × A, is the average annual hours of exposure to the initiator n while at full power ($t_{full\ power}$) per calendar year.

For demand-based initiator frequencies while at full power, they are again not proportional to the duration of time spent at full power, but rather to the average number of challenges per year while at full power. For demand-based initiators, the equation for the initiator portion of the sequence frequency is

$$\Lambda_m = t_{full\ power} \times N_{d,m} \times Q_{d,m} = 8766\ (hr/yr) \times A \times N_{hr,m} \times Q_{d,m}, \qquad A.4$$

where:

Λ_m = frequency of demand-based initiator m while at full power expressed in units of time-averaged events per calendar year;

$Q_{d,m}$ = initiator m occurrence probability per demand while full power;

$N_{hr,m}$ = number of challenges to demand based initiator m while at full power expressed as challenges per hour; and

A = plant average availability fraction.

The product, 8766 (hr/yr) × A × $N_{hr,m}$, is the time-average of challenges to the initiator m while at full power per calendar year.

Often, the number $N_{hr,m}$ is defined by test frequencies. For example, inadvertent turbine-trip events caused by problems during turbine-trip valve testing would generally be proportional to the test frequency. Often, however, the turbine-trip frequency from all causes is grouped into one initiator and instead reported as a time-based event. Equation A.4 could be used for demand-based initiators while at full power (although modeling demand-based initiators is not a current state of practice for full-power PRAs).

With the initiator frequencies for full power conditions developed using Eqs. A.3 and A.4, similar to the core damage sequences for evolutions, the full power time-averaged core damage sequence frequencies per calendar year are obtained by simply multiplying these initiator frequencies by the sequence specific plant response probabilities (which are dimensionless) that lead to the core damage end state. Summing over the resulting sequence core damage frequencies for all such full power core damage sequences leads to the total time-averaged CDF from full power conditions.

For the time-averaged CDF for full power conditions, the formula for the sum of such sequence frequencies is simply

$$\text{CDF}_{\text{full power}} = \Sigma_n\{\Lambda_n \times \Sigma_z(\text{SEQ}(z,n))\} + \Sigma_m\{\Lambda_m \times \Sigma_w(\text{SEQ}(w,m))\},$$

where:

(a) the sums are over all core damage sequences z and w for initiators n and m;

(b) SEQ(z,n) are the conditional probabilities of core damage for each full power sequence z given time-based initiator Λ_n; and

(c) SEQ(w,m) are the conditional probabilities of core damage for each full power sequence w given demand-based initiator Λ_m.

Since the full power conditions are exclusive of low power and shutdown POSs, this subtotal can be directly added to the time-averaged core damage frequencies for low power and shutdown conditions to obtain the total time-averaged CDF from all plant states:

$$\text{CDF}_{\text{TOTAL}} = \text{CDF}_{\text{LPSD}} + \text{CDF}_{\text{full power}}$$

3.A.5 POS-Dependent CDF per Reactor Year for Low Power and Shutdown Conditions

The POS-dependent CDF per calendar year for each POS is obtained by summing the frequencies of each core damage sequence that may initiate while in that POS after dividing out the frequency of entering the POS and dividing out the average duration of the POS if applicable. The POS-dependent CDFs per calendar year for each POS are in turn made up of the product of each sequence's initiator frequency and the conditional probabilities of plant equipment and operator responses that lead to the final consequence state. The plant response probabilities are dimensionless, whereas the initiator frequencies must be evaluated removing the frequency of entering the POS and the POS duration.

Again, we consider the two general types of initiators, time-based and demand-based. Once normalized to POS-dependent risk, the initiator frequencies can again be multiplied by the individual plant response probabilities (which are dimensionless), conditional on the occurrence of the initiator to quantify the POS-dependent frequencies of the associated sequences resulting in core damage or to other consequence end states, as determined by the risk metric.

The POS-dependent time-based initiator frequencies (Eq. A.5) are simply the frequencies of the initiators per hour given that the POS has been entered. The equation for the initiator portion of the POS-dependent sequence frequency is

$$\Lambda I_{n,j,,i} = P_{\mathrm{POS}(i,j)} \times \lambda_{hr,n,j,i} \times 8766, \qquad \text{A.5}$$

where:

$\Lambda I_{n,j,i}$ = POS-dependent frequency of time-based initiator n during evolution type j while in POS i expressed in units of events per reactor-operating-state-year; and

$P_{\mathrm{POS}(i,j)}$ = probability of entering POS i given evolution type j.

The quantity $P_{\mathrm{POS}(i,j)}$ is either 1.0 or 0.0 depending on whether the evolution type j includes POS i.

$\lambda_{hr,n,j,i}$ = initiator n frequency per hour of exposure while in evolution type j and POS i.

The differences between Eqs. A.5 and A.1 are that we have divided out the terms $f_{EVO(j)}$ and $t_{\mathrm{POS}(i,j)}$ and instead scaled the equation by 8766 hours in a year to convert the POS-dependent CDF per hour to events per reactor-operating-state-year.

For demand-based initiator frequencies, we again divide by the frequency of entering the POS and by the number of challenges in each POS. We also divide by one hour to in effect average the demand-based risk over a one-hour period. This one-hour averaging is not widely accepted in the risk community. Instead, the contributions of demand-based initiators are generally not reported to POS-dependent CDF, or some other averaging period is used.

For demand-based initiators, the equation for the initiator portion of the POS dependent sequence frequency is

$$\Lambda I_{m,j,i} = Q_{d,m,j,i} \times 8766 \qquad \text{A.6}$$

where:

$\Lambda I_{m,j,i}$ = POS-dependent frequency of demand-based initiator m during evolution type j;

$Q_{d,m,j,i}$ = initiator m occurrence probability per demand for evolution type j and POS i; and

8766 = hours per calendar year.

The differences between Eqs. A.6 and A.2 are that we have divided out the terms $f_{EVO(j)}$, $P_{\mathrm{POS}(i,j)}$, and $N_{d,m}$, and instead scaled the equation by 8766 hours in a year to convert the POS-dependent CDF per hour to events per year.

Often, the number $N_{d,m}$ is equal to 1.0. It is possible, however, that a single POS would involve more than one demand-based challenge, e.g., when more than one drain down is planned in the same POS. In this case, the POS-dependent demand-based initiator frequency would be reported each time the demand-based challenge occurs; i.e., the POS-dependent CDF would have to vary depending on whether the time reported includes the time of the demand-based activity or not. It is for this reason that configuration risk management models separate the time intervals of demand-based initiators into a separate POS.

The initiator frequencies expressed in Equations A.5 and A.6 are then multiplied with the individual plant response probabilities (which are dimensionless) conditional on the occurrence of the initiator to quantify the frequencies of the associated sequences resulting in core damage, or to other consequence end states as determined by the risk metric. The resulting core damage sequence frequencies are then also expressed in POS dependent, core damage events per calendar year. These POS-dependent core damage sequence frequencies can then be summed to obtain the total low power and shutdown POS-dependent CDF for the given instant in time. The equation for the instantaneous CDF for POS i in evolution j is:

$$\mathrm{CDF}(i,j) = \Sigma_n\{\Lambda I_{n,j,i} \times \Sigma_x(\mathrm{SEQ}(x,n,j,i))\} + \Sigma_m\{\Lambda I_{m,j,i} \times \Sigma_y(\mathrm{SEQ}(y,m,j,i))\},$$

where:

(a) the sums are over all core damage sequences x and y for initiators n and m, respectively, and the initiators are either time-based or demand-based but not both;

(b) SEQ(x,n,j,i) are the conditional probabilities of core damage for each sequence x given time-based initiator $\Lambda I_{n,j,i}$ for the same evolution j and POS i; and

(c) SEQ(y,m,j,i) are the conditional probabilities of core damage for each sequence y given demand-based initiator $\Lambda I_{m,j,i}$ for the same evolution j and POS i.

The above equation assumes that the demand-based initiators occur once per POS, and that we are interested in calculating the highest POS-dependent CDF over the whole POS. If more detail is needed for time points within the POS, then the demand based initiators are included or not depending on the times within the POS when they may be challenged.

3.A.6 Alternative Representation of Initiator Frequencies for Low Power and Shutdown Conditions

The preceding discussion in Sections 3.A.1 through 3.A.3 has described the process of computing CDF for each POS so that the resulting CDF values for each POS can be directly summed to obtain the total time-averaged CDF for all low power and shutdown conditions. The approach of incorporating the frequency of each evolution type j, $f_{EVO(j)}$, the probability of entering POS i given evolution type j, $P_{\mathrm{POS}(i,j)}$, and the average duration of POS i, $t_{\mathrm{POS}(i,j)}$, in the computation of time-based initiator frequencies is one modeling approach.

Some risk analysis software tools instead allow users to enter just the initiator n frequency expressed as the frequency per hour of exposure while in evolution j and POS i, $\lambda_{hr,n,j,i,}$ and the remaining terms are instead included separately in the conditional probabilities of core damage for each sequence x given the time-based initiator. This alternative approach is often easier to incorporate in the model when the initiator frequency per hour of exposure is essentially independent of the specific evolution or POS. This ease is in part because it greatly reduces the total number of initiators that must then be tracked and calculated.

Another alternative is to use the initiator frequency in units of per POS-year. This allows the full-power model to remain essentially unchanged, with the availability factor thought of as the probability of being in the specific POS, full-power in this case. The equation for the initiator portion of the sequence frequency is

$$\Lambda_{n,j,i} = FR_{EVO(j)} \times FR_{\mathrm{POS(i,j)}} \times \lambda_{yr,n,j,i}, \qquad \text{A.7}$$

where:

$\Lambda_{n,j,i}$ = frequency of time-based initiator n during evolution type j while in POS i expressed in units of annual average events per calendar year;

$FR_{EVO(j)}$ = fraction of time in evolution type j = [number of evolutions type j per calendar yr] × [avg hours in evolution type j per evolution type j / 8766 hours per calendar year];

$FR_{POS(i,j)}$ = fraction of time in POS i, given evolution type j = avg hours in POS i / avg hours in evolution type j; and

$\lambda_{hr,n,j,i}$ = initiator n frequency per year of exposure while in evolution j and POS i (per POS-year).

Similarly, for demand-based initiators, the initiator m occurrence probability per demand for evolution type j and POS i, $Q_{d,m,j,i}$, may alone be entered as the initiator frequency in the software. The other terms representing frequency of evolution type j in evolutions per calendar year, $f_{EVO(j)}$, probability of POS i given evolution type j, $P_{\mathrm{POS}(i,j)}$, and number of challenges to demand-based initiator m during POS(i,j), $N_{d,m}$, are again included in the conditional probabilities of core damage for each sequence y given the demand-based initiator.

For initiator frequency in units of per POS-year for demand-based initiators, the equation for the initiator portion of the sequence frequency is then

$$\Lambda_{m,j,i} = FR_{EVO(j)} \times FR_{\mathrm{POS}(i,j)} \times \lambda_{yr,m,j,i}, \quad \text{A.8}$$

where:

$\Lambda_{m,j,i}$ = frequency of demand-based initiator m during evolution type j in POS i expressed in units of annual average events per calendar year;

$FR_{EVO(j)}$ = fraction of time in evolution type j = $f_{EVO(j)} \times DUR_{EVO(j)}$/8766 hrs per calendar year;

$FR_{\mathrm{POS}(i,j)}$= fraction of time in POS i, given evolution type j = $DUR_{\mathrm{POS}(i)} / DUR_{\mathrm{EVO}(j)}$; and

$\lambda_{yr,m,j,i}$ = initiator m frequency per year of exposure while in evolution j and POS i (per POS-year) $= f_{EVO(j)} \times N_{d,m} \times Q_{d,m,j,i} / DUR_{\mathrm{POS}(i)}$,

where:

$f_{EVO(j)}$ = frequency of evolution *type j* in evolutions per calendar year;

$N_{d,m}$ = number of challenges to demand-based initiator m during POS(i,j);

$Q_{d,m,j,i}$ = initiator m occurrence probability per demand for evolution type j and POS i;

$DUR_{EVO(j)}$ = average duration of evolution type j (hrs); and

$DUR_{\mathrm{POS}(i)}$ = average duration of POS i (hrs).

The product $f_{EVO(j)} \times N_{d,m}$ is the annual average of challenges to the initiator m during POS i in evolution type j per calendar year.

This alternative approach to modeling initiator frequencies for LPSD conditions is also acceptable. Both approaches include all the factors needed to represent the contributions to time-averaged CDF per calendar year or to POS-dependent CDF per calendar year for each POS. The overall sequence frequency units and meanings are the same.

Part 4 Requirements for Internal Floods for LPSD (LIF)

4.1 Overview of Internal Flood PRA Requirements for LPSD

This section repeats the language in Part 3 of Reference [1], except as underlined.

4.1.1 PRA Scope

This section establishes technical requirements for a Level 1 and Large Early Release Frequency (LERF) analysis of the internal flood hazard group during LPSD.

4.1.2 Coordination with Other Sections of Standard

This section is intended to be used together with Parts 1, 2, and 3 of this standard. An internal events full power LPSD PRA developed in accordance with Part 3 is the starting point of the development of the flood-induced accident sequence model.

4.1.3 Internal Flood Events Scope

The scope of the flooding events covered in this section includes all floods originating within the plant boundary. It does not include floods resulting from external hazards, e.g., weather, offsite events such as upstream dam rupture, etc.

The overall objective of the internal flood PRA is to ensure that the impact of an internal flood caused by either an accident or a system failure is evaluated in such a way that:

(a) the fluid sources within the plant that could flood plant locations or create adverse conditions (e.g., spray, elevated temperature, humidity, pressure, pipe whip, jet impingement) that could damage mitigative plant equipment are identified; and

(b) the internal flood scenarios/sequences that contribute to the core damage frequency and large early release frequency are identified and quantified.[10]

4.2 Internal Flood PRA Technical Elements and Requirements

The objectives and high-level requirements of the Internal Flood (LIF) Analysis for LPSD conditions are the same as those identified in ASME/ANS RA-Sa-2009 [1] and shall be accomplished for each POS. The plant conditions defined for each POS or group of POSs for the internal hazard group may have to be refined for this analysis. Such refinements may be needed to appropriately consider hazard group-specific plant conditions for the selection of flooding sources and may impair hazard barriers, affect propagation pathways, or modify fragilities of structures, systems or components. For example, construction may create temporary impoundments for precipitation-induced floods or eliminate run-off pathways that

[10] In this Part of the Standard, "internal flood" is used as a modifier (e.g., "internal flood induced," and "internal flood scenarios") in several high-level and supporting requirements as a shorthand way of indicating that in meeting the requirement, consideration should be given to all applicable internal flood-related effects or SSC failure mechanisms (e.g., submersion, spray, elevated temperature, humidity, pressure, pipe whip, and jet impingement). Applicability of the various effects/failure mechanisms to a particular requirement may need to be determined based on consideration of related supporting requirements.

existed prior to construction. Construction material and trailers on site can increase missile exposure to high winds, and outage work can result in temporary removal of missile barriers. The plant conditions can change from POS to POS in ways that can influence risk.

There is the potential for a relatively large number of individual internal flood scenarios and accident sequences with unique spatial dependencies. Some degree of event and scenario screening out of flood-induced scenarios and accident sequences is typically employed in analyzing risk from internal floods so that although the high level and supporting requirements are written in a discrete manner, the requirements are not necessarily presented in sequential order of application and, in some cases, must be considered jointly so that screening is performed appropriately. Thus, in determining the degree to which a particular supporting requirement is to be met, it is necessary to consider the degree to which other related requirements (some of which may be under other high level requirements) are being addressed. Screening out is typically employed at the flood area, flood source, or flood scenario level with the understanding that screening out of areas and sources accounts for all relevant flood scenarios.

An Internal Flood PRA need not be performed at a uniform level of detail. The analyses performed for screened physical analysis units may be performed at a lower completeness level than analyses performed for flood areas, flood sources, and/or flood scenarios that are not screened out. An iterative process is also common in Internal Flood PRA. Those physical analysis units that represent the higher risk contributors may be analyzed repeatedly, each time incorporating additional detail for specific aspects of the analysis (e.g., flood source and propagation modeling, credit for drains or mitigation, refinements to the Internal Flood PRA plant response model, the HRA, etc.) At any stage, the additional detail may allow for the screening out of a physical analysis unit. It is intended that this standard allow for analysis flexibility in this regard. As such, the level of detail and resolution for lower risk and/or screened out physical analysis units may be lower than for higher risk and unscreened physical analysis units without affecting the overall Capability Category of the Internal Flood PRA. For example, a service building containing numerous flood sources may be treated as a single physical analysis unit (see plant partitioning below) and analyzed for screening purposes. If the building can be screened out (e.g., it contains no equipment modeled in the other portion of the PRA and there are no propagation paths to other buildings), then the overall categorization of the Internal Flood PRA is unaffected. Similarly, the requirements for developing specific internal flood scenarios, detailed HRA, etc., are not needed for screened-out physical analysis units and may not be needed for lower risk unscreened physical analysis units as long as the overall validity of the final results is unaffected.

The Capability Category required for various aspects of the Internal Flood PRA are determined by the intended PRA application and may not be uniform across all aspects of the Internal Flood PRA.

The following is a short description of each technical PRA element included in the internal flood PRA process.

(a) Internal Flood Plant Partitioning (LIFPP). This element defines the physical boundaries of the analysis (i.e., the locations within the plant where flood scenarios are postulated) and divides the various volumes within that boundary into physical analysis units referred to as flood areas.

(b) Internal Flood Source Identification and Characterization (LIFSO). The various sources of floods and equipment spray within the plant are identified along with the mechanisms resulting in flood or spray from these sources, and a characterization of the flood/spray sources (e.g., amount of liquid, flow rates, etc.) is made.

(c) Internal Flood Scenarios (LIFSN). A set of internal flood scenarios relating flood source, propagation path(s), and affected equipment is developed.

(d) Internal Flood-induced Initiating Events (LIFEV). The expected plant response(s) to the selected set of flood scenarios is determined, and an accident sequence from the internal events during LPSD that is reasonably representative of this response is selected for each scenario.

(e) Internal Flood Accident Sequences and Quantification (LIFQU). The CDF and LERF results for the internal flood plant response sequences are quantified.

4.2.1 Internal Flood Plant Partitioning

4.2.1.1 Objectives

The objective of plant partitioning for internal floods is to identify plant areas where internal floods could lead to core damage in such a way that plant-specific physical layout areas and separations are accounted for.

Table 4.2.1-1 High Level Requirements for Internal Flood Plant Partitioning (LIFPP)

Designator	Requirement
HLR-LIFPP-A	A reasonably complete set of flood areas of the plant shall be identified.
HLR-LIFPP-B	The internal flood plant partitioning shall be documented consistent with the applicable supporting requirements.

Table 4.2.1-2(a) Supporting Requirements for HLR-LIFPP-A

A reasonably complete set of flood areas of the plant shall be identified (HLR-LIFPP-A).

Index No. LIFPP-A	Capability Category I	Capability Category II	Capability Category III
LIFPP-A1	DEFINE flood areas by dividing the plant into physically separate areas where a flood area is viewed as generally independent of other areas in terms of the potential for internal flood effects and flood propagation. INCLUDE expected temporary alignments that may alter the flood areas from POS to POS [see Note (1)].		
LIFPP-A2	Same as IFPP-A2 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	Same as IFPP-A2 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].	
LIFPP-A3	Same as IFPP-A3 in ASME/ANS RA-Sa-2009 [1].		
LIFPP-A4	Same as IFPP-A4 in ASME/ANS RA-Sa-2009 [1].		
LIFPP-A5	Same as IFPP-A5 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].		

NOTES:
(1) Temporary alignments can cause variations in the definition of flood areas for the specific LPSD evolution or LPSD evolutions being modeled in the time-averaged CDF or LERF LPSD model. For example, this includes opened/impaired hazard doors, opened covering drains, and open/impaired equipment hatchways, etc. that affect the physical separation between areas.
(2) Walkdown(s) may be done in conjunction with the requirements of LIFSO-A6, LIFSN-A17, and LIFQU-A11.

Table 4.2.1-2(b) Supporting Requirements for HLR-LIFPP-B

The internal flood plant partitioning shall be documented consistent with the applicable supporting requirements (HLR-LIFPP-B).

Index No. LIFPP-B	Capability Category I	Capability Category II	Capability Category III
LIFPP-B1	Same as IFPP-B1 in ASME/ANS RA-Sa-2009 [1].		
LIFPP-B2	Same as IFPP-B2 in ASME/ANS RA-Sa-2009 [1].		
LIFPP-B3	DOCUMENT sources of model uncertainty and related assumptions (as identified in LQU-E1 and LQU-E2) associated with the internal flood plant partitioning.		

4.2.2 Internal Flood Source Identification

4.2.2.1 Objectives

The objective of internal flood source identification is to identify the plant-specific sources of internal floods that could lead to core damage and large early release.

Table 4.2.2-1 High Level Requirements for Internal Flood Source Identification (LIFSO)

Designator	Requirement
HLR-LIFSO-A	The potential flood sources in the flood areas and their associated internal flood mechanisms shall be identified and characterized.
HLR-LIFSO-B	The internal flood sources shall be documented consistent with the applicable supporting requirements.

Table 4.2.2-2(a) Supporting Requirements for HLR-LIFSO-A

The potential flood sources in the plant and their associated internal flood mechanisms shall be identified and characterized (HLR-LIFSO-A).

Index No. LIFSO-A	Capability Category I	Capability Category II	Capability Category III
LIFSO-A1	Same as IFSO-A1 in ASME/ANS RA-Sa-2009 [1].		
LIFSO-A2	Same as IFSO-A2 in ASME/ANS RA-Sa-2009 [1].		
LIFSO-A3	Same as IFSO-A3 in ASME/ANS RA-Sa-2009 [1].		
LIFSO-A4	Same as IFSO-A4 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].		
LIFSO-A5	Same as IFSO-A5 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].		
LIFSO-A6	Same as IFSO-A6 in ASME/ANS RA-Sa-2009 [1] [see Note (2)].		

NOTES:
(1) Maintenance-induced events could be more critical during LPSD. A careful study of the activities of an LPSD evolution schedule will need to be completed in this step.
(2) Walkdown(s) may be done in conjunction with the requirements of LIFPP-A5, LIFSN-A17, and LIFQU-A11.

Table 4.2.2-2(b) Supporting Requirements for HLR-LIFSO-B

The sources of internal floods shall be documented consistent with the applicable supporting requirements (HLR-LIFSO-B).

Index No. LIFSO-B	Capability Category I	Capability Category II	Capability Category III
LIFSO-B1	Same as IFSO-B1 in ASME/ANS RA-Sa-2009 [1].		
LIFSO-B2	Same as IFSO-B2 in ASME/ANS RA-Sa-2009 [1].		
LIFSO-B3	DOCUMENT sources of model uncertainty and related assumptions (as identified in LQU-E1 and LQU-E2) associated with the internal flood sources.		

4.2.3 Internal Flood Scenario Development

4.2.3.1 Objectives

The objective of internal flood scenario development is to identify the plant-specific internal flood scenarios that could lead to core damage and large early release.

Table 4.2.3-1 High Level Requirements for Internal Flood Scenario Development (LIFSN)

Designator	Requirement
HLR-LIFSN-A	The potential internal flood scenarios shall be developed for each flood source by identifying the propagation path(s) of the source and the affected SSCs.
HLR-LIFSN-B	Documentation of the internal flood scenarios shall be consistent with the applicable supporting requirements.

Table 4.2.3-2(a) Supporting Requirements for HLR-LIFSN-A

The potential internal flood scenarios shall be developed for each flood source by identifying the propagation path(s) of the source and the affected SSCs (HLR-LIFSN-A).

Index No. LIFSN-A	Capability Category I	Capability Category II	Capability Category III
LIFSN-A1	Same as IFSN-A1 in ASME/ANS RA-Sa-2009 [1] [see Note 1].		
LIFSN-A2	Same as IFSN-A2 in ASME/ANS RA-Sa-2009 [1] [see Note 2].		
LIFSN-A3	Same as IFSN-A3 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A4	Same as IFSN-A4 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A5	Same as IFSN-A5 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A6	Same as IFSN-A6 in ASME/ANS RA-Sa-2009 [1].		Same as IFSN-A6 in ASME/ANS RA-Sa-2009 [1].
LIFSN-A7	Same as IFSN-A7 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A8	Same as IFSN-A8 in ASME/ANS RA-Sa-2009 [1].	Same as IFSN-A8 in ASME/ANS RA-Sa-2009 [1].	Same as IFSN-A8 in ASME/ANS RA-Sa-2009 [1].

Table 4.2.3-2(a) Supporting Requirements for HLR-LIFSN-A (Cont'd)

Index No. LIFSN-A	Capability Category I	Capability Category II	Capability Category III
LIFSN-A8a	IDENTIFY impaired barriers, impaired flood mitigating features, and reconfigured penetrations such as equipment hatches/manways that have the ability to create new propagation pathways.		
LIFSN-A9	Same as IFSN-A9 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A10	Same as IFSN-A10 in ASME/ANS RA-Sa-2009 [1] [see Note (3)].		
LIFSN-A11	Same as IFSN-A11 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A12	Same as IFSN-A12 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A13	Same as IFSN-A13 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A14	Same as IFSN-A14 in ASME/ANS RA-Sa-2009 [1].	Same as IFSN-A14 in ASME/ANS RA-Sa-2009 [1].	Same as IFSN-A14 in ASME/ANS RA-Sa-2009 [1].
LIFSN-A15	Same as IFSN-A15 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A16	Same as IFSN-A16 in ASME/ANS RA-Sa-2009 [1].	Same as IFSN-A16 in ASME/ANS RA-Sa-2009 [1].	Same as IFSN-A16 in ASME/ANS RA-Sa-2009 [1].
LIFSN-A17	Same as IFSN-A17 in ASME/ANS RA-Sa-2009 [1] [see Note (4)].		

NOTES:
(1) Plant responses to internal flooding are likely to differ from responses during full power operations. Operating experience during LPSD shows that flooding may occur when no one is watching (e.g. when system filling is going on and workers are on a break). A dedicated watch would be in place when system filling occurs during full-power operations. (2) Temporary alignments during the specific POS can compromise plant design features relied on for terminating or containing flood propagation. These temporary alignments are considered in the definition of POS specific flood areas, i.e., see LIFPP-A1.
(3) Flood scenarios may be different for each POS.
(4) Walkdown(s) may be done in conjunction with the requirements of LIFPP-A5, LIFSO-A6, and LIFQU-A11.

Table 4.2.3-2(b) Supporting Requirements for HLR-LIFSN-B

Documentation of the internal flood scenarios shall be consistent with the applicable supporting requirements (HLR-LIFSN-B).

Index No. LIFSN-B	Capability Category I	Capability Category II	Capability Category III
LIFSN-B1	Same as IFSN-B1 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-B2	Same as IFSN-B2 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-B3	DOCUMENT sources of model uncertainty and related assumptions (as identified in LQU-E1 and LQU-E2) associated with the internal flood scenarios.		

4.2.4 Internal Flood-Induced Initiating Event Analysis

4.2.4.1 Objectives

The objectives of flood-induced event analysis are to identify the applicable flood-induced plant initiating event for each flood scenario that could lead to core damage and large early release and to quantify the frequency of the flood.

Table 4.2.4-1 High Level Requirements for Flood-Induced Initiating Event Analysis (LIFEV)

Designator	Requirement
HLR-LIFEV-A	Plant initiating events caused by internal floods shall be identified and their frequencies estimated.
HLR-LIFEV-B	Documentation of the internal flood-induced events shall be consistent with the applicable supporting requirements.

Table 4.2.4-2(a) Supporting Requirements for HLR-LIFEV-A

Plant initiating events caused by internal flood shall be identified and their frequencies estimated (HLR-LIFEV-A).

Index No. LIFEV-A	Capability Category I	Capability Category II	Capability Category III
LIFEV-A1	Same as IFEV-A1 in ASME/ANS RA-Sa-2009 [1].		
LIFEV-A1a	REVIEW relevant industry operating experience and LERs on flooding scenarios during LPSD evolutions to gain insights into estimating the frequencies of flood-induced initiating events [see Note (1)].		
LIFEV-A2	Same as IFEV-A2 in ASME/ANS RA-Sa-2009 [1].	Same as IFEV-A2 in ASME/ANS RA-Sa-2009 [1].	Same as IFEV-A2 in ASME/ANS RA-Sa-2009 [1].
LIFEV-A3	Same as IFEV-A3 in ASME/ANS RA-Sa-2009 [1].		Same as IFEV-A3 in ASME/ANS RA-Sa-2009 [1].
LIFEV-A4	Same as IFEV-A4 in ASME/ANS RA-Sa-2009 [1].		
LIFEV-A5	Same as IFEV-A5 in ASME/ANS RA-Sa-2009 [1].		
LIFEV-A6	Same as IFEV-A6 in ASME/ANS RA-Sa-2009 [1].	Same as IFEV-A6 in ASME/ANS RA-Sa-2009 [1].	

Table 4.2.4-2(A) Supporting Requirements For HLR-LIFEV-A (Cont'd)

Index No. LIFEV-A	Capability Category I	Capability Category II	Capability Category III
LIFEV-A7	Same as IFEV-A7 in ASME/ANS RA-Sa-2009 [1].	Same as CC-III in IFEV-A7.	Same as IFEV-A7 in ASME/ANS RA-Sa-2009 [1].
LIFEV-A7a	For temporary alignments during LPSD evolution, ESTIMATE the frequency of equipment failure-induced floods for each POS using generic industry data.	For temporary alignments during LPSD evolution, ESTIMATE the frequency of equipment failure-induced floods for each POS using generic and plant-specific date. USE a Bayes update process to combine the generic and plant-specific evidence and to characterize the uncertainty.	
LIFEV-A8	Same as IFEV-A8 in ASME PRA Standard (ASME/ANS RA-Sa-2009) [1].		

NOTE:
(1) Databases such as INPO/EPIX, lessons learned from industry LPSD evolutions, and lessons learned from self-assessment of previous LPSD evolutions are good sources for identifications of flood-induced initiating events and their frequencies.

Table 4.2.4-2(b) Supporting Requirements for HLR-LIFEV-B

Documentation of the internal flood-induced events shall be consistent with the applicable supporting requirements (HLR-LIFEV-B).

Index No. LIFEV-B	Capability Category I	Capability Category II	Capability Category III
LIFEV-B1	Same as IFEV-B1 in ASME/ANS RA-Sa-2009 [1].		
LIFEV-B2	Same as IFEV-B2 in ASME/ANS RA-Sa-2009 [1].		
LIFEV-B3	DOCUMENT sources of model uncertainty and related assumptions (as identified in LQU-E1 and LQU-E2) associated with the internal flood-induced initiating events.		

4.2.5 Internal Flood Accident Sequences and Quantification

4.2.5.1 Objectives

The objective of internal flood accident sequences and quantification is to identify the internal flood-induced accident sequences and quantify the likelihood of core damage and large early release.

Table 4.2.5-1 High Level Requirements for Internal Flood Accident Sequences and Quantification (LIFQU)

Designator	Requirement
HLR-LIFQU-A	Internal flood-induced accident sequences shall be quantified.
HLR-LIFQU-B	Documentation of the internal flood-induced accident sequences and quantification shall be consistent with the supporting requirements.

Table 4.2.5-2(a) Supporting Requirements for HLR-LIFQU-A

Internal flood-induced accident sequences shall be quantified (HLR-LIFQU-A).

Index No. LIFQU-A	Capability Category I	Capability Category II	Capability Category III
LIFQU-A1	Same as IFQU-A1 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-A2	Same as IFQU-A2 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-A3	Same as IFQU-A3 in ASME/ANS RA-Sa-2009 [1].		Same as IFQU-A3 in ASME/ANS RA-Sa-2009 [1].
LIFQU-A4	Same as IFQU-A4 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-A5	Same as IFQU-A5 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-A6	Same as IFQU-A6 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-A7	Same as IFQU-A7 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-A8	Same as IFQU-A8 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-A9	Same as IFQU-A9 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-A10	Same as IFQU-A10 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-A11	Same as IFQU-A11 in ASME/ANS RA-Sa-2009 [1] [see Note (1)].		

NOTE:
(1) Walkdown(s) may be done in conjunction with the requirements of LIFPP-A5, LIFSO-A6, and LIFSN-A17.

Table 4.2.5-2(b) Supporting Requirements for HLR-LIFQU-B

Documentation of the internal flood-induced accident sequences and quantification shall be consistent with the supporting requirements (HLR-LIFQU-B).

Index No. LIFQU-B	Capability Category I	Capability Category II	Capability Category III
LIFQU-B1	Same as IFQU-B1 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-B2	Same as IFQU-B2 in ASME/ANS RA-Sa-2009 [1].		
LIFQU-B3	DOCUMENT sources of model uncertainty and related assumptions (as identified in LQU-E1 and LQU-E2) associated with the internal flood accident sequences and quantification.		

4.3 Peer Review for Internal Flood PRA during LPSD

4.3.1 Purpose

This section provides requirements for peer review of an internal flood PRA.

4.3.2 Peer Review Team Composition and Personnel Qualification

In addition to the general requirements in Section 1.6 of ASME/ANS RA-Sa-2009 [1], the peer review team shall have combined experience in the technical elements of internal flood analysis.

4.3.3 Review of Internal Flood PRA Elements to Confirm the Methodology

A review shall be performed on the internal flood analysis. The portion of the internal flood analysis selected for review typically includes a sample of the screening of flood areas and the flooding scenarios contributing to significant sequences (CDF or LERF), including:

(a) internal flood event frequencies;
(b) internal flood scenarios involving each identified flood source;
(c) internal flood scenarios involving flood propagation to adjacent flood areas;
(d) internal flood scenarios that involve each of the flood-induced component failure mechanisms (i.e., one flood scenario for each mechanism);
(e) one internal flood scenario involving each type of identified accident initiator, e.g., transient and LOCA.

Part 5 Seismic Analysis

Text that is new in this part compared to that in Part 5 of Reference [1] is underlined below.

5.1 Overview of Seismic PRA Requirements during LPSD Conditions

The objectives and high level requirements for Seismic Analysis for LPSD conditions are basically the same as those identified for analysis during full power conditions in ASME/ANS RA-Sa-2009 [1] and shall be accomplished for each POS or group of POSs, where appropriate. This section is intended to be used together with Parts 1, 2, and 3 of this standard. Many of the technical requirements in Part 3 (Internal Events) are fundamental requirements for performing a PRA for any hazard group and are applicable to all the hazard groups within the scope of the LPSD PRA. They are incorporated by reference in those requirements that address the development of the plant response to the damage states created by the hazard groups addressed in this section. The plant conditions defined for each POS or group of POSs for the internal hazard group may have to be refined for this analysis. Such refinements may be needed to appropriately consider hazard group-specific plant conditions that may impair hazard barriers, affect propagation pathways, or modify fragilities of structures, systems, or components. Specifically, the scope of the requirements herein cover (a) a Level 1 analysis of the core damage frequency (CDF) and (b) a limited Level 2 analysis sufficient to evaluate the large early release frequency (LERF).

Section 1.1.8 of this standard contains an introduction that describes how the PRA analysis in this section is to be structured and also describes the relationship of the various aspects of a full power external-hazards PRA to the analysis here for LPSD conditions. Section 1.1.8.2, "Screening of External Hazards," describes the conditions under which, for a given POS, an external hazard may be screened out.

The introductory text in Section 5-1 of Part 5 (seismic PRA for full power conditions) of ASME/ANS RA-Sa-2009 [1] applies in full here.

Finally, there are technical requirements for Seismic Margin Assessment (SMA) in Part 10 of ASME/ANS RA-Sa-2009 [1]. For conditions other than at full power, these SMA requirements do not apply and should not be used.

Objectives: The objective of this section (Seismic Analysis) is to provide estimates of the core damage frequency (CDF) and large early release frequency (LERF) for accidents initiated by earthquakes during low-power or shutdown conditions, including uncertainties. Besides overall CDF and LERF estimates, the analysis must have as an explicit objective the determination of seismic hazards, the determination of seismic fragilities of those SSCs that contribute, the determination through systems analysis of the major sequences and damage states that contribute, and adequate documentation. The details that elaborate on what these introductory phrases mean in practice are contained in the Technical Requirements. Of course, both the hazard work and much of the fragilities work should already have been accomplished for the seismic PRA for full-power conditions and can be carried over as appropriate.

5.2 Technical Requirements for Seismic PRA during LPSD Conditions

The introductory text in Section 5-2 of ASME/ANS RA-Sa-2009 [1] applies in full.

5.2.1 Probabilistic Seismic Hazard Analysis (PSHA)

The introductory text in Section 5-2.1 of ASME/ANS RA-Sa-2009 [1] applies in full.

There are 10 high-level requirements for PSHA, as follows:

Table 5.2.1-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Probabilistic Seismic Hazard Analysis (LSHA)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LSHA-A	HLR-SHA-A	The frequency of earthquakes at the site shall be based on a site-specific probabilistic seismic hazard analysis (existing or new) that reflects the composite distribution of the informed technical community. The level of analysis shall be determined based on the intended application and on site-specific complexity.	Same as SHA-A in ASME/ANS RA-Sa-2009 [1].
HLR-LSHA-B	HLR-SHA-B	To provide inputs to the probabilistic seismic hazard analysis, a comprehensive up-to-date database including geological, seismological, and geophysical data, local site topography, and surficial geologic and geotechnical site properties shall be compiled. A catalog of historical, instrumental, and paleoseismicity information shall also be compiled.	Same as SHA-B in ASME/ANS RA-Sa-2009 [1].
HLR-LSHA-C	HLR-SHA-C	To account for the frequency of occurrence of earthquakes in the site region, the probabilistic seismic hazard analysis shall examine all credible sources of potentially damaging earthquakes. Both the aleatory and epistemic uncertainties shall be addressed in characterizing the seismic sources.	Same as SHA-C in ASME/ANS RA-Sa-2009 [1].

Table 5.2.1-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Probabilistic Seismic Hazard Analysis (LSHA) (Cont'd)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LSHA-D	HLR-SHA-D	The probabilistic seismic hazard analysis shall examine credible mechanisms influencing estimates of vibratory ground motion that can occur at a site given the occurrence of an earthquake of a certain magnitude at a certain location. Both the aleatory and epistemic uncertainties shall be addressed in characterizing the ground motion propagation.	Same as SHA-D in ASME/ANS RA-Sa-2009 [1].
HLR-LSHA-E	HLR-SHA-E	The probabilistic seismic hazard analysis shall account for the effects of local site response.	Same as SHA-E in ASME/ANS RA-Sa-2009 [1].
HLR-LSHA-F	HLR-SHA-F	Uncertainties in each step of the hazard analysis shall be propagated and displayed in the final quantification of hazard estimates for the site. The results shall include fractile hazard curves, median and mean hazard curves, and uniform hazard response spectra. For certain applications, the probabilistic seismic hazard analysis shall include seismic source deaggregation and magnitude-distance deaggregation.	Same as SHA-F in ASME/ANS RA-Sa-2009 [1].
HLR-LSHA-G	HLR-SHA-G	For further use in the seismic PRA, the spectral shape shall be based on a site-specific evaluation taking into account the contributions of deaggregated magnitude-distance results of the probabilistic seismic hazard analysis. Broad-band, smooth spectral shapes such as those presented in NUREG/CR-0098 [28] for lower-seismicity sites such as most of those east of the Rocky Mountains of the U.S. are also acceptable if they are shown to be appropriate for the site. The use of uniform hazard response spectra is also acceptable unless evidence comes to light that would challenge these uniform hazard spectral shapes.	Same as SHA-G in ASME/ANS RA-Sa-2009 [1].

Table 5.2.1-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Probabilistic Seismic Hazard Analysis (LSHA) (Cont'd)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LSHA-H	HLR-SHA-H	When use is made of an existing study for probabilistic seismic hazard analysis purposes, it shall be confirmed that the basic data and interpretations are still valid in light of current information, the study meets the requirements outlined in A through G above, and the study is suitable for the intended application.	Same as SHA-H in ASME/ANS RA-Sa-2009 [1].
HLR-LSHA-I	HLR-SHA-I	A screening analysis shall be performed to assess whether, in addition to the vibratory ground motion, other seismic hazards such as fault displacement, landslide, soil liquefaction, or soil settlement need to be included in the seismic PRA for the specific application. If so, the seismic PRA shall address the effects of these hazards through assessment of the frequency of hazard occurrence, the magnitude of hazard consequences, or both.	Same as SHA-I in ASME/ANS RA-Sa-2009 [1].
HLR-LSHA-J	HLR-SHA-J	Documentation of the probabilistic seismic hazard analysis shall be consistent with the applicable supporting requirements.	Same as SHA-J in ASME/ANS RA-Sa-2009 [1].

It is recognized that if the seismic hazard analyses has already been performed consistent with the requirements in [1], that there are no new requirements in this section to support low power and shutdown conditions.

High Level Requirements and Supporting Requirements for HLR-LSHA: All of the High Level Requirements and all of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-SHA shall apply in full, but are designated as HLR-LSHA in this standard.

5.2.2 Seismic Fragility Analysis

The introductory text in Section 5-2.2 of ASME/ANS RA-Sa-2009 [1] shall apply in full.

There are seven high-level requirements for seismic fragility analysis, as follows:

Table 5.2.2-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic-Fragility Analysis (LSFR)

Designator in This Standard	**Designator in ASME/ANS RA-Sa-2009 [1]**	**Requirement**	**Commentary**
HLR-LSFR-A	HLR-SFR-A	The seismic-fragility evaluation shall be performed to estimate plant-specific, realistic seismic fragilities of structures, systems, components, or combinations thereof whose failure may contribute to core damage, large early release, or both.	Same as SFR-A in ASME/ANS RA-Sa-2009 [1].
HLR-LSFR-B	HLR-SFR-B	If screening of high-seismic-capacity components is performed, the basis for the screening shall be fully described.	Same as SFR-B in ASME/ANS RA-Sa-2009 [1].
HLR-LSFR-C	HLR-SFR-C	The seismic-fragility evaluation shall be based on realistic seismic response that the SSCs experience at their failure levels.	Same as SFR-C in ASME/ANS RA-Sa-2009 [1].
HLR-LSFR-D	HLR-SFR-D	The seismic-fragility evaluation shall be performed for critical failure modes of structures, systems, components, or a combination thereof such as structural failure modes and functional failure modes identified through the review of plant design documents, supplemented as needed by earthquake experience data, fragility test data, generic qualification test data, and a walkdown.	Same as SFR-D in ASME/ANS RA-Sa-2009 [1].

Table 5.2.2-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic-Fragility Analysis (LSFR) (Cont'd)

Designator in This Standard	**Designator in ASME/ANS RA-Sa-2009 [1]**	**Requirement**	**Commentary**
HLR-LSFR-E	HLR-SFR-E	The seismic-fragility evaluation shall incorporate the findings of a detailed walkdown of the plant focusing on the anchorage, lateral seismic support, and potential systems interactions.	Same as SFR-E in ASME/ANS RA-Sa-2009 [1].
HLR-LSFR-F	HLR-SFR-F	The calculation of seismic-fragility parameters such as median capacity and variabilities shall be based on plant-specific data supplemented as needed by earthquake experience data, fragility test data, and generic qualification test data. Use of such generic data shall be justified.	Same as SFR-F in ASME/ANS RA-Sa-2009 [1].
HLR-LSFR-G	HLR-SFR-G	Documentation of the seismic-fragility analysis shall be consistent with the applicable supporting requirements.	Same as SFR-G in ASME/ANS RA-Sa-2009 [1].

Supporting Requirements for HLR-LSFR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-SFR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7.

5.2.3 Seismic Plant Response Analysis

The introductory text in Section 5-2.3 of ASME/ANS RA-Sa-2009 [1] shall apply in full.

There are six high-level requirements for seismic plant response analysis, as follows:

Table 5.2.3-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Systems Analysis (LSPR)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LSPR-A	HLR-SPR-A	The seismic-PRA systems models shall include seismic-caused initiating events and other failures including seismically induced SSC failures, non-seismically induced unavailabilities, and human errors that give rise to significant accident sequences and/or significant accident progression sequences.	Same as SPR-A in ASME/ANS RA-Sa-2009 [1].
HLR-LSPR-B	HLR-SPR-B	The seismic-PRA systems model shall be adapted to incorporate seismic analysis aspects that are different from corresponding aspects found in the full power, internal-events PRA or the LPSD internal-events PRA systems model.	Same as SPR-B in ASME/ANS RA-Sa-2009 [1].
HLR-LSPR-C	HLR-SPR-C	The seismic-PRA systems model shall reflect the as-built and as-operated plant being analyzed.	Same as SPR-C in ASME/ANS RA-Sa-2009 [1].
HLR-LSPR-D	HLR-SPR-D	The list of structures, systems, components, or combination thereof (SSCs) selected for seismic-fragility analysis shall include all SSCs that participate in accident sequences included in the seismic-PRA systems model [see Note (1)].	Same as SPR-D in ASME/ANS RA-Sa-2009 [1].
HLR-LSPR-E	HLR-SPR-E	The analysis to quantify core damage and large early release frequencies shall appropriately integrate the seismic hazard, the seismic fragilities, and the systems-analysis aspects.	Same as SPR-E in ASME/ANS RA-Sa-2009 [1].
HLR-LSPR-F	HLR-SPR-F	Documentation of the seismic plant response analysis and quantification shall be consistent with the applicable supporting requirements.	Same as SPR-F in ASME/ANS RA-Sa-2009 [1].

NOTE:
(1) Applicability of "full power" seismic fragilities is to be assessed for the specific conditions of the POS under study. The equipment configuration may be different from the "full power" mode.

Supporting Requirements for HLR-LSPR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-SPR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7. Of course, in reality, only a subset of the requirements herein are really dependent on the POS, so some judgment is needed. For the walkdowns, it is especially important to evaluate conditions that might be different during shutdown states than for full-power operations.

5.3 Peer Review for Seismic PRA during LPSD Conditions

The entire text under Section 5-3 of ASME/ANS RA-Sa-2009 [1] shall apply in full, except when modified, as appropriate, to refer to "LPSD conditions" instead of "at-power conditions."

A consideration in the selection of the peer reviewers is to assure that there is expertise and knowledge about LPSD evolutions within the team.

5.4 References

The entire list of References in Section 5-4 of ASME/ANS RA-Sa-2009 [1] is incorporated in this standard by reference.

Part 6 Requirements for Screening and Conservative Analysis of Other External Hazards during LPSD Conditions

Text that is new in this part compared to that in Part 6 of Reference [1] is underlined below.

6.1 Approach for Screening and Conservative Analysis for Other External Hazards during LPSD Conditions

The term "other external hazard" refers to an external hazard other than those for which requirements are provided in other sections of this standard, e.g., earthquakes, high winds, external floods. Appendix 6-A in ASME/ANS RA-Sa-2009 [1] includes a list of external hazards that may apply at specific sites. In this section, requirements for all external hazards other than earthquakes are established, although high winds and external flooding can also be assessed using the requirements in Parts 7 and 8, respectively, or using the generic requirements in Part 9. For hazards other than earthquakes, high winds, or external flooding that require PRA analysis because they cannot be screened out, the requirements here and in Part 9 apply. Note that in screening out a particular external hazard for a particular POS or group of POSs, it is appropriate to take account of the duration for the POS or group of POSs.

The following is taken directly from Section 6-1 of ASME/ANS RA-Sa-2009 [1]:

> *"Generally, the evaluation covered by the requirements in this section is the first task undertaken in a full-scope external events PRA. Through the work here, the analysis team ascertains which of the external events can be screened out so that no further PRA analysis is needed. This allows the team to focus on those events that remain (unscreened) within the analysis. Experience reveals that earthquakes can never be screened out using the methods herein; that sometimes high winds and external flooding can be screened out but sometimes they require further analysis, either a bounding analysis, a semi-quantitative analysis, or perhaps even a full PRA; and that occasionally one or more other external events also require a full PRA. Subsequent sections of this standard cover methods for a full PRA of the external events that may not be screened out."*

The objectives and high level requirements for screening and conservative analysis of "other external hazards" for LPSD conditions are basically the same as those identified for screening and conservative analysis during full power conditions in ASME/ANS RA-Sa-2009 [1] and shall be accomplished for each POS, as appropriate. This section is intended to be used together with Parts 1, 2, and 3 of this standard. Many of the technical requirements in Part 3 (Internal Events) are fundamental requirements for performing a PRA for any hazard group and are applicable to all the hazard groups within the scope of the LPSD PRA. They are incorporated by reference in those requirements that address the development of the plant response to the damage states created by the hazard groups addressed in this section. The plant conditions defined for each POS for the internal hazard group may have to be refined for this analysis. Such refinements may be needed to appropriately consider hazard group-specific plant conditions that may impair hazard barriers, affect propagation pathways, or modify fragilities of structures, systems, or components.

Specifically, the scope of the requirements herein cover (a) a Level 1 analysis of the core damage frequency (CDF) and (b) a limited Level 2 analysis sufficient to evaluate the large early release frequency (LERF).

Section 1.1.8 of this standard contains an introduction that describes how the PRA analysis in this section is to be structured and the relationship of the various aspects of a full power external-hazards PRA in general to the analysis here for LPSD conditions.

The introductory text in Part 6 of ASME/ANS RA-Sa-2009 [1], namely Section 6-1, applies in full. The Capability Categories and how they are to be applied for a specific application also apply in full.

6.2 Technical Requirements for Screening and Conservative Analysis of Other External Hazards during LPSD Conditions

The text in Section 6-2 of ASME/ANS RA-Sa-2009 [1] shall apply in full. Note that the HLRs are to be applied to each relevant POS.

There are five High Level Requirements, as follows:

Table 6.2-1 High Level Requirements for Other External Hazards: Requirements for Screening and Conservative Analysis (LEXT)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LEXT-A	HLR-EXT-A	All potential external hazards (i.e., all natural and man-made hazards) that may affect the site shall be identified.	Same as EXT-A in ASME/ANS RA-Sa-2009 [1].
HLR-LEXT-B	HLR-EXT-B	Preliminary screening, if used, shall be performed using a defined set of screening criteria.	Same as EXT-B in ASME/ANS RA-Sa-2009 [1].
HLR-LEXT-C	HLR-EXT-C	A bounding or demonstrably conservative analysis, if used for screening, shall be performed using defined quantitative screening criteria.	Same as EXT-C in ASME/ANS RA-Sa-2009 [1].
HLR-LEXT-D	HLR-EXT-D	The basis for the screening out of an external hazard shall be confirmed through a walkdown of the plant and its surroundings.	Same as EXT-D in ASME/ANS RA-Sa-2009 [1].
HLR-LEXT-E	HLR-EXT-E	Documentation of the screening out of an external hazard shall be consistent with the applicable supporting requirements.	Same as EXT-E in ASME/ANS RA-Sa-2009 [1].

GENERAL NOTES for Table 6.2-1:

(a) HLR-LEXT-B, HLR-LEXT-C, HLR-LEXT-D and HLR-LEXT-E are applicable when an external hazard has been selected for screening rather than for detailed analysis. At any time during the screening process, a decision can be made to bypass that process and go directly to the detailed-analysis requirements in Parts 7, 8, or 9. Appendix 6-A in ASME/ANS RA-Sa-2009 [1] contains a list of external hazards to be considered, and using this list is one acceptable approach to meeting this requirement. [See LEXT-A1.]

(b) If an external hazard cannot be screened out in its entirety using either the qualitative criteria under HLR-LEXT-B or the quantitative criteria under HLR-LEXT-C, then it shall be subjected to detailed analysis under Parts 7, 8 or 9 and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7.

Supporting Requirements for these Five High Level Requirements: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for these five High Level Requirements shall apply in full.

6.3 Peer Review for Screening and Conservative Analysis of Other External Hazards during LPSD Conditions

The entire text under Section 6-3 of ASME/ANS RA-Sa-2009 [1] shall apply in full.

A consideration in the selection of the peer reviewers is to assure that there is expertise and knowledge about LPSD evolutions within the team.

6.4 References

The entire list of References in Section 6-4 of ASME/ANS RA-Sa-2009 [1] is incorporated in this standard by reference.

Part 7 High Wind Analysis

Text that is new in this part compared to that in Part 7 of Reference [1] is underlined below.

7.1 Overview of High Wind PRA Requirements during LPSD Conditions

The objectives and high level requirements of the High Wind Analysis for LPSD conditions are basically the same as those identified for analysis during full power conditions in ASME/ANS RA-Sa-2009 [1] and shall be accomplished for each POS, where appropriate. This section is intended to be used together with Parts 1, 2, and 3 of this standard. Many of the technical requirements in Part 3 (Internal Events) are fundamental requirements for performing a PRA for any hazard group and are applicable to all the hazard groups within the scope of the LPSD PRA. They are incorporated by reference in those requirements that address the development of the plant response to the damage states created by the hazard groups addressed in this section. The plant conditions defined for each POS for the internal hazard group may have to be refined for this analysis. Such refinements may be needed to appropriately consider hazard group-specific plant conditions that may impair hazard barriers, affect propagation pathways, or modify fragilities of structures, systems, or components.

Specifically, the scope of the requirements herein cover (a) a Level 1 analysis of the core damage frequency (CDF) and (b) a limited Level 2 analysis sufficient to evaluate the large early release frequency (LERF).

Section 1.1.8 of this standard contains an introduction that describes how the PRA analysis in this section is to be structured and the relationship of the various aspects of a full power external-hazards PRA in general to the analysis here for LPSD conditions.

The introductory text in Part 7 of ASME/ANS RA-Sa-2009 [1], namely Section 7-1, applies in full here. The Capability Categories and how they are to be applied for a specific application also apply in full.

Objectives: The objective of this section (High Wind Analysis) is to provide estimates of the core damage frequency (CDF) and large early release frequency (LERF) for accidents initiated by high winds, including uncertainties. Besides overall CDF and LERF estimates, the analysis must have as an explicit objective the determination of high wind hazards, the determination of high wind fragilities of those SSCs that contribute, the determination through systems analysis of the major sequences and damage states that contribute, and adequate documentation. The details that elaborate on what these introductory phrases mean in practice are contained in the Technical Requirements.

7.2 Technical Requirements for High Wind PRA during LPSD Conditions

The opening two paragraphs in Section 7-2 of ASME/ANS RA-Sa-2009 [1] shall apply in full.

7.2.1 Probabilistic Wind Hazard Analysis (LWHA)

The objective of the hazard analysis is to assess the frequency of occurrence of high wind as a function of intensity on a site-specific basis.

There are two high-level requirements for LWHA, as follows:

Table 7.2.1-1 High Level Requirements for Wind Probabilistic Risk Assessment: Technical Requirements for Probabilistic Wind Hazard Analysis (LWHA)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LWHA-A	HLR-WHA-A	The frequency of high winds at the site shall be based on a site-specific probabilistic wind hazard analysis (existing or new) that reflects recent available regional and site-specific information. Uncertainties in the models and parameter values shall be properly accounted for and fully propagated in order to obtain a family of hazard curves from which a mean hazard can be derived.	Same as WHA-A in ASME/ANS RA-Sa-2009 [1].
HLR-LWHA-B	HLR-WHA-B	Documentation of the wind hazard analysis shall be consistent with the applicable supporting requirements.	Same as WHA-B in ASME/ANS RA-Sa-2009 [1].

Supporting Requirements for HLR-LWHA: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-WHA shall apply in full.

7.2.2 High Wind Fragility Analysis (LWFR)

The objective of high wind fragility analysis is to identify those structures, systems, and components that are susceptible to the effects of high winds and to determine their plant-specific failure probabilities as a function of the intensity of the wind.

There are two high-level requirements for high-wind fragility analysis, as follows:

Table 7.2.2-1 High Level Requirements for Wind Probabilistic Risk Assessment: Technical Requirements for Wind-Fragility Analysis (LWFR)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LWFR-A	HLR-WFR-A	A wind fragility analysis shall be performed to estimate plant-specific, realistic wind fragilities of structures, systems, components, or a combination thereof whose failure may contribute to core damage, large early release, or both.	Same as WFR-A in ASME/ANS RA-Sa-2009 [1].
HLR-LWFR-B	HLR-WFR-B	Documentation of the wind fragility analysis shall be consistent with the applicable supporting requirements.	Same as WFR-B in ASME/ANS RA-Sa-2009 [1].

Supporting Requirements for HLR-LWFR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-WFR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7.

7.2.3 High Wind Plant Response Analysis (LWPR)

The objectives of this element are to:

(a) develop a wind plant response model by modifying the LPSD PRA internal events model to include the effects of the wind in terms of initiating events and failures caused, including operator actions;
(b) quantify this model to provide the conditional core damage probability (CCDP) and conditional large early release probability (CLERP) for each defined wind plant damage state;
(c) evaluate the unconditional CDF and LERF by integrating the CCDP/CLERP with the frequencies of the plant damage states obtained by combining the wind hazard analysis and wind fragility analysis .

There are three high-level requirements for wind plant response model and quantification analysis (Table 7.2.3-1).

Table 7.2.3-1 High Level Requirements for Wind Plant Response Model and Quantification (LWPR)

Designator in This Standard	**Designator in ASME/ANS RA-Sa-2009 [1]**	**Requirement**	**Commentary**
HLR-LWPR-A	HLR-WPR-A	The high wind PRA systems models shall include wind-caused initiating events and other failures that can lead to core damage or large early release. The model shall be adapted from the internal events LPSD PRA systems model to incorporate wind-analysis aspects that are different from the corresponding aspects in the full power, internal-events PRA or the LPSD internal-events PRA systems model. The model(s) shall be appropriate for each relevant POS.	Same as WPR-A in ASME PRA Standard (ASME/ANS RA-Sa-2009 [1]).
HLR-LWPR-B	HLR-WPR-B	The analysis (or analyses) to quantify core damage and large early release frequencies shall apply to each desired POS state and shall appropriately integrate the wind hazard, the wind fragilities, and the systems-analysis aspects.	Same as WPR-B in ASME/ANS RA-Sa-2009 [1].
HLR-LWPR-C	HLR-WPR-C	Documentation of the high-wind plant response model development and quantification shall be consistent with the applicable supporting requirements.	Same as WPR-C in ASME/ANS RA-Sa-2009 [1].

Supporting Requirements for HLR-LWPR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-WPR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7.

7.3 Peer Review for High Wind PRA during LPSD Conditions

The entire text under Section 7-3 of ASME/ANS RA-Sa-2009 [1] shall apply in full, except where modified, as appropriate, to refer to "LPSD conditions" instead of "at-power conditions".

A consideration in the selection of the peer reviewers is to assure that there is expertise and knowledge about LPSD evolutions within the team.

7.4 References

The entire list of References in Section 7-4 of ASME/ANS RA-Sa-2009 [1] is incorporated in this standard by reference.

Part 8 External Flood Analysis

Text that is new in this part compared to that in Part 8 of Reference [1] is underlined below.

8.1 Overview of External Flood PRA Requirements during LPSD Conditions

The objectives and high level requirements of the External Flood Analysis for LPSD conditions are basically the same as those identified for analysis during full power conditions in ASME/ANS RA-Sa-2009 [1] and shall be accomplished for each POS, as appropriate. This section is intended to be used together with Parts 1, 2, and 3 of this standard. Many of the technical requirements in Part 3 (Internal Events) are fundamental requirements for performing a PRA for any hazard group and are applicable to all the hazard groups within the scope of the LPSD PRA. They are incorporated by reference in those requirements that address the development of the plant response to the damage states created by the hazard groups addressed in this section. The plant conditions defined for each POS for the internal hazard group may have to be refined for this analysis. Such refinements may be needed to appropriately consider hazard group-specific plant conditions that may impair hazard barriers, affect propagation pathways, or modify fragilities of structures, systems, or components.

Specifically, the scope of the requirements herein cover (a) a Level 1 analysis of the core damage frequency (CDF) and (b) a limited Level 2 analysis sufficient to evaluate the large early release frequency (LERF).

Section 1.1.8 of this standard contains an introduction that describes how the PRA analysis in this section is to be structured and the relationship of the various aspects of a full power external-hazards PRA in general to the analysis here for LPSD conditions.

The introductory text in Part 8 of ASME/ANS RA-Sa-2009 [1], namely Section 8-1, applies in full. The Capability Categories and how they are to be applied for a specific application also apply in full.

There may be configurations during certain shutdown POS conditions in which some items have been removed or barriers changed, which make the configuration different than at full power. Consideration of these is an important part of performing an external-flood analysis during shutdown conditions.

Objectives: The objective of this section (External Flood Analysis) is to provide estimates of the core damage frequency (CDF) and large early release frequency (LERF) for accidents initiated by external floods, including uncertainties. Besides overall CDF and LERF estimates, the analysis must have as an explicit objective the determination of external flood hazards, the determination of external flood fragilities of those SSCs that contribute, the determination through systems analysis of the major sequences and damage states that contribute, and adequate documentation. The details that elaborate on what these introductory phrases mean in practice are contained in the Technical Requirements.

8.2 Technical Requirements for External Flood PRA during LPSD Conditions

The text in Section 8-2 of ASME/ANS RA-Sa-2009 [1] shall apply in full.

8.2.1 Probabilistic External Flood Hazard Analysis (LXFHA)

The objective of the hazard analysis is to assess the frequency of occurrence of external floods of different types as a function of severity on a site-specific basis.

There are two high-level requirements for LXFHA, as follows:

Table 8.2.1-1 High Level Requirements for External Flood Probabilistic Risk Assessment: Technical Requirements for Probabilistic External Flood Hazard Analysis (LXFHA)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LXFHA-A	HLR-XFHA-A	The frequency of external flooding at the site shall be based on a site-specific probabilistic external-flood hazard analysis (existing or new) that reflects recent available regional and site-specific information. Uncertainties in the models and parameter values shall be properly accounted for and fully propagated in order to obtain a family of hazard curves from which a mean hazard curve can be derived.	Same as XFHA-A in ASME/ANS RA-Sa-2009 [1].
HLR-LXFHA-B	HLR-SFHA-B	Documentation of the external flood hazard analysis shall be consistent with the applicable supporting requirements.	Same as XFHA-B in ASME/ANS RA-Sa-2009 [1].

Supporting Requirements for HLR-LXFHA: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-XFHA shall apply in full.

8.2.2 External Flood Fragility Analysis (LXFFR)

The objective of the external flood fragility analysis is to identify those structures, systems, and components that are important to core/site protection and post-accident mitigation strategies during shutdown and are susceptible to the effects of external floods and to determine their plant-specific failure probabilities as a function of the severity of the external flood. Note that external-flood hazards include both flood levels and associated effects such as debris generation and transport, soil erosion issues, and the like. Also, note that during shutdown conditions, flooding challenges may be different than during full-power operation because alternate flooding pathways may exist, or equipment protection may be reduced.

There are two high-level requirements for external flood fragility analysis, as follows:

Table 8.2.2-1 High Level Requirements for External Flood Probabilistic Risk Assessment: Technical Requirements for External-Flood Fragility Analysis (LXFFR)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LXFFR-A	HLR-XFFR-A	An external-flood fragility analysis shall be performed to estimate plant-specific, realistic fragilities for those structures, systems, components, or combination thereof whose failure contributes to core damage, large early release, or both.	Same as XFFR-A in ASME/ANS RA-Sa-2009 [1].
HLR-LXFFR-B	HLR-XFFR-B	Documentation of the external flood fragility analysis shall be consistent with the applicable supporting requirements.	Same as XFFR-B in ASME/ANS RA-Sa-2009 [1].

NOTE: during shutdown conditions, flooding challenges to equipment may be different than "at power" as alternate flooding pathways to equipment are possible or equipment protection is reduced.

Supporting Requirements for HLR-LXFFR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-XFFR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7.

8.2.3 External Flood Plant Response Analysis (LXPR)

The objectives of this element are to:

(a) develop an external flood plant response model by modifying the internal events full power PRA model or the LPSD PRA internal events model to include the effects of the external flood in terms of initiating events and failures caused, including operator actions;
(b) quantify this model to provide the conditional core damage probability (CCDP) and conditional large early release probability (CLERP) for each defined external flood plant damage state;
(c) evaluate the unconditional CDF and LERF by integrating the CCDP/CLERP with the frequencies of the plant damage states obtained by combining the external-flood hazard analysis and external-flood fragility analysis.

There are three high-level requirements for external-flood plant-response and quantification analysis, as follows:

Table 8.2.3-1 High Level Requirements for External-Flood Plant Response Model and Quantification (LXFPR)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LXFPR-A	HLR-SFPR-A	The external flood PRA systems models shall include flood-caused initiating events and other failures that can lead to core damage or large early release. The model shall be adapted from the internal events LPSD PRA systems model to incorporate flood-analysis aspects that are different from the corresponding aspects in the LPSD internal-events PRA systems model.	Same as XFPR-A in ASME/ANS RA-Sa-2009 [1].
HLR-LXFPR-B	HLR-XFPR-B	The analysis to quantify core damage and large early release frequencies shall appropriately integrate the external-flood hazard, the external-flood fragilities, and the systems-analysis aspects.	Same as XFPR-B in ASME/ANS RA-Sa-2009 [1].
HLR-LXFPR-C	HLR-XFPR-C	Documentation of the external-flood plant response model development and quantification shall be consistent with the applicable supporting requirements.	Same as XFPR-C in ASME/ANS RA-Sa-2009 [1].

Supporting Requirements for HLR-LXFPR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-XFPR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7.

8.3 Peer Review for External Flood PRA during LPSD Conditions

The entire text under Section 8-3 of ASME/ANS RA-Sa-2009 [1] shall apply in full, except where modified, as appropriate, to refer to "LPSD conditions" instead of "at-power conditions."

A consideration in the selection of the peer reviewers is to assure that there is expertise and knowledge about LPSD evolutions within the team.

8.4 References

The entire list of References in Section 8-4 of ASME/ANS RA-Sa-2009 [1] is incorporated in this standard by reference.

Part 9 Other External Hazards Analysis

Text that is new in this part compared to that in Part 9 of Reference [1] is underlined below.

9.1 Overview of Requirements for Other External Hazards PRAs during LPSD Conditions

The term "other external hazard" refers to an external hazard other than those for which requirements are provided in other parts of this standard, e.g., earthquakes, high winds, and external floods. Appendix 6-A in ASME/ANS RA-Sa-2009 [1] includes a list of external hazards that may apply at specific sites.

The objectives and high level requirements for PRA analysis of other external hazards for LPSD conditions are basically the same as those identified for analysis during full power conditions in ASME/ANS RA-Sa-2009 [1] and shall be accomplished for each POS, as appropriate. This section is intended to be used together with Parts 1, 2, and 3 of this standard. Many of the technical requirements in Part 3 (Internal Events) are fundamental requirements for performing a PRA for any hazard group and are applicable to all the hazard groups within the scope of the LPSD PRA. They are incorporated by reference in those requirements that address the development of the plant response to the damage states created by the hazard groups addressed in this section. Note that each external hazard for which a unique approach is developed will constitute its own hazard group. The plant conditions defined for each POS for the external hazard group may have to be refined for this analysis. Such refinements may be needed to appropriately consider hazard group-specific plant conditions that may impair hazard barriers, affect propagation pathways, or modify fragilities of structures, systems, or components.

Specifically, the scope of the requirements herein cover (a) a Level 1 analysis of the core damage frequency (CDF) and (b) a limited Level 2 analysis sufficient to evaluate the large early release frequency (LERF).

Section 1.1.8 of this standard contains an introduction that describes how the PRA analysis in this section is to be structured and the relationship of the various aspects of a full power external-hazards PRA in general to the analysis here for LPSD conditions.

The introductory text in Part 9 of ASME/ANS RA-Sa-2009 [1], namely Section 9-1, applies in full. The Capability Categories and how they are to be applied for a specific application also apply in full.

Objectives: The objective of this section (PRA analysis for other external hazards) is to provide estimates of the core damage frequency (CDF) and large early release frequency (LERF) for accidents initiated by a single other external hazard, including uncertainties. Besides overall CDF and LERF estimates, the analysis must have as an explicit objective the determination of the hazard, the determination of the fragilities of those SSCs that contribute, the determination through systems analysis of the major sequences and damage states that contribute, and adequate documentation. The details that elaborate on what these introductory phrases mean in practice are contained in the Technical Requirements.

9.2 Technical Requirements for Other External Hazard PRA during LPSD Conditions

The text in Section 9-2 of ASME/ANS RA-Sa-2009 [1] shall apply in full.

9.2.1 Probabilistic Other-External-Hazard Analysis (LXHA)

The objective of the hazard analysis is to assess the frequency of occurrence of the external hazard as a function of intensity on a site-specific basis.

There are two high-level requirements for LXHA, as follows:

Table 9.2.1-1 High Level Requirements for Other External Hazard (LXHA)

Designator in This Standard	**Designator in ASME/ANS RA-Sa-2009 [1]**	**Requirement**	**Commentary**
HLR-LXHA-A	HLR-XHA-A	The analysis of the hazard (the frequency of occurrence of different intensities of the external hazard) shall be based on a site-specific probabilistic evaluation reflecting recent available data and site-specific information. The analysis can be based on historical data, a phenomenological model, or a mixture of the two.	Same as XHA-A in ASME/ANS RA-Sa-2009 [1].
HLR-LXHA-B	HLR-XHA-B	Documentation of the external hazard analysis shall be consistent with the applicable supporting requirements.	Same as XHA-B in ASME/ANS RA-Sa-2009 [1].

Supporting Requirements for HLR-LXHA: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-XHA shall apply in full.

9.2.2 Other External Hazard Fragility Analysis (LXFR)

The objective of external hazard fragility analysis is to identify those structures, systems, and components that are susceptible to the effects of the external hazard and to determine their plant-specific failure probabilities as a function of the severity of the hazard. Note that in this context, the plant operators are included as components of the system since some external hazards (e.g., toxic gas) may affect operators rather than equipment.

There are two high-level requirements for other-external-hazard fragility analysis, as follows.:

Table 9.2.2-1 High Level Requirements for Other External Hazards Probabilistic Risk Assessment: Technical Requirements for Other External Hazard Fragility Analysis (LXFR)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LXFR-A	HLR-XFR-A	The fragility of a structure, system, component, or a combination thereof (SSC) shall be evaluated using plant-specific, SSC-specific information and an accepted engineering method for evaluating the postulated failure.	Same as XFR-A in ASME/ANS RA-Sa-2009 [1].
HLR-LXFR-B	HLR-XFR-B	Documentation of the external hazard fragility analysis shall be consistent with the applicable supporting requirements.	Same as XFR-B in ASME/ANS RA-Sa-2009 [1].

Supporting Requirements for HLR-LXFR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-XFR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7.

9.2.3 Other External Hazard Plant Response Analysis

The objectives of this element are to:

(a) develop a plant response model by modifying the LPSD PRA internal events model to include the effects of the external hazard in terms of initiating events and failures caused, including operator actions;
(b) quantify this model to provide the conditional core damage probability (CCDP) and conditional large early release probability (CLERP) for each defined external hazard plant damage state;
(c) evaluate the unconditional CDF and LERF by integrating the CCDP/CLERP with the frequencies of the plant damage states obtained by combining the hazard analysis and the fragility analysis.

There are three high-level requirements for other-external-hazard plant-response and quantification analysis, as follows:

Table 9.2.3-1 High Level Requirements for Other External-Hazard Plant Response Model and Quantification (LXPR)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LXPR-A	HLR-XPR-A	The external hazard PRA plant model shall include external-hazard-caused initiating events and other failures that can lead to core damage or large early release. The model shall be adapted from the internal events LPSD PRA systems model to incorporate external-hazard-analysis aspects that are different from the corresponding aspects in the LPSD internal-events PRA systems model.	Same as XPR-A in ASME/ANS RA-Sa-2009 [1].
HLR-LXPR-B	HLR-XPR-B	The analysis to quantify core damage and large early release frequencies shall appropriately integrate the external hazard, the external-hazard fragilities, and the systems-analysis aspects.	Same as XPR-B in ASME/ANS RA-Sa-2009 [1].
HLR-LXPR-C	HLR-XPR-C	Documentation of the external-hazard plant response model development and quantification shall be consistent with the applicable supporting requirements.	Same as XPR-C in ASME/ANS RA-Sa-2009 [1].

Supporting Requirements for HLR-LXPR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-XPR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7.

9.3 Peer Review for Other External Hazard PRA during LPSD Conditions

The entire text under Section 9-3 of ASME/ANS RA-Sa-2009 [1] shall apply in full, except where modified, as appropriate, to refer to "LPSD conditions" instead of "at-power conditions."

A consideration in the selection of the peer reviewers is to assure that there is expertise and knowledge about LPSD evolutions within the team.

9.4 References

The entire list of References in Section 9-4 of ASME/ANS RA-Sa-2009 [1] is incorporated in this standard by reference.

Part 10 LPSD Quantitative Risk Assessment for a Specific LPSD Evolution

10.1 Overview of Risk Assessment for a Specific LPSD Evolution

As noted in Section 1.1, this standard is intended to be applicable to an LPSD PRA or an LPSD QLRA. For LPSD QLRA, the requirements in Part 11 are applicable for such applications. The supporting requirements presented in Parts 2 through 9 have been written for a PRA developed to support the assessment of time-averaged CDF and LERF risk metrics or alternate time-averaged risk metrics, as noted in Sections 1.1.2 and 1.3.3. These supporting requirements are not all necessarily applicable for LPSD PRA models developed to assess time-dependent risk metrics of a specific LPSD evolution.

The personnel at U.S. nuclear power plants (NPPs) routinely apply configuration risk management programs to manage risk for both full power and specific LPSD evolutions. For LPSD evolutions, essentially all U.S. NPPs have implemented these configuration risk management programs to support work planning, work scheduling, and equipment configuration control for specific LPSD evolutions. These programs typically involve the assessment of time-dependent CDF and LERF, often at much finer time intervals than those typically assigned to POSs, based on detailed modeling of planned maintenance activities for the specific outage.

The LPSD PRA supporting requirements developed for the evaluation of time-averaged risk metrics cannot necessarily all be used to assess time-dependent risk metrics. This part of the standard provides requirements on how to support such assessments. Specifically, information is provided for modifying the requirements developed for time-averaged risk so that an analysis of timed-dependent risk metrics can be performed. The selected scope of the PRA application (see Section 1.3.3) is also a factor in determining the applicability of the requirements. As this part is entirely new as compared to Reference [1], no underlining is used to show such differences. Underlining in Table titles from earlier parts are also retained in Part 10. Where REPLACEMENT REQUIREMENTS are inserted, underlining is also used to show the changes from earlier parts in this standard.

10.2 Supporting Requirements for Time-Dependent Risk Metrics for a Specific LPSD Evolution

For applications involving time-dependent risk metrics, all of the high-level requirements in Parts 2 through 9 are still applicable. Comments on individual supporting requirements that can be modified are noted in the following tables. The reader is referred to Parts 2 through 9 for the time-averaged risk assessment supporting requirements. The following tables were copied from Parts 2 through 9 in this standard. The tables have been numbered by adding "10." to the table numbers in Parts 2 through 9 so that the corresponding tables for time-averaged CDF and LERF can be easily identified. For Parts 2, 3, and 4, if the supporting requirements for time-dependent, specific LPSD evolutions do not change as compared to those for time-averaged CDF and LERF risk metrics, then this is noted in the table. For example, the table entry simply says "AS IN PART 2," and it is understood that the reader is to refer to the corresponding table in the part of the standard referenced. If the supporting requirement is the same except that an additional requirement is made, this is so noted by preceding the addition by "ADDITIONAL REQUIREMENT." In some cases, a clarification is offered, which is preceded by "CLARIFICATION." If the supporting requirement is not applicable to time-dependent specific LPSD evolution analyses, then the phrase "NOT APPLICABLE" is indicated. Finally, if the supporting requiring has been changed, then the revised wording is preceded by "REPLACEMENT REQUIREMENT."

The reader is reminded that Parts 2 and 3 refer to the requirements for the internal event hazard group. Part 4 refers to internal floods, and Parts 5 through 9 refer to the other hazard groups considered for an LPSD PRA time-averaged CDF and LERF. The internal fires hazard group is not discussed in this standard and so is also not discussed for time-dependent specific LPSD evolutions.

In addition to evaluating time-dependent CDF and LERF for a specific LPSD evolution (e.g., for a refueling outage), the assessment performed for a particular application may also use the time-averaged CDF and LERF or cumulative CDF and LERF as risk metrics. Such time-averaged and cumulative risk metrics can be developed from the evaluated time-dependent CDF and LERF values for all of the plant configurations during the LPSD evolution. The modifications to the supporting requirements for internal and external events described in the following tables consider both of these situations. It is expected that for most configuration risk management applications, the use of time-dependent CDF and LERF is sufficient.

As described in Section 1.6, a peer review is required prior to the use of a specific LPSD evolution PRA model. However, this model could be used for subsequent specific LPSD evolutions without additional peer review provided that the changes required for the subsequent LPSD evolutions can be classified as PRA maintenance changes rather than as PRA upgrades.

Table 10.2-2(a) Supporting Requirements for Plant Operating State Analysis – High Level Requirement A

The POS analysis shall use a structured, systematic process to identify and define a complete set of plant operating states to be analyzed in the LPSD PRA (HLR-LPOS-A).

	Capability Category I	Capability Category II	Capability Category III
LPOS-A1	AS IN PART 2. CLARIFICATION: IDENTIFY a single evolution type.	AS IN PART 2. CLARIFICATION: IDENTIFY a single evolution type.	AS IN PART 2. CLARIFICATION: IDENTIFY a single evolution type.
LPOS-A2	AS IN PART 2. CLARIFICATION: REVIEW documentation for the identified evolution type.		
LPOS-A3	AS IN PART 2. CLARIFICATION: DEFINE the set of exclusive POSs for the single identified evolution type. Account for the bulleted items in this SR either as plant conditions used to define the POSs or in the time-dependent quantifications of each plant configuration. A reduced set of POSs may be used provided all plant conditions listed in the SR are accounted for (see also Appendix 2.A).		
LPOS-A4	AS IN PART 2. CLARIFICATION: REVIEW the known plans only for the single identified evolution.		
LPOS-A5	AS IN PART 2.	AS IN PART 2. CLARIFICATION: FOCUS the INTERVIEW on the identified LPSD evolution.	
LPOS-A6	AS IN PART 2.	AS IN PART 2. CLARIFICATION: DETERMINE significant contributors by evaluating a representative LPSD evolution of the type to be assessed and assuming that no equipment outages take place other than those that define a POS. DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	
LPOS-A7	AS IN PART 2.		

Table 10.2-2(b) Supporting Requirements for Plant Operating State Analysis – High Level Requirement B

The POS analysis shall justify all screening and grouping of POSs or LPSD evolutions to facilitate an efficient but realistic estimation of CDF and LERF and to support subsequent requirements to be evaluated by POS or group of POSs (HLR-LPOS-B).

	Capability Category I	Capability Category II	Capability Category III
LPOS-B1	NOT APPLICABLE.	NOT APPLICABLE.	NOT APPLICABLE.
LPOS-B2	REPLACEMENT REQUIREMENT: DO NOT SCREEN any POSs that make up the identified LPSD evolution.		
LPOS-B3	AS IN PART 2.	AS IN PART 2.	AS IN PART 2.
LPOS-B4	AS IN PART 2.		
LPOS-B5	AS IN PART 2.		
LPOS-B6	AS IN PART 2.		
LPOS-B7	AS IN PART 2.	AS IN PART 2. CLARIFICATION: DETERMINE significant contributors by evaluating a representative LPSD evolution of the type to be assessed, assuming that no equipment outages take place other than those that define a POS. DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	

Table 10.2-2(c) Supporting Requirements for Plant Operating State Analysis – High Level Requirement C

The POS analysis shall determine the POS frequencies and durations along with the representative decay heat levels associated with each POS (HLR-LPOS-C).

	Capability Category I	Capability Category II	Capability Category III
LPOS-C1	NOT APPLICABLE.		
LPOS-C2	REPLACEMENT REQUIREMENT: To estimate the average duration and average time after shutdown for each POS, USE the planned POS durations for the specific LPSD evolution.		
LPOS-C3	REPLACEMENT REQUIREMENT: USE the planned POS durations for the specific LPSD evolution.		
LPOS-C4	AS IN PART 2. CLARIFICATION: USE the specific evolution plan to establish the decay heat level for each POS entry time.		
LPOS-C5	NOT APPLICABLE.		

Table 10.2-2(d) Supporting Requirements for Plant Operating State Analysis – High Level Requirement D

The POS analysis shall be documented consistent with the applicable supporting requirements (HLR-LPOS-D).

	Capability Category I	Capability Category II	Capability Category III
LPOS-D1	AS IN PART 2.		
LPOS-D2	AS IN PART 2. CLARIFICATION: Omit documentation of LPSD evolution types that are not applicable, and omit documentation of POS entry frequencies.		
LPOS-D3	AS IN PART 2.		

Table 10.3.2.1-2(a) Supporting Requirements for HLR-LIE-A

The initiating event analysis shall provide a reasonably complete identification of initiating events for all POSs retained for analysis (HLR-LIE-A).

<table>
<tr><th>Index No. LIE-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td>LIE-A1</td><td colspan="3">AS IN PART 3.
CLARIFICATION: IDENTIFY the initiating events that challenge normal plant operation and require successful mitigation for the single identified LPSD evolution type.</td></tr>
<tr><td>LIE-A2</td><td colspan="3">AS IN PART 3.
CLARIFICATION: INCLUDE the spectrum of initiating event challenges for the single identified LPSD evolution type.</td></tr>
<tr><td>LIE-A3</td><td colspan="3">AS IN PART 3.
CLARIFICATION: REVIEW initiating event experience for the single identified LPSD evolution type.</td></tr>
<tr><td>LIE-A4</td><td colspan="2">AS IN PART 3.
CLARIFICATION: REVIEW generic analyses for the single identified LPSD evolution type.</td><td>AS IN PART 3.
CLARIFICATION: REVIEW generic analyses for the single identified LPSD evolution type. ENSURE that at-initiator human failure events that impact later human responses for the single identified LPSD evolution type are tracked.</td></tr>
<tr><td>LIE-A5</td><td>AS IN PART 3.
CLARIFICATION: PERFORM systematic evaluation of each system and supporting system using a qualitative review of system impacts to identify potential initiating events for the single identified LPSD evolution type.</td><td>AS IN PART 3.
CLARIFICATION: PERFORM systematic evaluation of each system, including supporting systems, using a structured approach to identify potential initiating events for the single identified LPSD evolution type.</td><td>AS IN PART 3.
CLARIFICATION: PERFORM systematic evaluation of each system, including supporting systems, using a structured approach and detailed analysis of system interfaces to identify potential initiating events for the single identified LPSD evolution type.</td></tr>
</table>

Table 10.3.2.1-2(a) Supporting Requirements for HLR-LIE-A (Cont'd)

Index No. LIE-A	Capability Category I	Capability Category II	Capability Category III
LIE-A6	AS IN PART 3. CLARIFICATION: INCLUDE initiating events caused by common cause failures in the system evaluation for the single identified LPSD evolution type.	AS IN PART 3. CLARIFICATION: INCLUDE initiating events caused by common cause failure and system alignment in the evaluation for the single identified LPSD evolution type.	AS IN PART 3. CLARIFICATION: INCLUDE initiating events caused by random and common cause failures and by system alignment in the evaluation for the single identified LPSD evolution type.
LIE-A7	AS IN PART 3.		
LIE-A8	AS IN PART 3.	AS IN PART 3. CLARIFICATION: FOCUS the interview on the single identified LPSD evolution type.	
LIE-A9	AS IN PART 3.	AS IN PART 3. CLARIFICATION: REVIEW the plant-specific operating experience for the single identified LPSD evolution type.	AS IN PART 3. CLARIFICATION: REVIEW the plant-specific and industry operating experience for the single identified LPSD evolution type.
LIE-A9a	AS IN PART 3.	AS IN PART 3. CLARIFICATION: INCLUDE system alignment that could influence the likelihood of an initiating event or increase the severity of previously identified initiating events or cause a new initiating event in the search for initiating events for the single identified LPSD evolution type.	
LIE-A10	AS IN PART 3.		

Table 10.3.2.1-2(b) Supporting Requirements for HLR-LIE-B

The initiating event analysis shall group the initiating events within a POS so that events in the same group have similar mitigation requirements (i.e., the requirements for most events in the group are less restrictive than the limiting mitigation requirements defined for the group) to facilitate an efficient but realistic estimation of CDF (HLR-LIE-B).

Index No. LIE-B	Capability Category I	Capability Category II	Capability Category III
LIE-B1	AS IN PART 3. CLARIFICATION: GROUP initiating events by POS for the single identified LPSD evolution type. It is not necessary to group the initiating events for each plant configuration.		
LIE-B2	AS IN PART 3. CLARIFICATION: APPLY the process used for grouping initiating events by POS for the single identified LPSD evolution type. It is not necessary to apply the process to each plant configuration.		
LIE-B3	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LIE-B4	AS IN PART 3 CLARIFICATION: GROUP initiating events by POS for the single identified LPSD evolution type. It is not necessary to group the initiating events for each plant configuration.		
LIE-B5	AS IN PART 3.		

Table 10.3.2.1-2(c) Supporting Requirements for HLR-LIE-C

The initiating event analysis shall estimate the annual frequency of each initiating event or initiating event group for each POS (HLR-LIE-C).

Index No. LIE-C	**Capability Category I**	**Capability Category II**	**Capability Category III**
LIE-C1	AS IN PART 3. CLARIFICATION: CALCULATE initiating event frequency by the POS for the single identified LPSD evolution type. It is not necessary to calculate the initiating event frequency for each plant configuration.		
LIE-C2	AS IN PART 3.		
LIE-C3	AS IN PART 3.		
LIE-C4	AS IN PART 3.		
LIE-C5	REPLACEMENT REQUIREMENT: CALCULATE initiating event frequencies on a per calendar year basis for the single identified LPSD evolution type. CALCULATE initiating event frequencies for at-initiator human failure events for each applicable POS on a per reactor year basis. Specifically, for each applicable POS, ESTIMATE the number of times that the at-initiator is challenged during the POS and the frequency that the POS is entered per reactor year.		
LIE-C6	REPLACEMENT REQUIREMENT: For screening initiating events or initiating event groups for the single identified LPSD evolution type, DEVELOP and JUSTIFY the frequency screening criteria used.		
LIE-C6a	NOT APPLICABLE.	NOT APPLICABLE.	NOT APPLICABLE.
LIE-C7	AS IN PART 3.		AS IN PART 3.
LIE-C8	AS IN PART 3.		
LIE-C9	AS IN PART 3.		
LIE-C10	AS IN PART 3.		
LIE-C11	AS IN PART 3.		
LIE-C12	AS IN PART 3.		
LIE-C13	AS IN PART 3.		AS IN PART 3.
LIE-C14	AS IN PART 3.		AS IN PART 3.
LIE-C15	AS IN PART 3.		

Table 10.3.2.1-2(d) Supporting Requirements for HLR-LIE-D

Documentation of the initiating event analysis shall be consistent with the applicable supporting requirements (HLR-LIE-D).

Index No. LIE-D	Capability Category I	Capability Category II	Capability Category III
LIE-D1	AS IN PART 3.		
LIE-D2	AS IN PART 3.		
LIE-D3	AS IN PART 3.		

Table 10.3.2.2-2(a) Supporting Requirements for HLR-LAS-A

The accident sequence analysis shall describe the plant-specific scenarios that can lead to core damage following each modeled initiating event. These scenarios shall address system responses and operator actions including recovery actions that support the key safety functions necessary to prevent core damage (HLR-LAS-A).

<table>
<tr><th>Index No.
LAS-A</th><th>Capability Category I</th><th>Capability Category II</th><th>Capability Category III</th></tr>
<tr><td>LAS-A1</td><td colspan="3">AS IN PART 3.
CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.</td></tr>
<tr><td>LAS-A2</td><td colspan="3">AS IN PART 3.
CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.</td></tr>
<tr><td>LAS-A3</td><td colspan="3">AS IN PART 3.
CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.</td></tr>
<tr><td>LAS-A4</td><td colspan="3">AS IN PART 3.
CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.</td></tr>
<tr><td>LAS-A5</td><td colspan="3">AS IN PART 3.
CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.</td></tr>
<tr><td>LAS-A6</td><td colspan="3">AS IN PART 3.
CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.</td></tr>
<tr><td>LAS-A7</td><td colspan="2">AS IN PART 3.
CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.</td><td>AS IN PART 3
CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.</td></tr>
<tr><td>LAS-A8</td><td colspan="3">AS IN PART 3.
CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.</td></tr>
</table>

Table 10.3.2.2-2(a) Supporting Requirements for HLR-LAS-A (Cont'd)

Index No. LAS-A	Capability Category I	Capability Category II	Capability Category III
LAS-A9	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.
LAS-A10	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.
LAS-A11	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.2-2(b) Supporting Requirements for HLR-LAS-B

Dependencies that can impact the ability of the mitigating systems to operate and function shall be addressed (HLR-LAS-B).

Index No. LAS-B	Capability Category I	Capability Category II	Capability Category III
LAS-B1	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LAS-B2	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LAS-B3	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LAS-B4	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LAS-B5	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LAS-B6	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LAS-B7	AS IN PART 3. CLARIFICATION: PERFORM the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.2-2(c) Supporting Requirements for HLR-LAS-C

Documentation of the accident sequence analysis shall be consistent with the applicable supporting requirements (HLR-LAS-C).

Index No. LAS-C	**Capability Category I**	**Capability Category II**	**Capability Category III**
LAS-C1	AS IN PART 3. CLARIFICATION: DOCUMENT the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LAS-C2	AS IN PART 3. CLARIFICATION: DOCUMENT the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LAS-C3	AS IN PART 3. CLARIFICATION: DOCUMENT the sequence development by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.3-2(a) Supporting Requirements for HLR-LSC-A

The overall success criteria for the PRA and the system, structure, component, and human action success criteria used in the LPSD PRA shall be defined and referenced and shall be consistent with the features, procedures, and operating philosophy of the plant (HLR-LSC-A).

Index No. LSC-A	Capability Category I	Capability Category II	Capability Category III
LSC-A1	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSC-A2	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	
LSC-A3	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSC-A4	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSC-A5	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	
LSC-A6	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.3-2(b) Supporting Requirements for HLR-LSC-B

The thermal/hydraulic structural and other supporting engineering bases shall be capable of providing success criteria and event timing sufficient for quantification of CDF and LERF, determination of the relative impact of success criteria on SSC and human actions, and the impact of uncertainty on this determination (HLR-LSC-B).

Index No. LSC-B	Capability Category I	Capability Category II	Capability Category III
LSC-B1	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.
LSC-B2	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	
LSC-B3	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSC-B4	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSC-B5	AS IN PART 3. CLARIFICATION: DEVELOP success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.3-2(c) Supporting Requirements for HLR-LSC-C

Documentation of success criteria shall be consistent with the applicable supporting requirements (HLR-LSC-C).

Index No. LSC-C	Capability Category I	Capability Category II	Capability Category III
LSC-C1	AS IN PART 3. CLARIFICATION: DOCUMENT success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSC-C2	AS IN PART 3. CLARIFICATION: DOCUMENT success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSC-C3	AS IN PART 3. CLARIFICATION: DOCUMENT success criteria by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.4-2(a) Supporting Requirements for HLR-LSY-A

The systems analysis shall provide a reasonably complete treatment of the causes of system failure and unavailability modes represented in the initiating events analysis and sequence definition (HLR-LSY-A).

Index No. LSY-A	Capability Category I	Capability Category II	Capability Category III
LSY-A1	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A2	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A3	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A4	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	
LSY-A5	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A6	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A7	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.

Table 10.3.2.4-2(a) Supporting Requirements for HLR-LSY-A (Cont'd)

Index No. LSY-A	**Capability Category I**	**Capability Category II**	**Capability Category III**
LSY-A8	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A9	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A10	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A11	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A12	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A13	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A14	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A15	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A16	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.
LSY-A17	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A18	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.4-2(a) Supporting Requirements for HLR-LSY-A (Cont'd)

Index No. LSY-A	Capability Category I	Capability Category II	Capability Category III
LSY-A19	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A20	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A21	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A22	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.
LSY-A23	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-A24	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.4-2(b) Supporting Requirements for HLR-LSY-B

The systems analysis shall provide a reasonably complete treatment of common cause failures and intersystem and intra-system dependencies (HLR-LSY-B).

Index No. LSY-B	Capability Category I	Capability Category II	Capability Category III
LSY-B1	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	
LSY-B2	AS IN PART 3.		AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.
LSY-B3	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-B4	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-B5	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-B6	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.4-2(b) Supporting Requirements for HLR-LSY-B (Cont'd)

Index No. LSY-B	Capability Category I	Capability Category II	Capability Category III
LSY-B7	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.
LSY-B8	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-B9	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-B10	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.	
LSY-B11	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-B12	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-B13	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-B14	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-B15	AS IN PART 3. CLARIFICATION: PERFORM the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.4-2(c) Supporting Requirements for HLR-LSY-C

Documentation of the systems analysis shall be consistent with the applicable supporting requirements (HLR-LSY-C).

Index No. LSY-C	Capability Category I	Capability Category II	Capability Category III
LSY-C1	AS IN PART 3. CLARIFICATION: DOCUMENT the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-C2	AS IN PART 3. CLARIFICATION: DOCUMENT the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		
LSY-C3	AS IN PART 3. CLARIFICATION: DOCUMENT the systems analysis by POS for the specific LPSD evolution. It is not necessary to perform this for each plant configuration.		

Table 10.3.2.5-2(a) Supporting Requirements for HLR-LHR-A

Pre-Initiator HRA: A systematic process shall be used to identify those specific routine activities in each POS that, if not completed correctly, may impact the availability of equipment necessary to perform system function modeling in the LPSD PRA (HLR-LHR-A).

Index No. LHR-A	Capability Category I	Capability Category II	Capability Category III
LHR-A1	SAME AS PART 3.	SAME AS PART 3. ADDITIONAL REQUIREMENT: CONFIRM the reviews of applicable procedures and operational practices for the specific plant evolution assessment.	
LHR-A2	SAME AS PART 3.	SAME AS PART 3. ADDITIONAL REQUIREMENT: CONFIRM the calibration activities identified for the specific plant evolution assessment.	
LHR-A2a	SAME AS PART 3	SAME AS PART 3. ADDITIONAL REQUIREMENT: CONFIRM the activities that could have an adverse impact on the specific plant evolution assessment.	SAME AS PART 3. ADDITIONAL REQUIREMENT: CONFIRM the activities that could have an adverse impact on the specific plant evolution assessment.
LHR-A3	SAME AS PART 3. ADDITIONAL REQUIREMENT: CONFIRM the work practices identified for the specific plant evolution assessment.		

Table 10.3.2.5-2(b) Supporting Requirements for HLR-LHR-B

Pre-Initiator HRA: Screening of activities that need not be addressed explicitly in the model shall be based on an assessment of how plant-specific operational practices limit the likelihood of errors in such activities (HLR-LHR-B).

Index No. LHR-B	Capability Category I	Capability Category II	Capability Category III
LHR-B1	SAME AS PART 3. CLARIFICATION: PERFORM the screening by POS even if the HFE assessment is otherwise performed by plant configuration.	SAME AS PART 3. CLARIFICATION: PERFORM the screening by POS even if the HFE assessment is otherwise performed by plant configuration.	
LHR-B2	SAME AS PART 3. CLARIFICATION: PERFORM the screening by POS even if the HFE assessment is otherwise performed by plant configuration.		
LHR-B3	SAME AS PART 3. CLARIFICATION: PERFORM the screening by POS even if the HFE assessment is otherwise performed by plant configuration.		
LHR-B4	SAME AS PART 3. CLARIFICATION: PERFORM the screening by POS even if the HFE assessment is otherwise performed by plant configuration.		

Table 10.3.2.5-2(c) Supporting Requirements for HLR-LHR-C

Pre-Initiator HRA: For each activity that is not screened out, an appropriate human failure event (HFE) shall be defined for each applicable POS to characterize the impact of the failure as an unavailability of a component, system, or function modeled in the LPSD PRA (HLR-LHR-C).

Index No. LHR-C	Capability Category I	Capability Category II	Capability Category III
LHR-C1	SAME AS PART 3.		
LHR-C1a	SAME AS PART 3.		
LHR-C2	SAME AS PART 3.	SAME AS PART 3.	
LHR-C3	SAME AS PART 3.		

Table 10.3.2.5-2(d) Supporting Requirements for HLR-LHR-D

Pre-Initiator HRA: The assessment of the probabilities of the pre-initiator human failure events shall be performed by using a systematic process that addresses the plant-specific and activity-specific influences on human performance (HLR-LHR-D).

Index No. LHR-D	Capability Category I	Capability Category II	Capability Category III
LHR-D1	SAME AS PART 3.		
LHR-D2	SAME AS PART 3. USE **screening estimates** in the quantification of the pre-initiator HEPs.	SAME AS PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	SAME AS PART 3. **USE detailed assessments in the quantification of pre-initiator HEPs for each system.**
LHR-D3	SAME AS PART 3.	SAME AS PART 3.	
LHR-D4	SAME AS PART 3.		
LHR-D5	SAME AS PART 3.		SAME AS PART 3.
LHR-D6	SAME AS PART 3.		
LHR-D7	SAME AS PART 3.	SAME AS PART 3.	

Table 10.3.2.5-2(e) Supporting Requirements for HLR-LHR-E

Post-Initiator HRA: A systematic review of the relevant procedures and past operational events shall be used to identify the set of operator responses required for each of the accident sequences (HLR-LHR-E).

Index No. LHR-E	Capability Category I	Capability Category II	Capability Category III
LHR-E1	SAME AS PART 3. ADDITIONAL REQUIREMENT: CONFIRM the reviews of applicable procedures and system operation for the specific plant evolution assessment.		
LHR-E2	SAME AS PART 3.		
LHR-E3	SAME AS PART 3.	SAME AS PART 3.	
LHR-E4	SAME AS PART 3.	SAME AS PART 3.	

Table 10.3.2.5-2(f) Supporting Requirements for HLR-LHR-F

Post-Initiator HRA: Human failure events that represent the impact of not properly performing the required responses shall be defined for each POS consistent with the structure and level of detail of the accident sequences (HLR-LHR-F).

Index No. LHR-F	Capability Category I	Capability Category II	Capability Category III
LHR-F1	SAME AS PART 3.		SAME AS PART 3.
LHR-F2	SAME AS PART 3.	SAME AS PART 3.	SAME AS PART 3.
LHR-F3	SAME AS PART 3.	SAME AS PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	SAME AS PART 3.

Table 10.3.2.5-2(g) Supporting Requirements for HLR-LHR-G

<u>*Post-Initiator HRA*</u>*:* The assessment of the probabilities of the post-initiator HFEs shall be performed using a well-defined and self-consistent process that addresses the plant-specific and scenario-specific influences on human performance and potential dependencies between human failure events in the same accident sequence (HLR-LHR-G).

Index No. LHR-G	Capability Category I	Capability Category II	Capability Category III
LHR-G1	SAME AS PART 3.	SAME AS PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	SAME AS PART 3.
LHR-G2	SAME AS PART 3.		
LHR-G3	**SAME AS PART 3.**	SAME AS PART 3.	
LHR-G3a	SAME AS PART 3.	SAME AS PART 3.	SAME AS PART 3.
LHR-G4	SAME AS PART 3.	SAME AS PART 3. ADDITIONAL REQUIREMENT: ADJUST the times available to complete the actions from the available times for POSs for applicability to each plant configuration.	SAME AS PART 3. ADDITIONAL REQUIREMENT: ADJUST the times available to complete the actions from the available times for POSs for applicability to each plant configuration.
LHR-G5	SAME AS PART 3.	SAME AS PART 3. CLARIFICATION : DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	SAME AS PART 3.

Table 10.3.2.5-2(g) Supporting Requirements for HLR-LHR-G (Cont'd)

Index No. LHR-G	Capability Category I	Capability Category II	Capability Category III
LHR-G6	SAME AS PART 3.		
LHR-G7	SAME AS PART 3. ADDITIONAL REQUIREMENT: PERFORM the calculated joint human error probabilities for each plant configuration.		
LHR-G8	SAME AS PART 3.		

Table 10.3.2.5-2(h) Supporting Requirements for HLR-LHR-H

Post-Initiator HRA: Recovery actions (at the cut set or scenario level) shall be modeled only if it has been demonstrated that the action is plausible and feasible for those scenarios to which they are applied. Estimates of probabilities of failure shall address dependency on prior human failures in the scenario (HLR-LHR-H) [see Note (1)].

Index No. LHR-H	Capability Category I	Capability Category II	Capability Category III
LHR-H1	SAME AS PART 3.	SAME AS PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	SAME AS PART 3.
LHR-H2	SAME AS PART 3.		
LHR-H3	SAME AS PART 3. ADDITIONAL REQUIREMENT: CALCULATE the joint human error probabilities reflecting the dependencies between HFEs for operator recovery and any other HFEs for each plant configuration.		

Table 10.3.2.5-2(i) Supporting Requirements for HLR-LHR-I

At-Initiator HRA: A systematic process shall be used to identify routine test activities, maintenance activities, and activities needed to execute LPSD evolutions for each POS that could result in initiating events if incorrectly carried out (HLR-LHR-I).

Index No. LHR-I	**Capability Category I**	**Capability Category II**	**Capability Category III**
LHR-I1	SAME AS PART 3.	SAME AS PART 3.	
LHR-I2	SAME AS PART 3.		
LHR-I3	SAME AS PART 3.		SAME AS PART 3.

Table 10.3.2.5-2(j) Supporting Requirements for HLR-LHR-J

At-Initiator HRA: For each POS, the identified at-initiator human failure events shall be grouped so that events in the same group have similar mitigation requirements to facilitate an efficient but realistic estimation of CDF (HLR-LHR-J).

Index No. LHR-J	**Capability Category I**	**Capability Category II**	**Capability Category III**
LHR-J1	SAME AS PART 3.		
LHR-J2	SAME AS PART 3.	SAME AS PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	SAME AS PART 3.
LHR-J3	SAME AS PART 3.		
LHR-J4	SAME AS PART 3.		
LHR-J5	SAME AS PART 3.		

Table 10.3.2.5-2(k) Supporting Requirements for HLR-LHR-K

At-Initiator HRA: The assessment shall estimate the annual frequency of initiating events or initiating event groups made up of at-initiator human failure events (HLR-LHR-K).

Index No. LHR-K	**Capability Category I**	**Capability Category II**	**Capability Category III**
LHR-K1	SAME AS PART 3.		
LHR-K1a	SAME AS PART 3.		
LHR-K2	SAME AS PART 3.	SAME AS PART 3.	SAME AS PART 3.
LHR-K3	SAME AS PART 3.	SAME AS PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	SAME AS PART 3.
LHR-K4	SAME AS PART 3.		
LHR-K5	REPLACEMENT REQUIREMENT: CALCULATE initiating event frequencies for at-initiator human failure events for each applicable POS on a per reactor year basis. Specifically, for each applicable POS, assume that the probability that the at-initiator condition is challenged is 1.0, and that the duration of the POS is per year when assessing the at-initiator frequency.		
LHR-K6	REPLACEMENT REQUIREMENT: For screening at-initiator HFE-caused initiating events on a POS-by-POS basis, DEVELOP and JUSTIFY the frequency screening criteria used.		
LHR-K7	SAME AS PART 3.		
LHR-K8	SAME AS PART 3.		

Table 10.3.2.5-2(l) Supporting Requirements for HLR-LHR-L

At-Initiator HRA: Human failure events shall be defined to represent failure of a critical activity that leads to or contributes to an initiating event (HLR-LHR-L).

Index No. LHR-L	**Capability Category I**	**Capability Category II**	**Capability Category III**
LHR-L1	SAME AS PART 3.		SAME AS PART 3.
LHR-L2	SAME AS PART 3.	SAME AS PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	SAME AS PART 3.
LHR-L3	SAME AS PART 3.	SAME AS PART 3.	SAME AS PART 3.

Table 10.3.2.5-2(m) Supporting Requirements for HLR-LHR-I

Pre-, At-, and Post-Initiator HRA: Documentation of the human reliability analysis shall be consistent with the applicable supporting requirements (HLR-LHR-M).

Index No. LHRM	**Capability Category I**	**Capability Category II**	**Capability Category III**
LHR-M1	SAME AS PART 3.		
LHR-M2	SAME AS PART 3.		
LHR-M3	SAME AS PART 3. CLARIFICATION: DOCUMENT the sources of model uncertainty and related assumptions by POS even if the HFE assessment is otherwise performed by plant configuration.		

Table 10.3.2.6-2(a) Supporting Requirements for HLR-LDA-A

Each parameter shall be clearly defined in terms of the logic model, basic event boundary, and the model used to evaluate event probability (HLR-LDA-A).

Index No. LDA-A	Capability Category I	Capability Category II	Capability Category III
LDA-A1	AS IN PART 3. CLARIFICATION: It is not necessary to include basic events for equipment unavailability due to test and/or maintenance. .		
LDA-A2	AS IN PART 3.		
LDA-A3	AS IN PART 3.		
LDA-A4	ALTERNATE REQUIREMENT: IDENTIFY the parameter to be estimated and the data required for estimation. Examples are as follows: *(a)* For failures on demand, the parameter is the probability of failure, and the data required are the number of failures given a number of demands; *(b)* For standby failures, operating failures, and initiating events, the parameter is the failure rate, and the data required are the number of failures in the total (standby or operating) time; *(c)* For POS durations, the parameter is the duration for each POS, and the data required are the durations for past evolutions; *(d)* For POS frequencies, the parameter is POSs per evolution, and the data required are the number of evolutions during the calendar year.		

Table 10.3.2.6-2(b) Supporting Requirements for HLR-LDA-B

Grouping components into a homogeneous population for parameter estimation shall consider the design, environmental, and service conditions of the components in the as-built and as-operated plant (HLR-LDA-B).

Index No. LDA-B	Capability Category I	Capability Category II	Capability Category III
LDA-B1	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LDA-B2	AS IN PART 3.		AS IN PART 3.

Table 10.3.2.6-2(c) Supporting Requirements for HLR-LDA-C

Generic parameter estimates shall be chosen, and the collection of plant-specific data shall be consistent with the parameter definitions of HLR-LDA-A and the grouping rationale of HLR-LDA-B (HLR-LDA-C).

Index No. LDA-C	Capability Category I	Capability Category II	Capability Category III
LDA-C1	AS IN PART 3.		
LDA-C2	AS IN PART 3.		
LDA-C3	AS IN PART 3.		
LDA-C4	AS IN PART 3.		
LDA-C5	AS IN PART 3.		
LDA-C6	AS IN PART 3.		
LDA-C7	AS IN PART 3.	AS IN PART 3.	
LDA-C8	AS IN PART 3.	AS IN PART 3.	
LDA-C9	AS IN PART 3.		AS IN PART 3.
LDA-C10	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LDA-C11	NOT APPLICABLE.		
LDA-C12	AS IN PART 3.		
LDA-C13	NOT APPLICABLE.	NOT APPLICABLE.	
LDA-C14	NOT APPLICABLE.		
LDA-C15	AS IN PART 3.		
LDA-C16	AS IN PART 3.		
LDA-C17	NOT APPLICABLE.		
LDA-C18	AS IN PART 3.		
LDA-C19	NOT APPLICABLE.		

Table 10.3.2.6-2(d) Supporting Requirements for HLR-LDA-D

The parameter estimates shall be based on relevant generic industry and plant-specific evidence. Where feasible, generic and plant-specific evidence shall be integrated using acceptable methods to obtain plant-specific parameter estimates. Each parameter estimate shall be accompanied by a characterization of the uncertainty (HLR-LDA-D).

Index No. LDA-D	Capability Category I	Capability Category II	Capability Category III
LDA-D1	AS IN PART 3. CLARIFICATION: Since the single identified LPSD evolution is characterized by test and maintenance conditions, OMIT the associated parameter estimates for such events. .	AS IN PART 3. CLARIFICATION: Since the single identified LPSD evolution is characterized by test and maintenance conditions, OMIT the associated parameter estimates for such events. POS-by-POSDETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. . All POSs are to be assumed significant for the purposes of determining supporting requirements.	AS IN PART 3. CLARIFICATION: Since the single identified LPSD evolution is characterized by test and maintenance conditions, OMIT the associated parameter estimates for such events. .
LDA-D2	AS IN PART 3.		
LDA-D3	AS IN PART 3. CLARIFICATION: POS-by-POSDETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. . All POSs are to be assumed significant for purposes of determining supporting requirements.	AS IN PART 3. CLARIFICATION: POS-by-POSDETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. . All POSs are to be assumed significant for the purposes of determining supporting requirements.	AS IN PART 3.

Table 10.3.2.6-2(d) Supporting Requirements for HLR-LDA-D (Cont'd)

Index No. LDA-D	Capability Category I	Capability Category II	Capability Category III
LDA-D4	AS IN PART 3.	AS IN PART 3.	
LDA-D5	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LDA-D6	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LDA-D7	AS IN PART 3.		
LDA-D8	AS IN PART 3.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.

Table 10.3.2.6-2(e) Supporting Requirements for HLR-LDA-E

Documentation of data analysis shall be consistent with the applicable supporting requirements (HLR-LDA-E).

Index No. LDA-E	Capability Category I	Capability Category II	Capability Category III
LDA-E1	AS IN PART 3.		
LDA-E2	AS IN PART 3. CLARIFICATION: OMIT documentation of data used for estimating POS durations.		
LDA-E3	AS IN PART 3.		

Table 10.3.2.7-2(a) Supporting Requirements for Quantification HLR-LQU-A

The level 1 quantification shall quantify core damage frequency and shall support the quantification of LERF (HLR-LQU-A).

Index No. LQU-A	Capability Category I	Capability Category II	Capability Category III
LQU-A1	AS IN PART 3. ADDITIONAL REQUIREMENT: QUANTIFY the time-dependent CDF for each plant configuration in the specific LPSD evolution assuming for the quantification that all SSCs are available unless defined as out of service for the entire POS.		AS IN PART 3. ADDITIONAL REQUIREMENT: QUANTIFY the time-dependent CDF for each plant configuration in the specific evolution assuming for the quantification that all SSCs are available unless defined as out of service for the entire POS.
LQU-A2	AS IN PART 3.		
LQU-A3	REPLACEMENT REQUIREMENT: ESTIMATE the point estimate CDF by configuration, then aggregate by POS or group of POSs.		REPLACEMENT REQUIREMENT: CALCULATE the mean CDF by aggregating the configuration results by POS or group of POSs and by propagating the uncertainty distributions, ensuring the state-of-knowledge correlation between event probabilities is taken into account.
LQU-A4	AS IN PART 3.		
LQU-A5	AS IN PART 3.		

Table 10.3.2.7-2(b) Supporting Requirements for Quantification HLR-LQU-B

The quantification shall use appropriate models and codes, and shall account for method-specific limitations and features (HLR-LQU-B).

Index No. LQU-B	**Capability Category I**	**Capability Category II**	**Capability Category III**
LQU-B1	AS IN PART 3.		
LQU-B2	AS IN PART 3.		
LQU-B3	AS IN PART 3.		
LQU-B4	AS IN PART 3.		
LQU-B5	AS IN PART 3.		
LQU-B6	AS IN PART 3.		
LQU-B7	AS IN PART 3.		
LQU-B8	AS IN PART 3.		
LQU-B9	AS IN PART 3.		
LQU-B10	AS IN PART 3.		

Table 10.3.2.7-2(c) Supporting Requirements for Quantification HLR-LQU-C

Model quantification shall determine that all identified dependencies are addressed appropriately (HLR-LQU-C).

Index No. LQU-C	**Capability Category I**	**Capability Category II**	**Capability Category III**
LQU-C1	AS IN PART 3.		
LQU-C2	AS IN PART 3.		
LQU-C3	AS IN PART 3.		

Table 10.3.2.7-2(d) Supporting Requirements for Quantification HLR-LQU-D

The quantification results shall be reviewed, and significant contributors to CDF (and LERF) such as LPSD evolutions, POSs, initiating events, accident sequences, and basic events (equipment unavailabilities and human failure events) shall be identified. The results shall be traceable to the inputs and assumptions made in the PRA (HLR-LQU-D).

Index No. LQU-D	Capability Category I	Capability Category II	Capability Category III
LQU-D1	AS IN PART 3.		
LQU-D2	AS IN PART 3.		
LQU-D3	AS IN PART 3.		
LQU-D4	AS IN PART 3.	AS IN PART 3.	
LQU-D5	AS IN PART 3.		
LQU-D6	AS IN PART 3. CLARIFICATION: EVALUTE only the specific evolution. DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3. CLARIFICATION: EVALUTE only the specific evolution. DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	
LQU-D7	AS IN PART 3.		

Table 10.3.2.7-2(e) Supporting Requirements for Quantification HLR-LQU-E

Uncertainties in the LPSD PRA results shall be characterized. Sources of model uncertainty and key assumptions shall be identified, and their potential impact on the results understood (HLR-LQU-E).

Index No. LQU-E	Capability Category I	Capability Category II	Capability Category III
LQU-E1	AS IN PART 3.		
LQU-E2	AS IN PART 3.		AS IN PART 3.
LQU-E3	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LQU-E4	AS IN PART 3.		

Table 10.3.2.7-2(f) Supporting Requirements for Quantification HLR-LQU-F

Documentation of the quantification shall be consistent with the applicable supporting requirements (HLR-LQU-F).

Index No. LQU-F	Capability Category I	Capability Category II	Capability Category III
LQU-F1	AS IN PART 3.		
LQU-F2	AS IN PART 3. ADDITIONAL REQUIREMENT: DOCUMENT the timed-dependent contributions to CDF by POS for the specific LPSD evolution, assuming for the quantification that all SSCs are available unless defined as out of service for the entire POS.		
LQU-F3	AS IN PART 3. CLARIFICATION: Only the specific evolution is to be documented. DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3. CLARIFICATION: Only the specific evolution is to be documented. DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	
LQU-F4	AS IN PART 3.		
LQU-F5	AS IN PART 3.		
LQU-F6	AS IN PART 3.		

Table 10.3.2.8-2(a) Supporting Requirements for LERF Analysis – High Level Requirement A

Core damage sequences shall be grouped into plant damage states based on their accident progression attributes (HLR-LLE-A).

Index No. LLE-A	Capability Category I	Capability Category II	Capability Category III
LLE-A1	AS IN PART 3.		
LLE-A2	AS IN PART 3.		
LLE-A3	AS IN PART 3.		
LLE-A4	AS IN PART 3.		
LLE-A5	AS IN PART 3.		

Table 10.3.2.8-2(b) Supporting Requirements for LERF Analysis– High Level Requirement B

The accident progression analyses shall include an evaluation of the contributors (e.g., phenomena, equipment failures, human actions) to a large early release (HLR-LLE-B).

Index No. LLE-B	Capability Category I	Capability Category II	Capability Category III
LLE-B1	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LLE-B2	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LLE-B3	AS IN PART 3.		

Table 10.3.2.8-2(c) Supporting Requirements for LERF Analysis – High Level Requirement C

The accident progression analysis shall include identification of those sequences that would result in a large early release (HLR-LLE-C).

Index No. LLE-C	Capability Category I	Capability Category II	Capability Category III
LLE-C1	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LLE-C1a	**No requirement.**	AS IN PART 3.	
LLE-C1b	AS IN PART 3.		
LLE-C2	AS IN PART 3.	AS IN PART 3.	
LLE-C3	AS IN PART 3. No requirement to address repair.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	
LLE-C4	AS IN PART 3	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.
LLE-C5	AS IN PART 3	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.

Table 10.3.2.8-2(c) Supporting Requirements for LERF Analysis – High Level Requirement C (Cont'd)

Index No. LLE-C	Capability Category I	Capability Category II	Capability Category III
LLE-C6	AS IN PART 3.		
LLE-C7	AS IN PART 3.		
LLE-C8	AS IN PART 3.		
LLE-C9	AS IN PART 3.		
LLE-C10	AS IN PART 3.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.
LLE-C-11	AS IN PART 3.	AS IN PART 3.	
LLE-C12	AS IN PART 3.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.
LLE-C13	AS IN PART 3.	AS IN PART 3.	

Table 10.3.2.8-2(d) Supporting Requirements for LERF Analysis – High Level Requirement D

The accident progression analyses shall include an evaluation of the containment structural capability for those containment challenges that would result in a large early release (HLR-LLE-D).

Index No. LLE-D	Capability Category I	Capability Category II	Capability Category III
LLE-D1	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LLE-D2	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LLE-D3	AS IN PART 3.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.
LLE-D4	AS IN PART 3.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.
LLE-D5	AS IN PART 3.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.
LLE-D6	AS IN PART 3.	AS IN PART 3.	AS IN PART 3.
LLE-D7	AS IN PART 3.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.

Table 10.3.2.8-2(e) Supporting Requirements for LERF Analysis – High Level Requirement E

The frequency of different containment failure modes leading to a large early release shall be quantified and aggregated (HLR-LLE-E).

Index No. LLE-E	Capability Category I	Capability Category II	Capability Category III
LLE-E1	AS IN PART 3.		
LLE-E2	AS IN PART 3.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.
LLE-E3	AS IN PART 3.	AS IN PART 3. CLARIFICATION: DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3.
LLE-E4	REPLACEMENT REQUIREMENT: QUANTIFY LERF in a manner consistent with the applicable requirements in Tables 10.3-2.7-2(a), 10.3-2.7-2(b), and 10.3-2.7-2(c). LERF is to be quantified by POS for a specific LPSD evolution, assuming for the quantification that all SSCs are available unless defined as out of service for the entire POS.		

Table 10.3.2.8-2(f) Supporting Requirements for LERF Analysis – High Level Requirement F

The quantification results shall be reviewed, and significant contributors to LERF such as plant damage states, containment challenges, and failure modes shall be identified. Sources of model uncertainty and related assumptions shall be identified, and their potential impact on the results understood (HLR-LLE-F).

Index No. LLE-F	Capability Category I	Capability Category II	Capability Category III
LLE-F1	AS IN PART 3.	AS IN PART 3. ADDITIONAL REQUIREMENT: The time-dependent contributions to LERF are to be quantified by POS for the specific LPSD evolution, assuming for the quantification that all SSCs are available unless defined as out of service for the entire POS.	
LLE-F2	AS IN PART 3.		
LLE-F3	REPLACEMENT REQUIREMENT: IDENTIFY and CHARACTERIZE the LERF sources of model uncertainty and related assumptions in a manner consistent with the applicable requirements of Tables 10.3.2.7-2(d) and 10.3.2.7-2(e), except now for LERF. LERF is to be quantified by POS for a specific LPSD evolution assuming for the quantification that all SSCs are available unless defined as out of service for the entire POS.		

Table 10.3.2.8-2(g) Supporting Requirements for LERF Analysis – High Level Requirement G

The documentation of the LERF analysis shall be consistent with the applicable supporting requirements (HLR-LLE-G).

Index No. LLE-G	Capability Category I	Capability Category II	Capability Category III
LLE-G1	AS IN PART 3.		
LLE-G2	AS IN PART 3. ADDITIONAL REQUIREMENT: The time-dependent contributions to LERF are to be documented by POS for the specific LPSD evolution, assuming for the quantification that all SSCs are available unless defined as out of service for the entire POS.		
LLE-G3	AS IN PART 3. CLARIFICATION: Only the specific evolution is to be documented. DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	AS IN PART 3. CLARIFICATION: Only the specific evolution is to be documented. DETERMINE significance on a POS-by-POS basis as opposed to summing the risks over all POSs and comparing against the total. All POSs are to be assumed significant for the purpose of determining supporting requirements.	
LLE-G4	AS IN PART 3.		
LLE-G5	AS IN PART 3.		
LLE-G6	AS IN PART 3.		
LLE-G7	REPLACEMENT REQUIREMENT: DOCUMENT the screened-out core damage sequences and plant damage states and INCLUDE the technical justification.		

Table 10.4.2.1-2(a) Supporting Requirements for HLR-LIFPP-A

A reasonably complete set of flood areas of the plant shall be identified (HLR-LIFPP-A).

Index No. LIFPP-A	Capability Category I	Capability Category II	Capability Category III
LIFPP-A1	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that previously defined flood areas are applicable and appropriately divided into physical separate areas for the POSs of the single identified LPSD evolution type.		
LIFPP-A2	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously defined flood areas at the building level are applicable for the POSs of the single identified LPSD evolution type.	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously defined flood areas at the individual room level are applicable for the POSs of the single identified LPSD evolution type.	
LIFPP-A3	AS IN PART 4.		
LIFPP-A4	AS IN PART 4.		
LIFPP-A5	AS IN PART 4.		

Table 10.4.2.1-2(b) Supporting Requirements for HLR-LIFPP-A

The internal flood plant partitioning shall be documented consistent with the applicable supporting requirements (HLR-LIFPP-B).

Index No. LIFPP-B	Capability Category I	Capability Category II	Capability Category III
LIFPP-B1	AS IN PART 4.		
LIFPP-B2	AS IN PART 4.		
LIFPP-B3	AS IN PART 4.		

Table 10.4.2.2-2(a) Supporting Requirements for HLR-LIFSO-A

The potential flood sources in the plant and their associated internal flood mechanisms shall be identified and characterized (HLR-LIFSO-A).

Index No. LIFSO-A	Capability Category I	Capability Category II	Capability Category III
LIFSO-A1	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified flood sources are applicable for the POSs of the single identified LPSD evolution type.		
LIFSO-A2	AS IN PART 4.		
LIFSO-A3	AS IN PART 4.		
LIFSO-A4	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified flood mechanisms that would result in a release are applicable for the POSs of the single identified LPSD evolution type.		
LIFSO-A5	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified flood release characteristics are applicable for the POSs of the single identified LPSD evolution type.		
LIFSO-A6	AS IN PART 4.		

Table 10.4.2.2-2(b) Supporting Requirements for HLR-LIFSO-A

The sources of internal floods shall be documented consistent with the applicable supporting requirements (HLR-LIFSO-B).

Index No. LIFSO-B	Capability Category I	Capability Category II	Capability Category III
LIFSO-B1	AS IN PART 4.		
LIFSO-B2	AS IN PART 4.		
LIFSO-B3	AS IN PART 4.		

Table 10.4.2.3-2(a) Supporting Requirements for HLR-LIFSN-A

The potential internal flood scenarios shall be developed for each flood source by identifying the propagation path(s) of the source and the affected SSCs (HLR-LIFSN-A).

Index No. LIFSN-A	Capability Category I	Capability Category II	Capability Category III
LIFSN-A1	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified propagation paths are applicable for the POSs of the single identified LPSD evolution type. IDENTIFY any new propagation paths from the source area to the area of accumulation for the POSs of the single identified LPSD evolution type.		
LIFSN-A2	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified plant features to contain or terminate the flood propagation are applicable for the POSs of the single identified LPSD evolution type. IDENTIFY any new plant features for the POSs of the single identified LPSD evolution type.		
LIFSN-A3	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified automatic or operator responses are applicable for the POSs of the single identified LPSD evolution type. IDENTIFY any new automatic or operator response for the POSs of the single identified LPSD evolution type.		
LIFSN-A4	AS IN PART 4.		
LIFSN-A5	AS IN PART 4.		
LIFSN-A6	AS IN PART 4.		AS IN PART 4.
LIFSN-A7	AS IN PART 4.		
LIFSN-A8	AS IN PART 4.	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified inter-area propagation paths are applicable for the POSs of the single identified LPSD evolution type. IDENTIFY any new inter-area propagation paths for the POSs of the single identified LPSD evolution type. INCLUDE the potential for structural failure.	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified inter-area propagation paths are applicable for the POSs of the single identified LPSD evolution type. IDENTIFY any new inter-area propagation paths for the POSs of the single identified LPSD evolution type. INCLUDE the potential for structural failure and barrier unavailability.
LIFSN-A8a	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified impaired barriers are applicable for the POSs of the single identified LPSD evolution type. IDENTIFY any new impaired barriers for the POSs of the single identified LPSD evolution type. INCLUDE the potential for structural failure.		

Table 10.4.2.3-2(a) Supporting Requirements for HLR-LIFSN-A (Cont'd)

Index No. LIFSN-A	Capability Category I	Capability Category II	Capability Category III
LIFSN-A9	AS IN PART 4.		
LIFSN-A10	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously developed flood scenarios are applicable for the POSs of the single identified LPSD evolution type. DEVELOP any new flood scenarios for the POSs of the single identified LPSD evolution type.		
LIFSN-A11	AS IN PART 4.		
LIFSN-A12	AS IN PART 4.		
LIFSN-A13	AS IN PART 4.		
LIFSN-A14	AS IN PART 4.	AS IN PART 4.	AS IN PART 4.
LIFSN-A15	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously screened out flood areas are applicable for the POSs of the single identified LPSD evolution type. SCREEN OUT flood sources per the criteria specified in IFSN-A15 in ASME/ANS RA-Sa-2009 [1].		
LIFSN-A16	AS IN PART 4.	AS IN PART 4.	AS IN PART 4.
LIFSN-A17	AS IN PART 4.		

Table 10.4.2.3-2(b) Supporting Requirements for HLR-LIFSN-B

Documentation of the internal flood scenarios shall be consistent with the applicable supporting requirements (HLR-LIFSN-B).

Index No. LIFSN-B	Capability Category I	Capability Category II	Capability Category III
LIFSN-B1	AS IN PART 4.		
LIFSN-B2	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, DOCUMENT that the previously identified internal flood scenarios are applicable for the POSs of the single identified LPSD evolution type. IDENTIFY any new flood scenarios for the POSs of the single identified LPSD evolution type.		
LIFSN-B3	AS IN PART 4.		

Table 10.4.2.4-2(a) Supporting Requirements for HLR-LIFEV-A

Plant initiating events caused by internal flood shall be identified and their frequencies estimated (HLR-LIFEV-A).

Index No. LIFEV-A	Capability Category I	Capability Category II	Capability Category III
LIFEV-A1	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously identified plant initiating-event groups are applicable for the POSs of the single identified LPSD evolution type. If an appropriate plant initiating-event group does not exist, CREATE a new plant initiating-event group.		
LIFEV-A1a	AS IN PART 4. CLARIFICATION: The review should be focused on the POSs for the single identified LPSD evolution type.		
LIFEV-A2	AS IN PART 4.	AS IN PART 4.	AS IN PART 4.
LIFEV-A3	AS IN PART 4.		AS IN PART 4.
LIFEV-A4	AS IN PART 4.		
LIFEV-A5	AS IN PART 4.		
LIFEV-A6	AS IN PART 4.	AS IN PART 4.	
LIFEV-A7	AS IN PART 4.	AS IN PART 4.	AS IN PART 4.
LIFEV-A8	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously screened out flood scenarios are not applicable for the POSs of the single identified LPSD evolution type. SCREEN OUT flood scenarios per the criteria specified in IFEV-A8 in ASME/ANS RA-Sa-2009 [1].		

Table 10.4.2.4-2(b) Supporting Requirements for HLR-LIFEV-B

Documentation of the internal flood-induced events shall be consistent with the applicable supporting requirements (HLR-LIFEV-B).

Index No. LIFEV-B	Capability Category I	Capability Category II	Capability Category III
LIFEV-B1	AS IN PART 4.		
LIFEV-B2	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, DOCUMENT that the previously identified internal flood-induced initiating events are applicable for the POSs of the single identified LPSD evolution type. IDENTIFY any new flood-induced initiating events for the POSs of the single identified LPSD evolution type.		
LIFEV-B3	AS IN PART 4.		

Table 10.4.2.5-2(a) Supporting Requirements for HLR-LIFQU-A

Internal flood-induced accident sequences shall be quantified (HLR-LIFQU-A).

Index No. LIFQU-A	Capability Category I	Capability Category II	Capability Category III
LIFQU-A1	AS IN PART 4.		
LIFQU-A2	AS IN PART 4.		
LIFQU-A3	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, ENSURE that the previously screened-out flood areas are still valid for the POSs of the single identified LPSD evolution type. SCREEN OUT flood sources per the criteria specified in IFQU-A3 in ASME/ANS RA-Sa-2009 [1].		AS IN PART 4.
LIFQU-A4	AS IN PART 4.		
LIFQU-A5	AS IN PART 4.		
LIFQU-A6	AS IN PART 4.		
LIFQU-A7	AS IN PART 4.		
LIFQU-A8	AS IN PART 4.		
LIFQU-A9	AS IN PART 4.		
LIFQU-A10	AS IN PART 4.		
LIFQU-A11	AS IN PART 4.		

Table 10.4.2.5-2(b) Supporting Requirements for HLR-LIFQU-B

Documentation of the internal flood-induced accident sequences and quantification shall be consistent with the supporting requirements (HLR-LIFQU-B).

Index No. LIFQU-B	Capability Category I	Capability Category II	Capability Category III
LIFQU-B1	AS IN PART 4.		
LIFQU-B2	ADDITIONAL REQUIREMENT: If internal flooding is within the scope of the application, DOCUMENT that the previously developed flood scenarios are applicable for the POSs of the single identified LPSD evolution type. DOCUMENT the process used to define the applicable new internal flood accident sequences and their associated quantification for the POSs of the single identified LPSD evolution type.		
LIFQU-B3	AS IN PART 4.		

Table 10.5.2.1-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Probabilistic Seismic Hazard Analysis (LSHA)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LSHA-A	HLR-SHA-A	AS IN PART 5	AS IN PART 5
HLR-LSHA-B	HLR-SHA-B	AS IN PART 5	AS IN PART 5
HLR-LSHA-C	HLR-SHA-C	AS IN PART 5	AS IN PART 5
HLR-LSHA-D	HLR-SHA-D	AS IN PART 5	AS IN PART 5
HLR-LSHA-E	HLR-SHA-E	AS IN PART 5	AS IN PART 5
HLR-LSHA-F	HLR-SHA-F	AS IN PART 5	AS IN PART 5
HLR-LSHA-G	HLR-SHA-G	AS IN PART 5	AS IN PART 5
HLR-LSHA-H	HLR-SHA-H	AS IN PART 5	AS IN PART 5
HLR-LSHA-I	HLR-SHA-I	AS IN PART 5	AS IN PART 5
HLR-LSHA-J	HLR-SHA-J	AS IN PART 5	AS IN PART 5

Supporting Requirements for HLR-LSHA: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-LSHA shall apply in full.

Table 10.5.2.2-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Seismic-Fragility Analysis (LSFR)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LSFR-A	HLR-SFR-A	**AS IN PART 5**	AS IN PART 5
HLR-LSFR-B	HLR-SFR-B	**AS IN PART 5**	AS IN PART 5
HLR-LSFR-C	HLR-SFR-C	**AS IN PART 5**	AS IN PART 5
HLR-LSFR-D	HLR-SFR-D	**AS IN PART 5**	AS IN PART 5
HLR-LSFR-E	HLR-SFR-E	**AS IN PART 5**	AS IN PART 5
HLR-LSFR-F	HLR-SFR-F	**AS IN PART 5**	AS IN PART 5
HLR-LSFR-G	HLR-SFR-G	**AS IN PART 5**	AS IN PART 5

Supporting Requirements for HLR-LSFR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-SFR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7. If seismic events are within the scope of the application, and specific LPSD evolution activities in a given POS change the screening or fragility analyses of SSCs on the SEL, then revise the fragilities for the applicable POSs accordingly.

Table 10.5.2.3-1 High Level Requirements for Seismic Probabilistic Risk Assessment: Technical Requirements for Systems Analysis (LSPR)

Designator in This Standard	Designator in ASME/ANS RA-Sa-2009 [1]	Requirement	Commentary
HLR-LSPR-A	HLR-SPR-A	**AS IN PART 5**	AS IN PART 5
HLR-LSPR-B	HLR-SPR-B	**AS IN PART 5**	AS IN PART 5
HLR-LSPR-C	HLR-SPR-C	**AS IN PART 5**	AS IN PART 5
HLR-LSPR-D	HLR-SPR-D	**AS IN PART 5**	AS IN PART 5
HLR-LSPR-E	HLR-SPR-E	**AS IN PART 5**	AS IN PART 5
HLR-LSPR-F	HLR-SPR-F	**AS IN PART 5**	AS IN PART 5

NOTE:
(1) Applicability of "at-power" seismic fragilities are to be assessed for the specific conditions of the POS under study. The equipment configuration may be different from the "at-power" mode.

Supporting Requirements for HLR-LSPR: All of the Supporting Requirements in ASME/ANS RA-Sa-2009 [1] for HLR-SPR shall apply in full and shall be accomplished for each POS or group of POSs, where appropriate and in accordance with LPOS-A7. If seismic events are within the scope of the application, and specific LPSD evolution activities in a given POS change the assessment of human errors (e.g., preclude personnel access), revise the plant response models for the applicable POSs accordingly.