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A PROPOSED AMERICAN NATIONAL STANDARD

STANDARD FOR PROBABILISTIC RISK ASSESSMENT FOR NUCLEAR POWER PLANT APPLICATIONS

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The 2000 edition of this Standard is being issued with an automatic addenda subscription service. The use of an addenda allows revisions made in response to public review comments or committee actions to be published on a regular yearly basis; revisions published in addenda will become effective six months after the Date of Issuance of the addenda. The next edition of this Standard is scheduled for publication in 2003.

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FOREWORD

(This Foreword Is Not Part Of ASME PRA-S–2000)

The ASME Board on Nuclear Codes and Standards (BNCS) began considering the development of a consensus Standard for the use of Probabilistic Risk Assessment (PRA) in risk-informed decisionmaking in the summer of 1997. Newly published ASME Code Cases for risk-informed applications provided an impetus for a PRA Standard on the technical quality of the PRA necessary to support risk-informed changes to nuclear power plant design and operations.

The BNCS and the ASME Council on Codes and Standards evaluated this consideration in regards to ASME safety criteria and activities associated with risk-informed applications. Given the advancements in developing risk-informed Code Cases issued by the Boiler and Pressure Vessel Committee and the Operations and Maintenance Committee, it was determined that a need exists for a Standard to address the PRA quality necessary to support ASME applications of this emerging technology. After approval by the ASME Council on Codes and Standards, an ASME Project Team and a Standards Committee were formed in early 1998 to develop a PRA Standard that would provide a foundation for existing and future risk-informed applications for nuclear power plants. The Committee and Project Team charged with drafting the standard received strong support from NRC and Industry and maintains liaison with the American Nuclear Society (ANS), National Fire Protection Association (NFPA), and Institute of Electrical and Electronic Engineers (IEEE) nuclear standards developing groups.

The Project Team on Risk Management for Nuclear Facility Applications was made up of key individuals with the direct knowledge and experience to produce a technically adequate document in a timely manner under the ASME Codes and Standards Redesign Process. A unique part of this process was the review of two drafts of the Standard by experts inside and outside the ASME Committee structure. Comments provided by these reviewers have been addressed by the Project Team and incorporated within the Standard where they were considered to be appropriate.

The U.S. nuclear industry has developed a Peer Review process for assessing the technical quality and adequacy of a PRA to support risk-informed regulatory licensing applications (NEI 00-02). Peer Reviews have been conducted on most U.S. nuclear power plants. The guidelines of NEI 00-02 have been considered in the development of this PRA Standard and the Standard has been structured to facilitate comparison with a PRA reviewed by the industry guidelines.

Upon completion of the draft Standard and all reviews, it was sent to a single consensus technical committee, the Committee on Nuclear Risk Management (CNRM). The CNRM is responsible to ensure that this Standard is maintained and revised as necessary following its original publication by the ASME on XXXXXX XX, 2000. The committee will ensure that this Standard is appropriately linked to other standards under development for other risk-informed applications.

This publication was developed and is maintained by the ASME Committee on Nuclear Risk Management. The Committee operates under procedures accredited by the American National Standards Institute as meeting the criteria of consensus procedures for American National Standards. It was approved by the ASME Board on Nuclear Codes and Standards and subsequently approved by the American National Standards Institute on XXXXXX XX, 2000.

PREPARATION OF TECHNICAL INQUIRIES TO THE COMMITTEE ON NUCLEAR RISK MANAGEMENT

INTRODUCTION

The ASME Committee on Nuclear Risk Management will consider written requests for interpretations and revisions to Risk Management Standards and development of new requirements as dictated by technological development. The Committee's activities in this latter regard are limited strictly to interpretations of requirements, or to the consideration of revisions to the present requirements on the basis of new data or technology. As a matter of published policy, ASME does not "approve," "certify," "rate," or "endorse" any item, construction, propriety device, or activity, and accordingly, inquiries requiring such consideration will be returned. Moreover, ASME does not act as a consultant on specific engineering problems or on general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained. All inquiries that do not provide the information needed for the Committee's full understanding will be returned.

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 requirement or to propose consideration of a revision to the present requirements. Provide concisely the information needed for the Committee'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) The inquiry shall be submitted in typewritten form; however, legible, handwritten inquiries will be considered.

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

(g) The inquiry shall be submitted to the following address:

Secretary, Committee on Nuclear Risk Management
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(As Of March 1, 2000)

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SUMMARY OF CHANGES

The 2000 edition of this Standard is the first publication approved by the Committee on Nuclear Risk Management and ASME, and after public review, ASME PRA-S–2000 was approved by the American National Standards Institute on XXXXX XX, 2000.

PREFACE

(This Preface Is Not Part Of ASME PRA-S–2000)

ORGANIZATION OF THIS STANDARD

This Standard is organized into Sections as follows:

<u>*Sections*</u>

1 Introduction
2 Definitions
3 Risk Assessment Application Process
4 Risk Assessment Technical Requirements
5 PRA Configuration Control
6 Peer Review

Each Section is subdivided into Subsections, Paragraphs, and Subparagraphs with Bullets and Sub-bullets identified as follows:

<u>*Examples*</u>

Subsections	=	**3.1**
Paragraphs	=	3.1.2
Subparagraphs	=	*3.1.2.1*

(When Paragraphs or Subparagraphs are used to identify sequential requirements they will be identified by adding a lower case letter such as *(a)*, *(b)*, *(c)*, etc.)

Bullets	=	•
Sub-bullets	=	⇒

<u>*Tables and Figures*</u> provided in this Standard are identified by the applicable Subsection, Paragraph, or Subparagraph number for which they apply, with either "TABLE" or "FIG." and labeled sequentially as follows: 3.2.1-1, 3.2.1-2, etc. Each Table or Figure is located immediately following the Subsection, Paragraph, or Subparagraph text that applies to its use.

<u>*References*</u> are identified sequentially within the text of each Paragraph as follows: [3.1.2-1], [3.1.2-2], or [3.1.2-3], etc., and then listed at the end of the Paragraph.

When required by context in this Standard, the singular shall be interpreted as the plural, and vice versa; and the feminine, masculine, or neuter gender shall be treated as such other gender as appropriate.

DESCRIPTION OF SECTIONS IN THIS STANDARD

The following descriptions of the individual Sections in this Standard are intended to provide the reader with general information on the scope of coverage and the rationale applied in their development.

1 Introduction

This Section summarizes the scope, applicability, and contents of the Standard.

2 Definitions

This Section identifies and describes unique terms, abbreviations, and acronyms that are used in this Standard.

3 Risk Assessment Application Process

This Section describes a process for determining the capability of a PRA to support specific risk-informed applications.

4 Risk Assessment Technical Requirements

This Section contains High Level Requirements (HLRs) and Supporting Requirements (SRs) for a PRA to be used in support of risk-informed decisionmaking within the scope of this Standard.

5 PRA Configuration Control

This Section describes requirements for maintaining and updating a PRA to be used in support of risk-informed decisionmaking within the scope of this Standard.

6 Peer Review

This Section provides the requirements for a peer review of a PRA to be used in support of risk-informed decision making within the scope of this Standard.

PROPOSED SECTION EXPANSIONS

In addition to the criteria provided in this Standard, consideration will be given in the future to expanding the Standard to other risk assessment methodologies beyond a Level 1 analysis of internal events (excluding fires) while at power and the limited Level 2 analysis provided.

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 this Standard or inclusion of additional topics shall be sent to the following address: Secretary, Committee on Nuclear Risk Management, The American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990.

ADDENDA SERVICE

This edition of ASME PRA-S–2000 includes an automatic addenda subscription service up to the publication of the next edition. The addenda subscription service includes approved new Sections, revisions to existing Sections, and issued interpretations. The interpretations included as part of the addenda service are not part of this Standard.

1 INTRODUCTION

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INTRODUCTION

1.1 Scope

This Standard sets forth requirements for probabilistic risk assessments (PRAs) used to support risk-informed decisions for commercial nuclear power plants, and prescribes a method for adapting these requirements for specific applications.

1.2 Applicability

This Standard applies to PRAs used to support applications of risk-informed decision making related to design, licensing, procurement, construction, operation, and maintenance. This Standard establishes requirements for a Level 1 analysis of internal events (excluding fires) while at power. In addition, this Standard establishes requirements for a limited Level 2 analysis sufficient to evaluate the large early release frequency (LERF) for internal events (excluding fires) while at power.

1.3 Risk Assessment Application Process

Section 3 describes a process to determine the capability of a PRA to support applications of risk-informed decisionmaking. The use of a PRA will differ from application to application. The Standard, which is application-non-specific, is concerned only with the capability of the PRA to support an application. Three different capability levels are described in Subsection 1.5. **PRA capabilities are evaluated for each Supporting Requirement, rather than by specifying a "capability level" for the whole PRA. Therefore, only those aspects of a PRA Element required to support the application in question need the capability level appropriate for that application.** For a given application, supplementary analyses may be used in place of, or to augment, those aspects of PRA Elements that do not fully meet the requirements in Section 4.

1.4 Requirements for PRA Elements

The requirements of this Standard are organized by nine PRA Elements that comprise an internal-events, at-power, Level-1 and Level-2/LERF PRA. For each Element, there are High Level Requirements and related Supporting Requirements presented in Section 4.

1.4.1 PRA Elements. The nine Elements used to characterize a PRA in this Standard and their abbreviations are as follows:

Initiating Events Analysis	(IE)
Accident Sequence Analysis	(AS)
Success Criteria	(SC)
Systems Analysis	(SY)
Human Reliability Analysis	(HR)
Data Analysis	(DA)
Internal Flooding	(IF)
Quantification	(QU)
Level 2 /LERF Analysis	(L2)

1.4.2 High Level Requirements. A set of High Level Requirements (HLRs) is given for each PRA Element. All PRAs using this Standard must satisfy these HLRs, but to differing degrees, as explained in Subsection 1.5. The HLRs are general, reflecting not only the diversity of approaches that have been used to develop the existing industry PRAs, but also the need to accommodate future technological innovations.

1.4.3 Supporting Requirements. The Supporting Requirements (SRs) for each of the nine PRA Elements are presented in the tables of Section 4, using the three categories described in Subsection 1.5. In these tables, some action statements apply only to one category and some extend across two or three categories. When an action statement extends to more than one category, it applies equally to all categories but the scope of applicability will be appropriate for applications in that category. Section 4 also specifies the required documentation to facilitate PRA applications, updates, and peer review.

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. 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 6.

1.5 Application Categories

This Standard is intended for a wide range of applications. While the range of applications falls on a continuum, three categories of applications are defined so that requirements can be developed and presented in a manageable way. They are designated as Categories I, II, and III.

The boundaries between these categories are arbitrary and when a specific application of the Standard is undertaken (see Section 3), judgment is needed to determine which category is to be applied. When a comparison is made between the capabilities of any given PRA and the SRs of this Standard, it is expected that the PRA's capabilities will not all fall within one of the three categories, but will likely be distributed among all three categories. Indeed, for some SRs, the PRA may fail to meet any of these categories. Only when a specific application is considered will the category of an SR become relevant (see Section 3).

1.5.1 Application Attributes. For a given application, it is necessary to determine which category is appropriate. When determining the appropriate category, the following considerations apply:

(a) Extent of the reliance of the decision on the PRA;

(b) Required level of resolution/specificity of the PRA results relative to the needs of the specified applications within a given Category;

(c) Degree of accuracy required of the PRA results;

(d) Degree of confidence in the results; and

(e) Safety significance of the application.

<u>CATEGORY I</u>

This Category is appropriate for applications that require bounding or low-level characterization of PRA results. Requirements generally apply to modeling of the dominant sequences and risk contributors.

An application that falls under this category generally has most of the following attributes:

(a) Decision based on deterministic analysis supplemented with PRA insights;
(b) PRA products are used to differentiate among broad categories of safety significance;
(c) Only order of magnitude estimates of the PRA results needed;
(d) Only a general understanding of the sources and magnitudes of the uncertainties and of their impact is needed;
(e) PRA applications are not expected to impact safety-related SSCs.

Typical applications of a PRA in this category include:

- SSC risk significance determination for the Maintenance Rule (10 CFR 50.65)
- General use of (a)(4) Maintenance Rule requirements within the framework of the plant's Technical Specifications
- The NRC Significant Determination Process
- Prioritization of activities that must be done with or without the benefit of PRA insights

<u>CATEGORY II</u>

This category is appropriate for applications that require moderate level characterization of PRA results. Requirements generally apply to modeling of the risk-significant sequences and risk contributors.

An application that falls under this category generally has most of the following attributes:

(a) Decision based on PRA insights supplemented with deterministic analyses;

(b) PRA products are used to prioritize/categorize/rank SSCs with respect to

safety significance;
(c) Sufficient characterization of PRA results to determine whether risk acceptance criteria for applications have been achieved;
(d) Detailed understanding of the sources and magnitudes of the uncertainties and of their impact on all risk significant sequences and risk contributors are needed;
(e) PRA applications are expected to impact safety-related SSCs.

Typical applications of a PRA in this category include:

- Risk-informed prioritization of GL 96-05 periodic valve verification testing requirements
- Risk-informed Inservice Testing and Inspection
- Risk-monitoring applications
- Determining the extent of quality assurance controls for SSCs
- Risk-informed Technical Specification modification

<u>CATEGORY III</u>

This category is appropriate for applications that require high level characterization of PRA results. Requirements generally apply to modeling of all relevant sequences.

An application that falls under this category generally has most of the following attributes:
(a) Decision based primarily on PRA insights supplemented with little deterministic analyses;
(b) PRA products are used to prioritize/rank SSCs with respect to safety significance;
(c) Better than an order of magnitude accuracy of the PRA results needed;
(d) Thorough and quantified understanding of the sources and magnitudes of the uncertainties and of their impact on all risk significant sequences and risk contributors are needed;
(e) PRA applications are expected to impact safety-related SSCs.

Typical applications of a PRA in this category include are those in which decision criteria for risk-informed applications are exceeded or approached such that confidence in the absolute PRA results is particularly important.

1.5.2 PRA Attributes. Table 4.4-1 describes the attributes of PRA Elements appropriate to support the three categories of applications.

1.6 PRA Configuration Control

Section 5 provides requirements for configuration control of a PRA (i.e., maintaining and upgrading a plant specific PRA) such that the PRA reflects the as-built, as-operated facility to a degree sufficient for the application in which it is used.

1.7 Peer Review Requirements

Section 6 provides the requirements for a peer review to determine if the PRA methodology and its implementation meet the requirements of Section 4 of this Standard.

2 DEFINITIONS

The following definitions are provided to ensure a uniform understanding of select terms and acronyms as they are used in this standard.

AOT – Allowed Outage Time
ADS **–** Automatic Depressurization System
ARI **–** Alternate Rod Insertion
ASEP - Accident Sequence Evaluation Program
ATWS – Anticipated Transient Without Scram
BWR – Boiling Water Reactor
CCW – Component Cooling Water
ECCS – Emergency Core Cooling System
EDG – Emergency Diesel Generator
EOPs/AOPs – Emergency Operating Procedures/Abnormal Operating Procedures
EPIX – Equipment Performance and Information Exchange System (replacement data base for NPRDS*)*
HFE **-** Human Failure Event
HLR **–** High Level Requirements
HPCI – High Pressure Coolant Injection
HVAC – Heating, Ventilation, and Air Conditioning
I&C – Instrumentation and Control
ISLOCA – Interfacing Systems Loss of Coolant Accident
LCO – Limiting Condition for Operation
LER – Licensee Event Report
LOCA – Loss of Coolant Accident
LOOP **–** Loss of Offsite Power
LPCI **–** Low Pressure Coolant Injection
MOV – Motor Operated Valve
MTC – Moderator Temperature Coefficient
NPRDS – Nuclear Plant Reliability Data System (see EPIX)
NPSH – Net Positive Suction Head
NRC – United States Nuclear Regulatory Commission
NSSS – Nuclear Steam Supply System
P&IDs – Piping And Instrumentation Drawings (or Diagrams)
PDS – Plant Damage State
PWR – Pressurized Water Reactor
QA – Quality Assurance
RCP – Reactor Coolant Pump
RCIC – Reactor Core Isolation Cooling
RCS – Reactor Coolant System
RPT – Reactor Pump Trip
RPV – Reactor Pressure Vessel
RWST **–** Refueling Water Storage Tank
SAR **–** Safety Analysis Report
SBLC – Standby Liquid Control System
SBO – Station Blackout
SGTR – Steam Generator Tube Rupture
SORV – Solenoid Operated Relief Valve
SSCs – Structures, Systems, and Components
SR **–** Supporting Requirements
SW – Service Water
THERP – Technique For Human Error Rate Prediction (see NUREG/CR-1278)
TS – Technical Specifications
accident class – a grouping of severe accidents with similar characteristics (such as accidents initiated by transients, loss of coolant accidents, station blackout accidents, and containment bypass accidents)
accident conditions – conditions resulting from deleterious environmental effects or degraded equipment, components, or systems, occurring during events that are not expected in the course of plant operation, but are postulated by design or analysis
accident consequences – the extent of plant damage or the radiological release and health effects to the public or the economic costs of a core damage accident
accident sequence – a combination of events - beginning with an initiating event that challenges safety systems and resulting in an undesired consequence (such as core damage or large early release). An accident sequence may contain many unique variations of events (cut sets) that are similar.
accident sequence analysis – the process to determine the combinations of initiating events, safety functions, and system failures and successes that may lead to core damage or large early release
at 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
availability - the fraction of time that a test or maintenance activity does not disable a system or component (see unavailability)
available time – the time from which an indication is given that the human action is needed to when the action must be performed

to advert core damage. Estimates of the *overall system time* available in a specific accident sequence is determined from engineering analyses which are intimately related to the accident sequence development and success criteria. Includes the point at which operators receive relevant cue indications in determining available time

basic event – an event in a fault tree model that requires no further development, because the appropriate limit of resolution has been reached

Birnbaum importance measure – for a specified basic event, the rate of change in any figure of merit with the change in that basic event probability

common cause failure (CCF) – a failure of two or more components during a short period of time as a result of a shared cause

component – an item in a nuclear power plant, such as a vessel, pump, valve, or a circuit breaker

containment analysis – the process to evaluate of the failure thresholds or leakage rates of the containment

containment bypass – an event that opens a direct or indirect flow path that may allow the release of radioactive material directly to the environment bypassing the containment

containment failure – loss of integrity of the containment pressure boundary that results in unacceptable leakage to the environment

containment performance – a measure of the response of a nuclear plant containment to severe accident conditions

core damage – uncovery and heatup of the reactor core to the point at which prolonged oxidation and severe fuel damage is anticipated representing the onset of gap release of radionuclides

core damage frequency (CDF) – frequency of core damage per unit of time

core melt – severe damage to the reactor fuel and core internal structures that includes the melting and relocation of core materials

community distribution Ä for any specific expert judgment, the distribution of expert judgments of the entire relevant (informed) technical community of experts knowledgeable about the given issue

cumulative distribution function – integral of the probability density function; it gives the probability of a parameter of being less than or equal to a specified value

dependency – requirement external to an item and upon which its function depends

diagnosis – examination and evaluation of data to determine either the condition of a SSC or the cause of the condition

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 Level 2 sequences

equipment qualification – the generation and maintenance of data and documentation to demonstrate that equipment is capable of operating under the conditions of a qualification test, or test and analysis

evaluator expert - an expert who is capable of evaluating the relative credibility of multiple alternative hypotheses, and who is expected to evaluate all potential hypotheses and bases of inputs from proponents and resource experts, to provide both evaluator input and other experts' representation of the community distribution

event tree – a quantifiable, logical network that begins with an initiating event or condition and progresses through a series of branches that represent expected system or operator performance that either succeeds or fails and arrives at either a successful or failed end state

event tree top event – the conditions (i.e., system behavior or operability, human actions, or phenomenological events) that are considered at each branch point in an event tree

expert elicitation - a formal, highly structured, and documented process whereby expert judgments, usually of multiple experts, are obtained

expert judgment – information provided by a technical expert, in the expert's area of expertise, based on opinion, or on an interpretation based on reasoning that includes evaluations of theories, models, or experiments

external event – an initiating event originating outside a nuclear power plant that, in combination with safety system failures, operator errors, or both, and may lead to core damage or large early release. Events such as earthquakes, tornadoes, and floods from sources outside the plant and fires from sources inside or outside the plant are considered external events (see also internal event)

facilitator/integrator - a single entity (individual, team, company, etc.) who is responsible for aggregating the judgments and community distributions of a panel of experts to develop the composite distribution of the informed technical community (herein called the community distribution)

failure mechanism – any of the processes that results in failure modes, including chemical, electrical, mechanical, physical, thermal, and human error

failure mode – a condition or degradation mechanism that precludes the successful operation of a piece of equipment, a component, or a system

failure modes and effects analysis (FMEA) – a process for identifying failure modes of specific components and evaluating their effects on other components, subsystems, and systems

failure probability – the expected number of failures per demand expressed as the ratio of the number of failures to the number of type of actions requested (demands)

failure rate – expected number of failures per unit of time expressed as the ratio of the number of failures to a selected unit of time

fault tree – a deductive logic diagram that depicts how a particular undesired event can occur as a logical combination of other undesired events

figures of merit – the quantitative value, obtained from a PRA analysis, used to evaluate the results of an application (e.g., CDF or LERF)

front-line system – an engineered safety system used to provide core or containment cooling and to prevent core damage, reactor coolant system failure, or containment failure

Fussell-Vesely (FV) importance measure – for a specified basic event , Fussell-Vesely importance is the fractional contribution to any figure of merit for all accident sequences containing that basic event

harsh environment – an environment expected as a result of the postulated accident conditions appropriate for the design basis or beyond design basis accidents

human error (HE) – any member of a set of human actions that exceeds some limit of acceptability including inaction where required, excluding malevolent behavior

human error probability (HEP) – a measure of the likelihood that the operator will fail to initiate the correct, required, or specified action or response needed to allow the continuous or correct function of equipment, a component, or system, or by commission performs the wrong action that adversely effects the continuous or correct function of these same items

human failure event (HFE) – an integrated logic description of HEPs based on the error modes, performance shaping factor assessment, and any other qualitative information needed to justify a single input to the risk model

human reliability analysis (HRA) – a structured approach used to identify potential human errors and to systematically estimate the probability of those errors using data, models, or expert judgment

initiating event – any event either internal or external to the plant that perturbs the steady state operation of the plant, if operating, thereby initiating an abnormal event such as transient or LOCA within the plant. Initiating events trigger sequences of events that challenge plant control and safety systems potentially leading to core damage or large early release.

initiating event categories – There are two types of initiating event categories used in this standard. When initiating events are grouped for the purpose of sequence definition they create <u>initiating event functional categories.</u> When they are grouped for the purpose of accident sequence quantification, they are referred to as <u>initiating event quantification categories.</u>

integrator – a single entity (individual, team, company, etc.) who is ultimately responsible for developing the composite representation of the informed technical community (herein called the community distribution). This sometimes involves informal methods such as deriving information relevant to an issue from the open literature or through informal discussions with experts, and sometimes involves more formal methods

interfacing systems LOCA (ISLOCA) – 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 subjected to RCS pressure and can result in containment bypass

internal event – an event originating within a nuclear power plant that, in combination with safety system failures, operator errors, or both, can effect the operability of plant systems and may lead to core damage or large early release

internal flooding event – an event located within plant buildings leading to equipment failure by the intrusion of water into equipment through submergence, spray, dripping, or splashing

large early release – the rapid, unscrubbed release of airborne fission products from the containment to the environment occurring before the effective implementation of off-site emergency response and protective actions

large early release frequency (LERF) – mean frequency of a large early release per unit of time

latent human error – a human error (typically by mispositioning or miscalibrating a component) that, if not detected and corrected, predisposes the affected component to failure when demanded

Level 1 analysis – identification and quantification of the sequences of events leading to the onset of core damage

Level 2 analysis – evaluation of containment response to severe accident challenges and quantification of the mechanisms, amounts, and probabilities of subsequent radioactive material releases from the containment

Level 3 analysis – evaluation and quantification of the consequences to both the public and the environment from radioactive material releases from the containment

level of detail – different levels of logic modeling used in a PRA (a failure event in a fault tree analysis can address various levels of detail, depending on how much useful information is available concerning the contributors to the failure event

level of complexity – the four different l*evels of complexity* in the use of experts are defined as follows:

- *Level A*: an integrator evaluates/ weights models based on literature review and experience; estimates the community distribution
- *Level B*: an integrator interacts with proponent experts and resource experts to develop and explore alternative interpretations, and, acting as an evaluator, estimates the community distribution
- *Level C*: an integrator brings together proponent experts and resource experts for debate and interactions, develops and explores alternative interpretations, and acting as an evaluator, estimates the community distribution.
- *Level D*: a facilitator/integrator organizes a panel of evaluator experts to interpret and evaluate, facilitates discussions and interactions among the panel of experts, avoids inappropriate behavior on the part of the evaluator experts, and develops a composite distribution of the evaluators' estimates of the entire community's distribution

master logic diagram – summary fault tree constructed to guide the identification and grouping of initiating events and their associated sequences to ensure completeness

may – used to state an option to be implemented at the user's discretion

minimal cut set (MCS) – minimum combination of events in a fault tree that, if they occur, will result in an undesired event such as the failure of a system or the failure of a safety function

mission time – is the time that a system or component is required to operate in order to successfully perform its function

model – an approximate mathematical representation that simulates the behavior of a process, item, or concept (such as failure rate)

mutually exclusive events – a set of events where the occurrence of any one precludes the simultaneous occurrence of any remaining events in the set

operating time – total time during which components or systems are performing their designed function

performance shaping factor (PSF) – a factor that influences human error probabilities as considered in a PRA's human reliability analysis and includes such items as level of training, quality/availability of procedural guidance, time available to perform a action, etc.

plant – a general term used to refer to a nuclear power facility (for example, plant could be used to refer to a single unit or multi-unit site)

plant damage state (PDS) – group of accident sequence end states that have similar characteristics with respect to accident progression, and containment or engineered safety feature operability

plant-specific data – data consisting of observed sample data from the plant being analyzed

point estimate – estimate of a parameter in the form of a single number

post-initiator human failure events – human errors committed during actions performed in response to an accident initiator

pre-initiator human failure events – human errors committed during actions performed prior to the initiation of an accident, for example, during maintenance or calibration procedures

prior distribution (priors) – a statistical distribution that is combined with new information or data in the Bayesian updating process to form a new distribution (posterior) that reflects the influence of both the prior distribution and the new information

probabilistic risk assessment (PRA) – a qualitative and quantitative assessment of the risk associated with plant operation and maintenance that is measured in terms of frequency of occurrence of risk metrics, such as core damage or a radioactive material release and its effects on the health of the public (also referred to as a probabilistic safety assessment, PSA)

PRA application – is a documented analysis influenced by a plant-specific PRA that effects the design, operation, or maintenance of a nuclear power plant.

PRA maintenance – the update of the PRA models to reflect plant changes such as modifications, procedure changes, or plant performance (data)

PRA upgrade – the incorporation into the PRA models of a new methodology that has not been previously peer reviewed. This could include new human error analysis methodology, new data update methods, new approaches to quantification or truncation, or new treatment of common cause failure

proponent expert - an expert who advocates a particular hypothesis or technical position

recovery – a general term describing restoration and repair acts required to change the state the initial or current state of a system or component into a position or condition needed to accomplish a desired function for a given plant state

recovery action – a human action performed to regain equipment or system operability from a specific failure or human error in order to mitigate or reduce the consequences of the failure

recovery factor – a factor that is used to modify the likelihood of an accident sequence in order to account for potential recovery actions

recovery models – types of Human Reliability Models that represent the act, process, or instance of recovering as a probability for use in a fault tree, event tree or cutset

respond – to react in response to a cue for action in initiating or recovering a desired function

response models – represent post-initiator control-room operator actions, following a cue or symptom of an event, to satisfy the procedural requirements for control of a function or system

restore – to put back into a former or desired state

restoration models – represent pre-initiator actions for returning systems or components back to an operational readiness state following tests, maintenance, calibrations or other causes of unavailability according to procedures

repair – to restore a function, system or component by replacing a part or putting together what is torn or broken

repair models – represent local post-initiator actions taken at the direction of control room operators according to training and or local procedures to diagnose and fix components and systems needed to establish an operational function

required time – the time that is needed by operators to successfully perform and complete an action. Estimates of *required time* are derived from actual time measurements based on walk-throughs and simulator observations

resource expert – a technical expert with knowledge of a particular technical area of importance to a PRA

risk – probability and consequences of an event, as expressed by the “risk triplet” that is the answer to the following three questions: (1) What can go wrong? (2) How likely is it?

and (3) What are the consequences if it occurs?

risk achievement worth (RAW) importance measure – for a specified basic event, risk achievement worth importance reflects the increase in any figure of merit when an SSC is assumed to be unavailable due to testing, maintenance, or failure. It is the ratio or interval of the figure of merit, evaluated with the SSC's basic event probability set to one, to the base case figure of merit

safety systems – those systems that are designed to prevent or mitigate a design-basis accident

safe stable state – a plant condition, following an initiating event, in which RCS conditions are controllable at or near desired values within the specified mission time, and for which no further system or operator actions are required following the mission time to prevent core damage

screening analysis – an analysis that eliminates items from further consideration based on their negligible contribution to the probability of a significant accident or its consequences

screening criteria – the values and conditions used to screen results to determine whether an item is a negligible contributor to the probability of an accident sequence or its consequences

severe accident – an accident that usually involves extensive core damage and fission product release into the reactor vessel, containment, or the environment

shall **-** used to state a mandatory requirement

should **–** used to state a recommendation

split fraction – a unitless parameter used by some PRA analysis techniques when quantifying an event tree. It represents the relative frequency or degree-of-belief that each possible outcome, or branch, of a particular top event may be expected to occur

standby system – a system that is not normally operating, but is intended to be ready to operate upon demand

station blackout – loss of all on-site and off-site power at a nuclear power plant

success criteria – criteria for the establishing the minimum number or combinations of systems or components required to operate, or minimum levels of performance per component during a specific period of time, to ensure that their safety functions are satisfied within the limits of the acceptance criteria

supplementary analysis – any analysis that is used in conjunction with PRA in evaluating a PRA application

support system – a system that provides a support function (e.g., electric power, control power, or cooling) for one or more other systems

system failure – termination of the ability of a system to perform any one of its designed functions. Note: Failure of a line/train within a system may occur in such a way that the system retains its ability to perform all its required functions; in this case, the system has not failed

time available – the time for determining the condition of the plant (t_d) and deciding on the subsequent action is then the difference between the *overall system time* available (t_a) and the *time required* (t_r) to determine and perform the action (t_r), (i.e., $t_d = t_a - t_r$)

top event – undesired state of a system in the fault tree model (e.g., the failure of the system to accomplish its function) that is the starting point (at the top) of the fault tree

truncation limits – the numerical cutoff value of probability or frequency below which results are not retained in the quantitative PRA model or used in subsequent calculations (such limits can apply to accident sequences/cut sets, system level cut sets, and sequence/cut set database retention)

unavailability – the fraction of time that a test or maintenance activity disables a system or component (see availability); also the average unreliability of a system or component over a defined time period

uncertainty **–** a representation (usually numerical) of the state of knowledge about data, a model, or process, usually associated with random variability of a parameter, lack of knowledge about data, a model, or process, or imprecision in the model or process

uncertainty analysis – estimation of the uncertainties in the overall results of a PRA *(i.e., CDF or LERF)*

verify – to determine that a particular action has been performed in accordance with the rules and requirements of this standard, either by witnessing the action or by reviewing records.

walkdown – inspection of local areas in a nuclear power plant where systems and components are physically located in order to ensure accuracy of procedures and drawings, equipment location, operating status, and environmental effects or system interaction effects on the equipment which could occur during accident conditions.

3 RISK ASSESSMENT APPLICATION PROCESS

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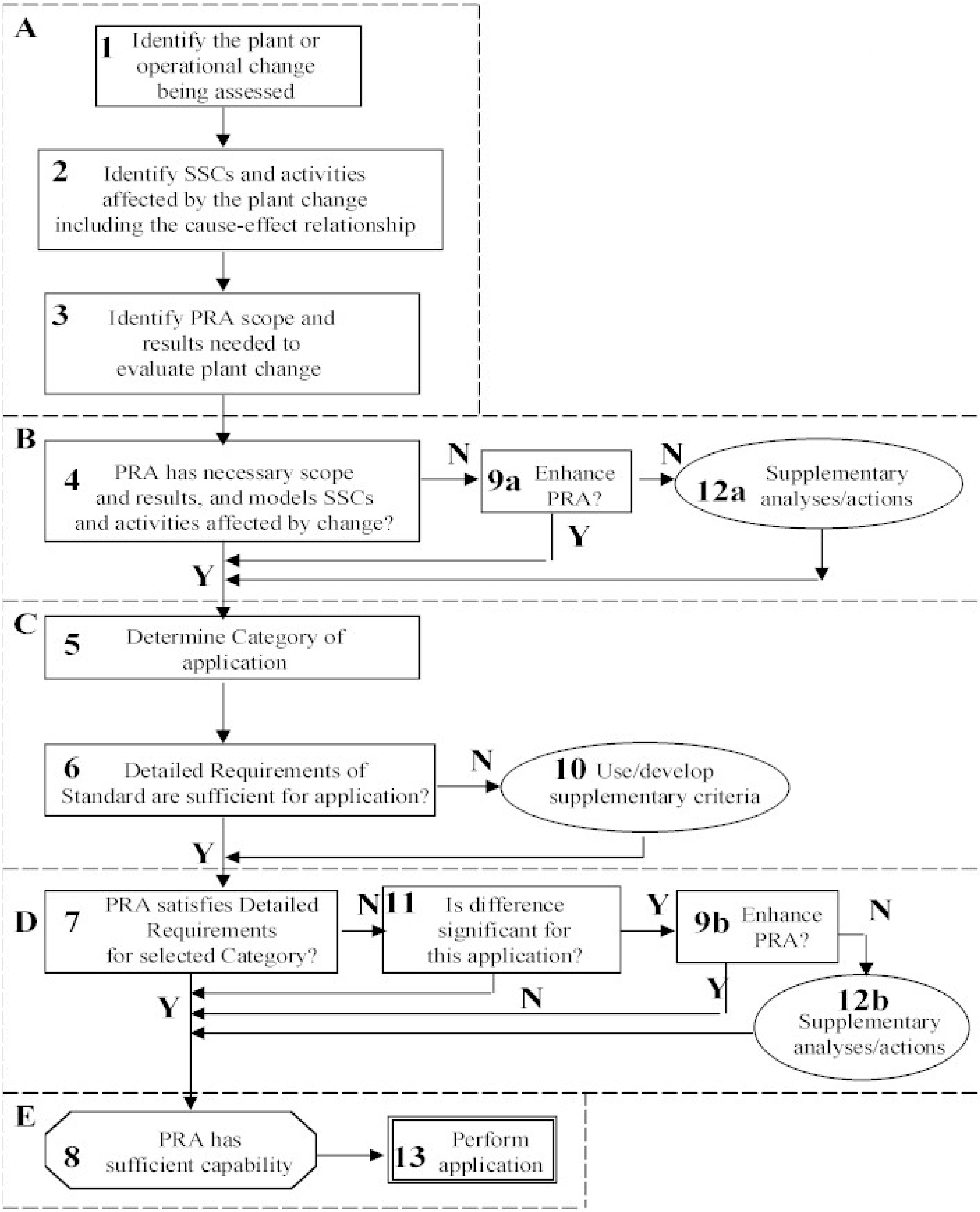
3 RISK ASSESSMENT APPLICATION PROCESS

3.1 Purpose

This section describes a process to determine the capability of a PRA to support a particular application of risk-informed decision making. PRA capabilities are evaluated for each Supporting Requirement, rather than by specifying a "capability level" for the whole PRA. Therefore, only those aspects of a PRA Element required to support the application in question need the capability level appropriate for that application. The process is intended to be used with PRAs that have had a peer review that meets the requirements of Section 6 of this Standard.

As shown in the dashed-line boxes, Figure 3.1-1, there are five stages to this process:

A. An application is defined in terms of the structures, systems and components (SSCs) and activities affected by the proposed change.
B. The PRA is examined to determine that its scope and level of detail is sufficient for the application. If the PRA is found lacking in one or more areas, it may be enhanced or supplemented by other analyses.
C. For the particular application, its Category is determined by using the information in Subsection 1.5. The level of detail in the requirements of the Standard is evaluated to determine if it is sufficient for the application. If not, the requirements of the Standard are augmented by supplementary criteria.
D. The PRA is compared to the appropriate requirements in the Standard in order to determine whether the PRA has adequate capability.
E. The application is performed.


A
1 Identify the plant or operational change being assessed
2 Identify SSCs and activities affected by the plant change including the cause-effect relationship
3 Identify PRA scope and results needed to evaluate plant change
B
4 PRA has necessary scope and results, and models SSCs and activities affected by change?
N
9a Enhance PRA?
N
12a Supplementary analyses/actions
Y
Y
C
5 Determine Category of application
6 Detailed Requirements of Standard are sufficient for application?
N
10 Use/develop supplementary criteria
Y
D
7 PRA satisfies Detailed Requirements for selected Category?
N
11 Is difference significant for this application?
Y
9b Enhance PRA?
N
12b Supplementary analyses/actions
Y
N
Y
E
8 PRA has sufficient capability
13 Perform application

3.2 Identification of Application (Box A)

Define the application by:

- evaluating the plant design or operational change being assessed (Box 1 of Figure 3.1-1).
- identifying the SSCs and plant activities affected by the change including the cause-effect relationship between the plant design and operational change and the PRA model (Box 2 of Figure 3.1-1). (Reference [3.2-1])
- identifying the PRA scope and PRA results that are needed to assess the change (Box 3 of Figure 3.1-1).

<u>Example</u>: *A change in technical specifications (TS) is proposed that redefines the requirements for an operable service water (SW) system. This change removes the requirement for an allowed outage time (AOT) from one of the three pumps in each SW loop. In addition, the AOT for other selected combinations of inoperable components is increased. 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, those SSCs, such as the SW system, affected by the proposed change need to be identified. The plant SW system has two redundant loops, each having two full capacity SW pumps which use the ocean as the ultimate heat sink, and a third SW pump which uses a cooling-tower and the atmosphere as the heat sink. The SW system is designed such that, in the event of a LOCA concurrent with a loss of offsite power, a single SW pump powered from its associated EDG will have sufficient capacity to meet the heat load. The existing TS require two operable SW loops with each loop having three operable pumps. This requirement exceeds single failure criteria since the second SW pump is required for neither normal conditions nor the design basis accident and the CT SW pump provides the redundancy for the design basis LOCA. The proposed change redefines an operable SW loop as having one operable SW pump and one operable CT SW pump, removes the AOT requirements from two SW pumps, lengthens the AOT requirement for SW pumps in the same loop to bring it into line with the AOT for single SW train unavailability and increases the standby CT SW pump AOT based on its lower risk importance.

The proposed change in the AOT impacts the core damage frequency (CDF) by increasing the likelihood that a SW pump would be unavailable due to planned or unplanned maintenance. This change is evaluated by considering the impact on system unavailability and on the frequency of a shutdown due to the loss of one train of SW. These impacts are combined in the plant model to calculate the change in CDF. Since only the ΔCDF is needed, only CDFs before and after the change in TS are needed.

<u>Reference</u>

[3.2-1] True, D., et al, PSA Applications Guide, EPRI Report TR-105396, August 1995.

3.3 Assessment of PRA for necessary scope, results, and models. (Box B)

3.3.1 Necessary Scope and Results. Determine if the PRA provides the results needed to assess the plant or operational change (Box 4 of Figure 3.1-1). If some aspects of the PRA are insufficient to assess the change, then either enhance the PRA in accordance with the Supporting Requirements of Section 4 (Box 9a of Figure 3.1-1), or generate supplementary analyses (Box 12a of Figure 3.1-1). These supplementary analyses will depend on the particular application being considered, but could involve deterministic methods such as bounding or screening analyses, and determinations made by an expert panel. Such supplementary analyses shall be documented.

If it is determined that the PRA is sufficient, the bases for this determination shall be documented. Any enhancement of the PRA shall be done and documented in accordance with Section 5.

<u>Example</u>: *The proposed change in the SW AOT has been determined to affect the SW unavailability. For the plant in question, the SW provides cooling to the ECCS pumps, the Diesel Generators, the Feedwater Pumps, the CCW system, and the Radwaste system. Therefore, the scope of the Initiating Event Analysis element of the PRA must include: (1) LOCA initiators, since the change in SW unavailability will affect ECCS pump cooling in the recirculation phase, (2) Loss of Offsite Power initiators, since the SW change will affect the Diesel Generators, and (3) Loss of*

Feedwater initiators, since the feedwater pumps are SW cooled. Although the SW cools the CCW system, there is enough thermal inertia in the CCW system to allow it to function for several hours after the loss of SW and so a loss of CCW initiator would not be needed for this application. Also, since the Radwaste System does not play a part in determining CDF, it need not be considered.

3.3.2 Modeling of SSCs and Activities. Determine if the SSCs or plant activities affected by the plant design or operational change are modeled in the PRA (Box 4 of Figure 3.1-1). If the affected SSCs or plant activities are not modeled, then either enhance the PRA to include the SSCs in accordance with the Supporting Requirements of Section 4 or generate supplementary analyses (Box 12 of Figure 3.1-1). These supplementary analyses will depend on the particular application being considered, but could involve deterministic methods such as bounding or screening analyses, and determinations made by an expert panel. Such supplementary analyses shall be documented.

If it is determined that the PRA is sufficient, the bases for this determination shall be documented. Any enhancement of the PRA shall be done and documented in accordance with Section 5.

<u>Example</u>: *Continuing with the previous example: The SSCs and plant activities related to the systems impacted by the proposed change in the SW, and which contribute to the change in CDF, i.e., ECCS, DGs, Feedwater, and CCW, need to be modeled in the PRA. For example, if, as is likely, the loss of feedwater initiator is modeled as one global initiator, then either the PRA needs to be enhanced to include the relationship between SW and Feedwater, or the effect of SW on Feedwater must be resolved supplementary analyses outside of the standard.*

<u>Example of supplementary analysis</u>: *A change in testing frequency is desired for MOVs judged to be of low safety significance by using a risk-informed ranking method. Not all MOVs or MOV failure modes of interest within the program are represented in the PRA. Specifically, valves providing an isolation function between the reactor vessel and low pressure piping may only be represented in the interfacing system LOCA initiator frequency. The inadequate PRA model representation can be supplemented by categorizing the group of high/low pressure interface MOVs in an appropriate LERF category. The categorization is based on PRA insights which indicate that failure of MOVs to isolate reactor vessel pressure have the potential to lead to a LERF condition. This example illustrates a process of addressing SSC model adequacy by using general risk information to support the placement of MOVs into the appropriate risk category.*

3.4 Determination of Application Category and the Standard's level of detail. (Box C)

3.4.1 Determination of Category. Section 4 of this Standard sets forth Supporting Requirements for three Application Categories whose attributes are described in Subsection 1.5. Determine the Category of an application (Box 5 of Figure 3.1-1) by using the guidance in Subsection 1.5.

The Application Category and the bases for its determination shall be documented.

3.4.2 Scope of Coverage and Level of Detail. For the Application Category determined in Subsection 3.4.1, determine if the scope of coverage and level of detail of the Supporting Requirements stated in Section 4 are sufficient to assess the application under consideration (Box 6 of Figure 3.1-1).

If it is determined that the standard is sufficient to support the application and does not need to be supplemented, the bases for this determination shall be documented. If supplementary criteria are used (Box 10 of Figure 3.1-1), they shall be described and justified.

<u>Example</u>: *For the example discussed in Subsection 3.3, the PRA elements defined in Section 4 of this Standard are sufficient and adequate to assess the plant change.*

<u>Example of supplementary requirements</u>: *A risk ranking/categorization for a plant's ISI program is being pursued. The current PRA model meets the requirements set forth in this Standard. However, the Standard does not provide requirements for modeling piping or pipe segments adequate to support a detailed quantitative ranking. The Standard can be supplemented with an expert panel to determine the safety significance of pipe segments. Considerations of deterministic and other*

traditional engineering analyses, defense-in-depth philosophy, or maintenance of safety margins could be used to categorize pipe segments. Use of published industry or NRC guidance documents on risk-informed ISI could also be used to supplement the Standard. The PRA model could also be used to supplement the Standard by estimating the impact of each pipe segment's failure on risk without modifying the PRA's logic. This estimate could be accomplished by identifying an initiating event, basic event, or group of events, already modeled in the PRA, whose failures capture the effects of the pipe segment failure.

<u>Second example of supplementary requirements</u>: *It is desired to rank the snubbers in a plant according to their risk significance for the purpose of developing a graded approach to snubber testing. With the exception of snubbers on large primary system components, snubbers have been shown to have a small impact on CDF; therefore, the standard does not require their failure to be addressed in determining CDF and LERF. However, snubbers are considered safety related and testing programs are required to demonstrate their capability to perform their dynamic support function. Evaluation of failure mechanisms may show that the safety significance of snubbers can be approximated by the safety significance of the components that they support, and this supplementary criterion could be used to rank the safety importance of the snubbers.*

<u>Reference</u>

[3.4-1] "Requirements for Safety Significance Categorization of Snubbers using Risk Insights and Testing Strategies for Inservice Testing of LWR Power Plants," ASME Code for Operation and Maintenance of Nuclear Power Plants-Code Case OMN-10.

3.5 Comparison of PRA Model to Standard (Box D)

Determine if the PRA satisfies the Supporting Requirements stated in Section 4 for the selected Category (Box 7 of Figure 3.1-1). The results of the Peer Review (Section 6) may be used. If the PRA meets the Supporting Requirements stated in Section 4 for the selected Category, the PRA is acceptable for the application being considered (Box 8 of Figure 3.1-1). The bases for this determination shall be documented.

If the PRA does not satisfy a Supporting Requirement for the selected Category, then determine if the difference is significant (Box 11 of Figure 3.1-1). Acceptable requirements for determining the significance of this difference include:

- The difference is not applicable or does not affect quantification relative to the impact of the proposed application, or
- Functional level dominant sequences accounting for at least 90% of CDF/LERF, as applicable, are not affected by appropriate sensitivity studies or bounding evaluations. These studies or evaluations should measure the aggregate impact of the exceptions to the requirements in Section 4 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.

As a result of the evaluation of the requirements above, compensatory measures may be used (either quantifiable or non-quantifiable) that render the potential impact on the application negligible. These measures shall be documented and justified.

If the difference is not significant, then the PRA need not be enhanced. If the difference is significant, then either enhance the PRA to address the corresponding Supporting Requirements stated in Section 4 (Box 9b of Figure 3.1-1), or generate supplementary analyses (Box 12b of Figure 3.1-1). 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. Such supplementary analyses shall be documented.

Any enhancement of the PRA shall be done and documented in accordance with Section 5.

<u>*Example*</u>*: The examples provided under Subsection 3.3 are applicable.*

4 RISK ASSESSMENT TECHNICAL REQUIREMENTS

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4 RISK ASSESSMENT TECHNICAL REQUIREMENTS

4.1 Purpose

This Section provides requirements for addressing specific elements of a PRA to be used with this Standard in risk-informed decisions at nuclear power plants. The scope of the PRA described in this Standard is limited to a Level 1 analysis of internal events (excluding fires), for nuclear power plants operating at-power. The scope is also limited to a Level 2 PRA sufficient to evaluate LERF for internal events (excluding fires) while at power.

4.2 Derivation of PRA Requirements

The objective of this Section is to provide requirements by which adequate PRA quality can be identified when a PRA is used to support applications of risk-informed decisionmaking. This objective requires a Standard that recognizes the ability of different PRA quality levels to support different possible PRA applications. Central to the objective is the nature of the PRA application itself and the inherent requirements that it dictates. Additionally, this Standard defines "high level" PRA requirements, which are really PRA characteristics, that any PRA used in risk-informed decisions at nuclear power plants ought to possess. Thus, for each PRA element, a set of high level technical criteria are stated as requirements, followed by more detailed technical criteria for which the requirements are defined on a graded basis. The process used to develop the requirements of this Section is shown in Figure 4.2-1.

4.2.1 <u>PRA Element Objectives</u> Objectives were established for each of the nine elements used to characterize a PRA. These Objectives form the basis for development of the High Level Requirements for each element that were used, in turn, to define the supporting requirements in the tables of Subsection 4.4. The Objectives reflect substantial experience accumulated with PRA development and usage, and are consistent with the PRA Procedures Guide (Reference 4.2.1-1) and the NEI-00-02 Peer Review Process Guidance (Reference 4.2.1-2). The Objectives for each PRA element are listed along with the Requirements for that element in Tables 4.4-1 to 4.4-9.

4.2.2 <u>PRA Element High Level Requirements</u> In setting the High Level Requirements 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 Supporting Requirements. This goal reflects the diversity of approaches that have been used to develop existing industry PRAs and the need to allow for technological innovations in the future. An additional goal was to derive a reasonably small set of High Level Requirements that capture all the important technical issues that were identified in the efforts to develop this Standard and to implement the NEI-00-02 PRA Peer Review process guidance.

The High Level Requirements generally address attributes of the PRA Element such as:

- scope
- completeness
- treatment of dependencies (if applicable)
- degree of realism
- plant fidelity
- output or quantitative results (if applicable)
- documentation

4.2.3 <u>PRA Element Supporting Requirements</u> Three sets of Supporting Requirements were developed to support the High Level Requirements (HLRs) at the various levels of applications in the Standard. Therefore, there is a complete set of Supporting Requirements provided for each of the three PRA application categories described in Subsection 1.5. The Supporting Requirements are numbered and labeled to identify the HLRs that are supported and the source of the specific requirement.

<u>References</u>

4.2.1-1 A Guide to the Performance of Probabilistic Risk Assessments for Nuclear Power Plants, NUREG/CR-2300, January 1983

4.2.1-2 Probabilistic Risk Assessment Peer Review Process Guidance, NEI-00-02, March 2000

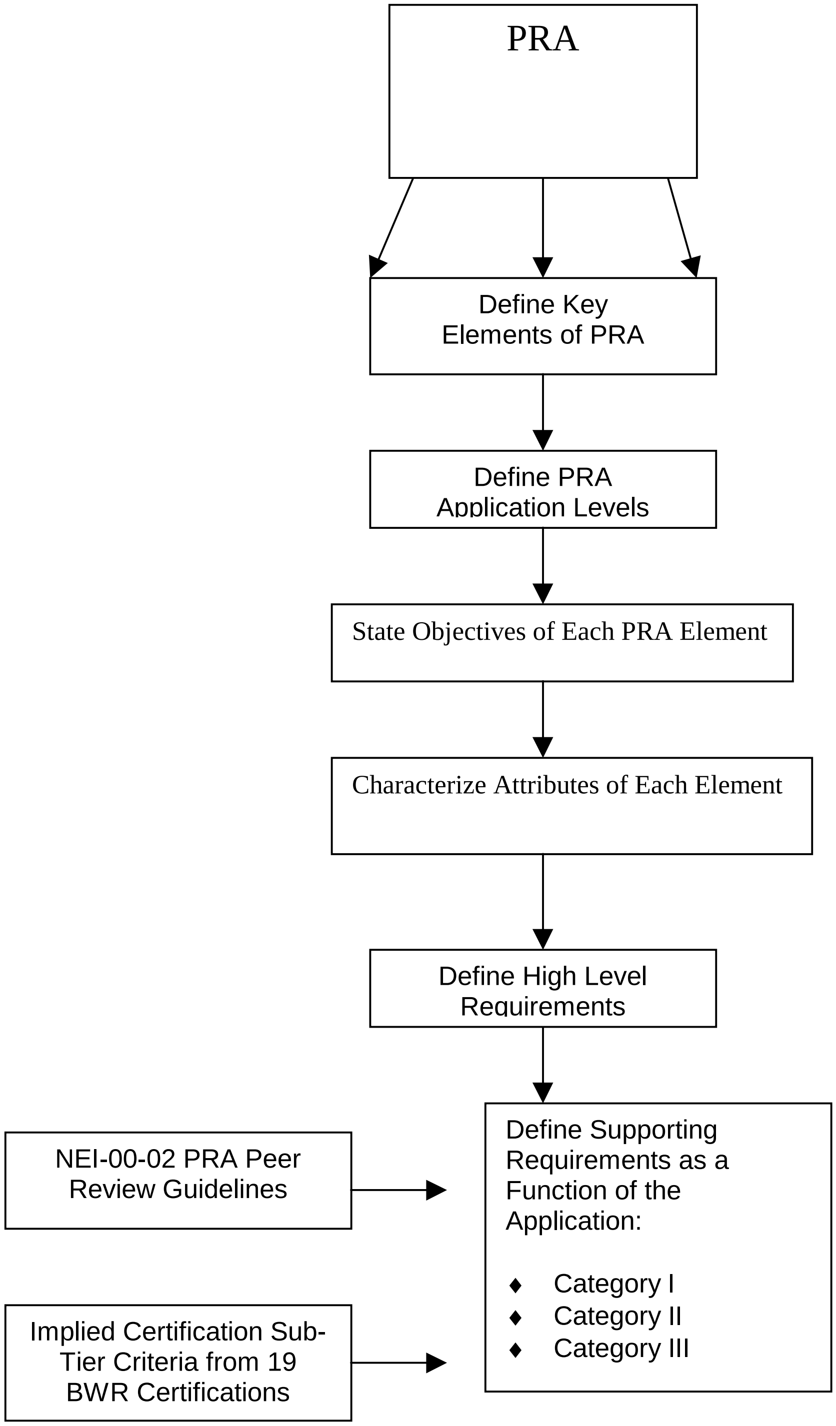

Figure 4.2-1 Derivation of Supporting Requirements for PRA Elements

4.3 PRA Elements and Attributes

Table 4.3-1 describes the attributes of PRA Elements appropriate to the three categories of applications described in Subsection 1.5.

TABLE 4.3-1 PRA ATTRIBUTES

ELEMENT		CATEGORY I	CATEGORY II	CATEGORY III
Initiating Events Analysis	IE	Identification and quantification of dominant accident initiating events	Identification and realistic quantification of risk significant accident initiating events	Identification and realistic quantification of initiating events
Accident Sequence Analysis	AS	Modeling of dominant core damage and large early release accident sequences	Modeling of risk significant core damage and large early release accident sequences	Modeling of core damage and large early release accident sequences
Success Criteria	SC	Bases and supporting analyses for establishing success or failure in dominant accident sequences	Realistic bases and supporting analyses for establishing success or failure in risk significant accident sequences	Realistic bases and supporting analyses for establishing success or failure for modeled accident sequences
Systems Analysis	SY	Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
Human Reliability Analysis	HR	Modeling of major human actions (i.e., latent, response and recovery) with screening Human Error Probabilities (HEPs)	Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in risk significant sequences	Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs
Data Analysis	DA	Quantification of point estimates for basic events, and associated parameters with generic data for dominant accident sequences	Realistic quantification of mean values for basic events, and associated parameters in a manner that accounts for relevant plant specific and generic data for risk significant sequences	Realistic quantification of risk significant basic events in a manner that quantifies impacts of uncertainties
Internal Flooding	IF	Modeling of dominant flood sequences	Realistic modeling of risk significant flood contributors	Realistic and thorough modeling of flooding contributors
Quantification	QU	Quantification of CDF and key contributors	Realistic quantification of CDF and key contributors supported by	Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties

ELEMENT		CATEGORY I	CATEGORY II	CATEGORY III
		supported by an understanding of the impact of key uncertainties	a sound understanding of the impact of uncertainties	
Level 2 Analysis	L2	Quantification of LERF with an understanding of the impact of key uncertainties for the dominant LERF contributors	Realistic quantification of LERF with a sound understanding of the impact of uncertainties for risk significant accident sequences.	Realistic quantification of LERF supported by a sound understanding and quantification of the impact of uncertainties

4.4 Requirements

Tables 4.4-1 to 4.4-9 list the High Level Requirements (HLRs) and the Supporting Requirements (SRs) for each of the nine PRA Elements. For each PRA Element, the Supporting Requirements shall be met using written guidance sufficient to enable the development and updating of the PRA models and documentation, and to enable third-party review.

Numbering Scheme: The SRs are labeled to identify the Element and HLR that they related to. The relationship to the NEI-00-02 Process is also given. Each SR is labeled as follows:

X-Zn
[ICP]

X = PRA Element (e.g., IE for initiating events analysis);

Z = Letter identifying HLR supported by the SR;

n = unique index number for detailed criterion

[ICP] = The corresponding Industry Certification Process requirements

Example: For example, the SR labeled as: IE-A3 [IE-7] corresponds to
a requirement within "Initiating Events Analysis" that supports HLR A,
and corresponds to the Industry Certification Process, Criterion IE-7.

Objectives of the Initiating Events Element

- Be consistent with the scope of the PRA (e.g., internal events, internal flooding)
- Assure adequate completeness through a systematic approach
- Assure adequate fidelity with the as-built, as-operated plant
- Establish initiating event groups for development of functional and systematic accident sequences, as appropriate
- Begin the process of defining accident sequences for the PRA
    - definition of initiating events classes affecting frontline or support systems
    - definition of specific causes of initiating events
- Clarify definition of events to facilitate modeling
- Define the impact of initiating events on plant performance
    - capabilities of the plant to maintain safety functions (success criteria)
    - capability of the primary system and containment barriers to contain any releases
    - capabilities of the operators to maintain emergency procedures and accident management programs
- Support the tasks related to realistic estimation of accident sequence frequency
    - realistic estimation of initiating event frequencies
    - proper identification of plant impacts of initiators
    - adequate treatment of common cause initiating events and other dependent effects (e.g., loss of service water common cause failure)
    - proper consideration of degraded plant initial conditions that could increase initiating event frequencies and amplify impacts on plant performance
    - subsume initiating events within a group because of similarity of impacts on plant response
- Document methods, assumptions and results in a form that can be reviewed and used

TABLE 4.4-1 HIGH LEVEL REQUIREMENTS FOR INITIATING EVENTS ANALYSIS (HLR-IE)

A	COMPLETENESS – FUNCTIONAL CATEGORIES: The initiating event analysis shall provide a reasonably complete and appropriately grouped treatment of initiating event functional categories[1] that challenge continued normal plant operation and that require mitigation to prevent core damage. (HLR-IE-A)
B	COMPLETENESS – TRIPS AND PRECURSORS: The initiating event analysis shall provide reasonably complete coverage of the causes of plant trip events and plant trip precursors. (HLR-IE-B)
C	DEPENDENCIES: The initiating-event analysis shall provide reasonably complete and reasonably accurate treatment of initiating events caused by dependencies such as support-system failures. These dependencies include functional, environmental, spatial, and common cause impacts of each modeled initiating event. (HLR-IE-C)
D	QUANTIFICATION: The initiating event analysis shall provide a quantification of the annual frequency of each initiating event or initiating event quantification category that needs to be treated separately to obtain a quantification of CDF and LERF (HLR-IE-D).
E	PLANT FIDELITY: The initiating events shall be selected, grouped, and quantified in a manner that ensures model-plant fidelity and accounts for plant specific and unique factors that could influence the potential for, and frequency of, each initiating event category. (HLR-IE-E)
F	DOCUMENTATION: The initiating event analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed to select, group, and screen the initiating event list and to model and quantify the initiating event frequencies, with assumptions and bases stated. (HLR-IE-F)

[1]Functional initiating event categories are categories of events that impact key safety functions defined by frontline or support systems. Each functional initiating event category has a specific impact on the plant's capability to support key safety functions. Key safety functions are the minimum set of safety functions that must be maintained to prevent core damage and large early release. These include, at a minimum, reactivity control, core heat removal, reactor coolant inventory control, reactor coolant heat removal, and containment bypass integrity in appropriate combinations to prevent core damage and large early release. While grouping of individual initiating events into categories is not strictly required, implying that each event is associated with a unique accident sequence model and quantification, in practice it is almost always necessary to make the analysis manageable. Hence, an initiating event category may have as few as one event, or may have many individual events.

TABLE 4.4-1a SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH LEVEL REQUIREMENT A

The initiating events analysis shall provide a reasonably complete and appropriately grouped treatment of initiating event functional categories that challenge continued normal plant operation and that require mitigation to prevent core damage. (HLR-IE-A)

Index No. IE	**CATEGORY I APPLICATIONS** Identification and quantification of dominant accident initiating events	**CATEGORY II APPLICATIONS** Identification and realistic quantification of risk significant accident initiating events	**CATEGORY III APPLICATIONS** Identification and realistic quantification of initiating events
IE-A1 [IE-7] **3.3.1.1**	USE a structured, systematic process for identifying initiating events and for grouping the events into initiating event categories. *For example, such a systematic search MAY employ master logic diagrams, heat balance fault trees, or failure modes and effects analysis (FMEA).*		
IE-A2	Initiating events MAY be grouped into categories to facilitate definition of accident sequences in the *Accident Sequence Analysis* element and to facilitate quantification in the *Quantification* element. Functional initiating event categories refer to initiating event grouped for the purpose of accident sequence definition, while quantification initiating event categories refer to those grouped for separate quantification of the accident sequences. When initiating events are not grouped for either of these purposes; PROVIDE a separate PRA evaluation for each selected initiating event.		
IE-A3 **3,3,1**	IDENTIFY those initiating event categories that challenge normal plant operation and that require successful mitigation to prevent core damage.		
IE-A4 [IE-7] **3.3.1,** **3.3.1(b)**	INCLUDE in the spectrum of internal-event challenges at least the following general categories, and within each general category INCORPORATE each initiating event category in the model quantitatively in terms of its frequency. In the categorization, SEPARATE into different categories based on whether events have different impacts on plant performance, safety functions, and possibilities for recovery. The following list is not intended to be all-inclusive: Transients Loss of offsite power and other station blackout precursors Manual shutdowns LOCAs Small LOCAs include RCP seal LOCAs include stuck open safety and relief valves Medium LOCAs include stuck open safety or relief valves Large LOCAs include inadvertent ADS include component ruptures Excessive LOCA include RPV rupture LOCAs Outside Containment include pipe breaks outside containment include ISLOCA		

TABLE 4.4-1a SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH LEVEL REQUIREMENT A
The initiating events analysis shall provide a reasonably complete and appropriately grouped treatment of initiating event functional categories that challenge continued normal plant operation and that require mitigation to prevent core damage. (HLR-IE-A)

Index No. **IE**	**CATEGORY I APPLICATIONS** Identification and quantification of dominant accident initiating events	**CATEGORY II APPLICATIONS** Identification and realistic quantification of risk significant accident initiating events	**CATEGORY III APPLICATIONS** Identification and realistic quantification of initiating events
IE-A1 [IE-7] **3.3.1.1**	Special initiators (e.g., support systems failures, instrument line breaks)* Internal flooding initiators* * These initiators may result in either a transient or a LOCA type of sequence		
IE-A5 **3.3.1**	In the identification of initiating event categories, ACCOUNT FOR the plant-specific safety functions**.**		
IE-A6 [IE-4], [IE-12] **3.3.1.2** **(a)** **(b)** **(c)**	GROUP initiating events only when the following can be assured: a) Events can be considered similar in terms of plant and operator response, success criteria, timing, or b) events can be subsumed into a group and bounded by the worst case impacts within the "new" group. CONFIRM that any conservatism introduced by the grouping or the subsuming of initiating events is not so severe as to distort Category-I applications.	GROUP initiating events only when the following can be assured: (a) Events can be considered similar in terms of plant and operator 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. To avoid excess conservatism, DO NOT ADD initiating events to a group and DO NOT SUBSUME events into a group unless the impacts are comparable to or less than those of the remaining events in that group.	GROUP initiating events only when the following can be assured: (a) Events can be considered similar in terms of plant and operator 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. To avoid conservatism, DO NOT ADD initiating events to a group and DO NOT SUBSUME events into a group unless the impacts are comparable to or less than those of the remaining events in that group, or it is demonstrated that such grouping does not appreciably impact CDF or LERF and associated Category III applications.

TABLE 4.4-1a SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH LEVEL REQUIREMENT A

The initiating events analysis shall provide a reasonably complete and appropriately grouped treatment of initiating event functional categories that challenge continued normal plant operation and that require mitigation to prevent core damage. (HLR-IE-A)

Index No. IE	**CATEGORY I APPLICATIONS** Identification and quantification of dominant accident initiating events	**CATEGORY II APPLICATIONS** Identification and realistic quantification of risk significant accident initiating events	**CATEGORY III APPLICATIONS** Identification and realistic quantification of initiating events
IE-A7 [IE-4]	TREAT separately from other initiating event categories those categories with significantly different plant response impacts or which could have more severe radionuclide release potential (e.g., LERF). This includes such initiators as excessive LOCA, interfacing systems LOCA, SG tube ruptures, and unisolated breaks outside containment.		

TABLE 4.4-1b SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH LEVEL REQUIREMENT B
COMPLETENESS – TRIPS AND PRECURSORS: The initiating event analysis shall provide reasonably complete coverage of the causes of plant trip events and plant trip precursors. (HLR-IE-B)

Index No. IE	**CATEGORY I APPLICATIONS** Identification and quantification of dominant accident initiating events	**CATEGORY II APPLICATIONS** Identification and realistic quantification of risk significant accident initiating events	**CATEGORY III APPLICATIONS** Identification and realistic quantification of initiating events
IE-B1 [IE-8] **3.3.1.1(d)** IE-B1 [IE-9] **3.3.1.1(a)**	REVIEW the plant-specific initiating event experience of all initiators to assess whether the list of challenges accounts for plant experience. REVIEW experience and analyses at similar plants to assess whether the list of challenges included in the model accounts for industry experience. INCLUDE initiators generally identified in industry PRAs or other pertinent documents, except when not applicable to the specific plant.		
IE-B2 [IE-17]	PERFORM a systematic qualitative evaluation of each system to assess the possibility of an initiating event occurring due to the system.	PERFORM a systematic evaluation to ascertain whether a technique such as an FMEA or fault tree needs to be developed for a given system, with the intent of identifying whether an initiating event needs to be included for the given system or train.	PERFORM a systematic evaluation using a defined process (FMEA or fault tree analysis) to assess the possibility of an initiating event due to each plant system and train.
IE-B3 **3.3.1**	INCLUDE among the transients both equipment and human induced events that disrupt the plant and leave the primary system pressure boundary intact.		
IE-B4 **3.3.1**	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.		
IE-B5 **3.3.1.1(c), 3.3.1.2**	INCLUDE postulated events representing active components 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 [e.g., interfacing systems LOCAs).		
IE-B6 **3.3.1.1(e), 3.3.1.1(i)**	In the identification of the initiating events, CONSIDER INCORPORATING (i) events that have occurred at conditions other than at-power operation (i.e. during low-power or shutdown conditions) unless it is determined that they are not applicable to at-power operation; and (ii) events resulting in a controlled shutdown that includes a scram prior to reaching low-power conditions.		
IE-B7	CONSIDER INTERVIEWING plant operations, maintenance, engineering, and safety-analysis personnel to determine if any potential initiating events have been overlooked.		
IE-B8 [IE-10] **3.3.1.1**	CONSIDER INCLUDING initiating event precursors, and CONSIDER INCLUDING each system alignment and alignments of supporting systems.		
IE-B9 **3.3.1.1(g)**	CONSIDER INCLUDING initiating events resulting from multiple equipment failures, if the equipment failures result from a common cause.		

TABLE 4.4-1b SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS <u>HIGH LEVEL REQUIREMENT B</u>
COMPLETENESS – TRIPS AND PRECURSORS: The initiating event analysis shall provide reasonably complete coverage of the causes of plant trip events and plant trip precursors. (HLR-IE-B)

Index No. **IE**	**CATEGORY I APPLICATIONS** Identification and quantification of dominant accident initiating events	**CATEGORY II APPLICATIONS** Identification and realistic quantification of risk significant accident initiating events	**CATEGORY III APPLICATIONS** Identification and realistic quantification of initiating events
IE-B10 [IE-6] **3.3.1.1(h)**	CONSIDER those multi-unit initiators such as dual unit LOOP events or total loss of service water, that may impact the model at multi-unit sites with shared systems. PERFORM at least a qualitative evaluation to ensure that Category-I applications are not distorted.	TREAT and QUANTIFY EXPLICITLY those multi-unit site initiators such as dual unit LOOP events or total loss of service water that may impact the model at multi-unit sites	

TABLE 4.4-1c SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS <u>HIGH LEVEL REQUIREMENT C</u>

DEPENDENCIES: The initiating-event analysis shall provide reasonably complete and reasonably accurate treatment of initiating events caused by dependencies such as support-system failures. These dependencies include functional, environmental, spatial, and common cause impacts of each modeled initiating event. (HLR-IE-C)

Index No. **IE**	**CATEGORY I APPLICATIONS** Identification and quantification of dominant accident initiating events	**CATEGORY II APPLICATIONS** Identification and realistic quantification of risk significant accident initiating events	**CATEGORY III APPLICATIONS** Identification and realistic quantification of initiating events
IE-C1 [IE-10] **3.3.1.1(f)**	PERFORM a qualitative review of system impacts to identify potentially risk-significant support system initiating events.	USE a structured approach (such as a system-by-system review of initiating event potential, or an FMEA or fault tree) to assess and document the possibility of an initiating event resulting from support system failures**.**	DEVELOP a detailed model of system interfaces including fault tree development. PERFORM an FMEA to assess and document the possibility of an initiating event resulting from individual systems or train failures.
IE-C2 [IE-5] **3.3.1.1(f)**	Support system failures selected as initiating events MAY INCLUDE truncation or subsuming within broader groups if it can be shown that Category I applications are not distorted.	INCLUDE support system failures quantitatively in the PRA in a realistic fashion. TREAT EXPLICITLY the individual support systems (or trains) that can cause a plant trip.	

TABLE 4.4-1d SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH-LEVEL REQUIREMENT D
QUANTIFICATION: The initiating event analysis shall provide a quantification of the annual frequency of each initiating event or initiating event quantification category that needs to be treated separately to obtain a quantification of CDF and LERF (HLR-IE-D).

<table>
<tr><th>Index No.
IE</th><th>CATEGORY I APPLICATIONS
Identification and quantification of dominant accident initiating events</th><th>CATEGORY II APPLICATIONS
Identification and realistic quantification of risk significant accident initiating events</th><th>CATEGORY III APPLICATIONS
Identification and realistic quantification of initiating events</th></tr>
<tr><td>IE-D1
3.3.1.1(a) (b) (c)

3.3.1.3</td><td colspan="3">USE as screening criteria the following characteristics (or more stringent characteristics as devised by the analyst) to eliminate initiating events from further evaluation:
a) the frequency of the event is less than 1E-7 per reactor-year (/ry) and the event does not involve either an ISLOCA, containment bypass, or vessel rupture;
b) the frequency of the event is less than 1E-6/ry and core damage could not occur unless at least two active trains of diverse mitigating systems are independently failed;
c) the resulting reactor trip 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 requirements in the *Data-Analysis* and *Level-1-Quantification* sections.</td></tr>
<tr><td>IE-D2
[IE-16]</td><td colspan="3">CALCULATE the initiating event frequency from plant specific data, if sufficient data are available. USE the most recent applicable data to quantitatively characterize the initiating event frequencies. CONSIDER CREDITING rectification actions as appropriate.</td></tr>
<tr><td>IE-D3</td><td colspan="2">Time trend analysis MAY BE USED to account for established trends, e.g., decreasing reactor trip rates in recent years. If used, JUSTIFY the exclusion of earlier years that are not representative of current data. One acceptable methodology for time-trend analysis is found in Reference [4.4.1-1].</td><td>USE time trend analysis to account for established trends, e.g., decreasing reactor trip rates in recent years. JUSTIFY exclusion of earlier years that are not representative of current data. One acceptable methodology for time-trend analysis is found in Reference [4.4.1-1].</td></tr>
<tr><td>IE-D4
[IE-16]</td><td colspan="3">DO NOT USE data from the initial year of commercial operation in the quantification.</td></tr>
<tr><td>IE-D5</td><td colspan="3">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. When the fault-tree approach is used, USE the appropriate systems-analysis requirements for fault-tree modeling found in the *Systems Analysis* section.</td></tr>
<tr><td>IE-D6</td><td colspan="3">When using fault tree models for initiating events, QUANTIFY the initiating event frequency (as opposed to the probability of an initiating event over a specific time frame, which is the usual fault tree quantification model described in the *Systems Analysis* section.). Thus, MODIFY AS NECESSARY the fault tree computer codes that are designed to compute the top event probabilities to compute the top event failure frequency rather than the top event probability.</td></tr>
<tr><td>IE-D7</td><td colspan="3">If fault-tree modeling is used, CAPTURE within the initiating event fault tree models all relevant combinations of events involving the annual frequency of one component failure combined with the unavailability (or failure during the repair time of the first component) of other components.</td></tr>
</table>

TABLE 4.4-1d SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH-LEVEL REQUIREMENT D
QUANTIFICATION: The initiating event analysis shall provide a quantification of the annual frequency of each initiating event or initiating event quantification category that needs to be treated separately to obtain a quantification of CDF and LERF (HLR-IE-D).

Index No. IE	**CATEGORY I APPLICATIONS** Identification and quantification of dominant accident initiating events	**CATEGORY II APPLICATIONS** Identification and realistic quantification of risk significant accident initiating events	**CATEGORY III APPLICATIONS** Identification and realistic quantification of initiating events
IE-D8 [IE-16]	In the quantification of initiating event frequencies, USE a Bayesian update process of generic industry data if only limited plant-specific data are available.		
IE-D9 [IE-13]			MAKE the calculated frequencies and any associated recovery consistent with industry experience, unless a design or procedural difference exists that would provide the basis for a difference.
IE-D10 [IE-16]	USE plant-specific information in the assessment and quantification of recovery actions where available.		
IE-D11 [IE-13]	COMPARE the results of the initiating event analysis with generic data sources to provide a reasonableness check of the quantitative and qualitative results.		
IE-D12 [IE-13]	PERFORM a review/comparison with industry generic data.		
IE-D13	COLLECT and PRESENT initiating event frequencies on a calendar-year basis.		
IE-D14	For sequences initiated at power, ACCOUNT in the initiating event analysis for the plant availability, such that the frequencies are weighted by the fraction of time the plant is at-power. ACCOUNT FOR differences between historical plant availability over the period of event occurrences in the plant database and future plant availability which could be different from historical values.		
IE-D15 [IE-15]	For rare initiating events, USE industry generic data or AUGMENT with a plant specific fault tree evaluation that accounts for plant specific features. For extremely rare initiating events, CONSIDER USING engineering judgment, augmented by applicable generic data sources. ACCOUNT for plant specific features to the extent necessary to support Category I applications.	For rare initiating events, USE industry generic data and AUGMENT with a plant specific fault tree evaluation that accounts for plant specific features, if applicable. For extremely rare initiating events, engineering judgment MAY be used; if used, AUGMENT with applicable generic data sources. INCLUDE in the quantification the plant specific features that could influence initiating events and recovery probabilities. *Examples of plant specific features that merit inclusion are the following:* · *Plant geography, climate, and meteorology for LOOP and LOOP recovery* · *Service water intake characteristics and plant experience* · *LOCA frequency calculation*	

TABLE 4.4-1d SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH-LEVEL REQUIREMENT D
QUANTIFICATION: The initiating event analysis shall provide a quantification of the annual frequency of each initiating event or initiating event quantification category that needs to be treated separately to obtain a quantification of CDF and LERF (HLR-IE-D).

<table>
<tr><th>Index No.
IE</th><th>CATEGORY I APPLICATIONS
Identification and quantification of dominant accident initiating events</th><th>CATEGORY II APPLICATIONS
Identification and realistic quantification of risk significant accident initiating events</th><th>CATEGORY III APPLICATIONS
Identification and realistic quantification of initiating events</th></tr>
<tr><td>IE-D16
[IE-14]
3.3.1.1(c)
3.3.1.2</td><td colspan="2">In the interfacing system LOCA frequency analysis, ADDRESS those features of plant and procedures that could significantly influence the ISLOCA frequency.</td><td>In the ISLOCA frequency analysis:
· EVALUATE surveillance procedure steps
· INCLUDE surveillance test intervals explicitly
· ASSESS on-line surveillance testing quantitatively
· QUANTIFY pipe rupture probability
· ADDRESS valve design (e.g., air operated testable check valves) explicitly
· INCLUDE quantitatively the valve isolation capability given the high-to-low-pressure differential.</td></tr>
<tr><td colspan="4">References

[4.4.1-1]: NUREG/CR-5750, “Rates of Initiating Events at U.S. Nuclear Power Plants”, Idaho National Engineering and Environmental Laboratory, Idaho Falls, February 1999</td></tr>
</table>

TABLE 4.4-1e SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH-LEVEL REQUIREMENT E
PLANT FIDELITY: The initiating events shall be selected, grouped, and quantified in a manner that ensures model-plant fidelity and accounts for plant specific and unique factors that could influence the potential for, and frequency of, each initiating event category. (HLR-IE-E)

Index No. **IE**	**CATEGORY I APPLICATIONS** Identification and quantification of dominant accident initiating events	**CATEGORY II APPLICATIONS** Identification and realistic quantification of risk significant accident initiating events	**CATEGORY III APPLICATIONS** Identification and realistic quantification of initiating events
There are no SUPPORTING REQUIREMENTS for this High Level Requirement			

TABLE 4.4-1f SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH-LEVEL REQUIREMENT F
DOCUMENTATION: The initiating event analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed to select, group, and screen the initiating event list and to model and quantify the initiating event frequencies, with assumptions and bases stated. (HLR-IE-F)

Index No. IE	CATEGORY I APPLICATIONS Identification and quantification of dominant accident initiating events	CATEGORY II APPLICATIONS Identification and realistic quantification of risk significant accident initiating events	CATEGORY III APPLICATIONS Identification and realistic quantification of initiating events
IE-F1	**Selection of Initiating Events** LIST and JUSTIFY functional categories considered, in accordance with the safety functions considered in the accident sequence model. For each functional category, DOCUMENT the specific initiating events considered. DOCUMENT : • the systematic search for plant unique and plant specific support system initiators, along with the resulting support system initiators disposition • the systematic search for RCS pressure boundary failures and interfacing system LOCAs • the approach for assessing completeness and consistency of initiating events with plant specific experience, industry experience, other comparable PRAs and FSAR initiating events • the assumptions		
IE-F2 [IE-20]	**Grouping and Screening of Initiating Events** DOCUMENT: • the basis for screening out initiators as risk insignificant. • the basis for grouping and subsuming initiating events. This may interface with the required success criteria from the *Systems Analysis* and *Success Criteria* Elements of this Standard. • the assumptions • the dismissal of any observed initiating events, including any credit for rectification		

TABLE 4.4-1f SUPPORTING REQUIREMENTS FOR INITIATING EVENTS ANALYSIS HIGH-LEVEL REQUIREMENT F
DOCUMENTATION: The initiating event analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed to select, group, and screen the initiating event list and to model and quantify the initiating event frequencies, with assumptions and bases stated. (HLR-IE-F)

Index No. IE	**CATEGORY I APPLICATIONS** Identification and quantification of dominant accident initiating events	**CATEGORY II APPLICATIONS** Identification and realistic quantification of risk significant accident initiating events	**CATEGORY III APPLICATIONS** Identification and realistic quantification of initiating events
IE-F3	**Quantification of Initiating Event Frequencies** DOCUMENT: • the derivation of the initiating event frequencies and the recoveries used in conjunction with the initiating event • the approach to quantification of each initiating event frequency as data analysis or model approach. EXPLAIN any large deviations from comparable generic data. • how the applicable system failure modes are taken into account for each fault tree minimal cutset • the methodology and approach when using data analysis methods to estimate initiating event frequencies and IDENTIFY the data used • the justification for exclusion of any data • the availability factor used to convert initiating event frequencies to events per calendar year • recovery probabilities, their bases, and their tie to the initiating events • potential time dependent aspects of the initiating event frequencies, and assumptions made to obtain average frequencies • the process for computing initiating event frequencies and recovery probabilities • the assumptions When fault tree models are used to estimate initiating event frequencies, APPLY appropriate aspects of system analysis documentation requirements including any modeling assumptions.		
IE-F4 **3.3.1.4**	**Interfaces with Other PRA Tasks** DOCUMENT specific interfaces with other PRA tasks for traceability, and to facilitate configuration control when interfacing tasks are updated.		

4.4.1 Objectives of the Accident Sequence Analysis Element

- The accident sequence modeling addresses the accident scenarios that can affect the risk profile for CDF or LERF.
- The accident sequences address critical safety functions for all initiators identified in the initiating event analysis.
- Accident scenarios are realistic representations considering the postulated system failures.
- Dependencies are reflected in the accident sequence structure (event trees and/or fault trees) where necessary to support realistic and plant specific CDF and LERF determination
  - initiating event dependencies
  - sequence functional dependency
  - phenomenological dependencies (e.g., high containment pressure, loss of NPSH)
- End states are clearly defined to be core damage or successful mitigation with capability to support the Level 1 to Level 2 interface sufficient for the applications.
- 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.
- Significant operator actions, mitigation measures, or phenomena that can alter sequences are appropriately included in the accident sequence model event tree structure and sequence definition.
- The accident sequences are adequate to support realistic and plant specific quantification of CDF and LERF.
- The accident sequences reflect plant specific operating and emergency procedures.
- There is adequate fidelity with the as-built, as-operated plant.
- Model clarity is adequate and assumptions adequately documented.
- Transfers of accident sequences are explicitly treated.
- Unique plant features are addressed.
- The methodology for sequence development is consistently applied and described.
- The output from this element is a set of well defined accident scenarios that lead to core damage.
- The documentation for the element clearly describes the methodology, the development process and the resulting accident sequences

Table 4.4.2 HIGH LEVEL REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS (HLR-AS)

A	**Functional Sequence Categories** The *Accident Sequence Analysis* shall provide a reasonably complete set of scenarios that can lead to core damage following each initiating event or initiating event category defined in *Initiating Events Analysis.* These scenarios shall cover system responses and operator actions, including recovery actions, that support the key safety functions[(2)] necessary to prevent core damage, and shall be defined in a manner that supports the Level 1/Level 2 interface. (HLR-AS-A)
B	**Plant Specific CDF and LERF Quantification** The *Accident Sequence Analysis* shall provide a sequence definition structure that is capable of supporting plant specific quantification of the CDF, and LERF via the Level 1/Level 2 interface. (HLR-AS-B)
C	**Interface with Success Criteria** *Accident Sequence Analysis* shall provide an interface with the success criteria, mission times, and time windows needed to support each key safety function[(2)] represented in the modeled scenarios. (HLR-AS-C)
D	**Treatment Of Dependencies** Dependencies due to initiating events, human interface, functional dependencies, environmental and spatial impacts, and common cause failures shall be addressed. (HLR-AS-D)
E	**Documentation** The *Accident Sequence Analysis* shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed, with assumptions and bases stated. (HLR-AS-E)

[(2)] Key safety functions are the minimum set of safety functions that must be maintained to prevent core damage and large early release. These include, at a minimum, reactivity control, core heat removal, reactor coolant inventory control, reactor coolant heat removal, and containment bypass integrity in appropriate combinations to prevent core damage and large early release.

TABLE 4.4-2a SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS <u>HIGH LEVEL REQUIREMENT A</u>
FUNCTIONAL SEQUENCE CATEGORIES: The *Accident Sequence Analysis* shall provide a reasonably complete set of scenarios that can lead to core damage following each initiating event or initiating event category defined in *Initiating Events Analysis*. These scenarios shall cover system responses and operator actions, including recovery actions, that support the key safety functions[2] necessary to prevent core damage, and shall be defined in a manner that supports the Level1/Level 2 interface. (HLR-AS-A)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-A1 [AS-6] [3.3.2.2]	CHOOSE a method for *Accident Sequence Analysis* that explicitly models the appropriate combinations of system responses and operator actions that affect the key plant safety functions for each modeled initiating event. DEFINE and INCLUDE the critical safety functions that are assumed to be necessary to reach a safe stable state in the model.		
AS-A2 [AS-4] [3.3.2.2]	USE a method for *Accident Sequence Analysis* that : a) includes a reasonably complete set of event sequences involving core damage that could result from each modeled initiating event. b) considers the different plant responses and containment challenges that could result from each modeled initiating event; and c) provides a framework to support sequence quantification. d) reflects the initiating event categories defined in the *Initiating Events Analysis*	USE a method for *Accident Sequence Analysis* that : a) includes a reasonably complete set of event sequences involving core damage that could result from each modeled initiating event. b) models the different plant responses and addresses the containment challenges that could result from each modeled initiating event; and c) provides a framework to support sequence quantification. d) is explicitly traceable to the initiating event categories defined in the *Initiating Events Analysis*	
AS-A3 [AS-4]	DEFINE separate accident sequences as needed to address differences in timing, system success criteria, and operator actions.		
AS-A4 [AS-8]	ADDRESS a level of discrimination in the event tree structure that represents the key procedurally directed operator actions and delineates the differences in success criteria reflected in challenges to the critical safety functions.	DEVELOP a level of discrimination in the event tree structure that represents the key procedurally directed operator actions and delineates the differences in success criteria reflected in challenges to the critical safety functions.	
AS-A5 [AS-4] [3.3.2.2]	USE event trees or their equivalent to represent the accident sequence logic. JUSTIFY the use of alternatives to event trees (e.g., single top fault tree).		

(2) Key safety functions are the minimum set of safety functions that must be maintained to prevent core damage and large early release. These include, at a minimum, reactivity control, core heat removal, reactor coolant inventory control, reactor coolant heat removal, and containment bypass integrity in appropriate combinations to prevent core damage and large early release.

TABLE 4.4-2a SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT A
FUNCTIONAL SEQUENCE CATEGORIES: The *Accident Sequence Analysis* shall provide a reasonably complete set of scenarios that can lead to core damage following each initiating event or initiating event category defined in *Initiating Events Analysis*. These scenarios shall cover system responses and operator actions, including recovery actions, that support the key safety functions(2) necessary to prevent core damage, and shall be defined in a manner that supports the Level1/Level 2 interface. (HLR-AS-A)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-A6 [AS-4] [3.3.2.2]	USE an acceptable event tree/fault tree method for interfacing the Accident Sequence Analysis with the Systems Analysis tasks. Acceptable approaches for event tree/fault tree modeling include. event trees with conditional split fractions(also referred to as event tree linking), and fault tree linking, both described in (Reference [4.4.2-1]). JUSTIFY the use of alternative approaches for this function.		
AS-A7 [3.3.2.4.1]	DEVELOP the event trees in sufficient detail to: a) determine which safety systems, functions, and operator actions have been challenged for each accident sequence b) determine whether core damage has occurred or core damage may be assumed initially in the PRA development c) identify the conditions needed to define the appropriate operator recovery actions and the necessary conditions for each sequence.		
AS-A8 [AS-4]	INCLUDE each necessary critical safety function in the quantitative model. JUSTIFY exceptions to the critical safety functions that are omitted from the model.		
AS-A9 [AS-7]	INCLUDE those relevant systems that support each critical safety function in the event sequence model in support of sequence quantification.		
AS-A10 [AS-8]	Transfers between event trees MAY be used to reduce the size and complexity of individual event trees. DEFINE any transfers that are used and the method that is used to implement them in the qualitative definition of accident sequences and in their quantification. USE a method for implementing an event tree transfer that preserves the dependencies that are part of the transferred sequence. These include functional, system, initiating event, operator, and spatial or environmental dependencies.		
AS-A11 [AS-8]	When event tree branching and event tree transfers are employed, DEVELOP the structure in a manner that maintains and unambiguously resolves the definition of success and failure paths.		
AS-A12 [3.3.2.4]	CONSIDER USING one or more accepted methods for developing and documenting the event sequence modeling process. Accepted methods include: a) functional and systemic event trees or both (as explained in Reference [4.4.2-1]) b) event sequence diagrams c) system dependency matrices	USE one or more accepted methods for developing and documenting the event sequence modeling process. Accepted methods include: a) functional and systemic event trees or both (as explained in Reference [4.4.2-1]) b) event sequence diagrams c) system dependency matrices	
AS-A13 [3.3.2.4]	INCLUDE a traceable interface between the event tree development process and the method or methods chosen from above or JUSTIFY use of alternative methods	INCLUDE a traceable interface between the event tree development process and the method or methods chosen from above.	

TABLE 4.4-2b SUPPORTING REQUIREMENTS ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT B
PLANT SPECIFIC CDF AND LERF QUANTIFICATION: The accident sequence analysis shall provide a sequence definition structure that is capable of supporting plant specific quantification of the CDF and LERF via the Level 1/Level 2 interface. (HLR-AS-B)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-B1 [AS-5]	INCLUDE models and analyses for *Accident Sequence Analysis* that are consistent with the as-built and as-operated plant. PERFORM realistic modeling of the as-built plant as supported by available information. Conservative modeling of the as-built plant MAY be performed to the extent that Category I applications are not distorted..	INCLUDE models and analysis for *Accident Sequence Analysis* that are consistent with the as-built and as-operated plant. PERFORM realistic modeling of the as-built plant as supported by available information.	
AS-B2 [AS-9]	DEFINE the success paths in the *Accident Sequence Analysis* that are logically consistent with the plant specific definition of core damage. Conservative treatment of success paths MAY be implemented only to the extent that Category I applications are not distorted by such conservative assumptions.	DEFINE the success paths in the *Accident Sequence Analysis* that are logically consistent with the definition of core damage and in a manner that supports a realistic and plant specific quantification of CDF.	
AS-B3 [AS-16]	INCLUDE models for repair and recovery that are based on data or accepted models applicable to the plant and that account for accident sequence dependencies such as time available, adverse environment, and lack of access, lighting, or room cooling. Conservative evaluations of repair and recovery MAY be incorporated only to extent that the relative risk significance of modeled SSCs is not distorted.	INCLUDE models for repair and recovery that are based on data or accepted models applicable to the plant and that account for accident sequence dependencies such as time available, adverse environment, and lack of access, lighting, or room cooling.	
AS-B4 [AS-19]	PROVIDE functions and structure of the event trees in a manner that is consistent with the plant specific EOPs and abnormal procedures.		

TABLE 4.4-2b SUPPORTING REQUIREMENTS ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT B
PLANT SPECIFIC CDF AND LERF QUANTIFICATION: The accident sequence analysis shall provide a sequence definition structure that is capable of supporting plant specific quantification of the CDF and LERF via the Level 1/Level 2 interface. (HLR-AS-B)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-B5 [AS-19]	ACCOUNT FOR procedurally directed operator actions (both positive and negative impacts) that substantially influence the accident sequence progression or its probability in the accident sequence structure or the supporting fault tree analysis. INCORPORATE into the *Accident Sequence Analysis* the expected responses to an initiator as reflected in the plant emergency and abnormal operating procedures, training simulator exercises, and existing plant transient analysis. CHARACTERIZE the operator responses in a manner that is consistent with operator training and results of applicable simulator exercises. INCLUDE operator training input in the interpretation of proceduralized steps. INCLUDE operator actions that influence accident progression in the accident sequence model. Exceptions to this requirement MAY be taken only to the extent that Category I applications are not distorted.	ACCOUNT FOR procedurally directed operator actions (both positive and negative impacts) that substantially influence the accident sequence progression or its probability in the accident sequence structure or the supporting fault tree analysis. INCORPORATE into the *Accident Sequence Analysis* the expected responses to an initiator as reflected in the plant emergency and abnormal operating procedures, training simulator exercises, and existing plant transient analysis. CHARACTERIZE the operator responses in a manner that is consistent with operator training and results of applicable simulator exercises. INCLUDE operator training input in the interpretation of proceduralized steps. INCLUDE operator actions that influence accident progression in the accident sequence model.	
AS-B6 [AS-20, AS-22]	Clearly DEFINE the Level 1 end states as core damage or a safe stable state. USE a definition of core damage that is consistent with the requirements for *Success Criteria*		
AS-B7 [AS-20, AS-22]	RESOLVE other end states such as "core vulnerable" into core damage or safe stable states. ADDRESS the treatment of the impact of containment failure or vent on continued RPV makeup capability and basis for assumptions regarding ultimate end-state when such resolutions are made.		
AS-B8 [AS-20, AS-22]	Conservative definitions of core damage MAY be used only to the extent that Category I applications are not impacted.	DO NOT USE conservative definitions of core damage	

TABLE 4.4-2b SUPPORTING REQUIREMENTS ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT B
PLANT SPECIFIC CDF AND LERF QUANTIFICATION: The accident sequence analysis shall provide a sequence definition structure that is capable of supporting plant specific quantification of the CDF and LERF via the Level 1/Level 2 interface. (HLR-AS-B)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-B9 [AS-21]	USE a method for *Accident Sequence Analysis* that supports the development of an interface between Level 1 and Level 2 LERF analysis. To accomplish this, core damage sequences MAY be further developed by using accident sequence knowledge or information or consequence questions to unambiguously assign the modeled sequence to an appropriate plant damage state (PDS).		
AS-B10	USE Level 1 plant damage states that provide adequate information to support Level 2 analysis with minimal loss of information. If individual sequence cut sets are assigned to Plant Damage States (PDS), PROVIDE sufficient information to be able to remove ambiguities in mapping the basic event cutsets to unique PDS. Exceptions to this requirement MAY be made only to the extent that Category I applications are not distorted.	USE Level 1 plant damage states that provide adequate information to support Level 2 analysis with minimal loss of information. If individual sequence cut sets are assigned to Plant Damage States (PDS), PROVIDE sufficient information to be able to remove ambiguities in mapping the basic event cutsets to unique PDS.	
AS-B11 [AS-14]	Grouping of sequences into broader plant damage state categories MAY be performed only to the extent that Category I applications are not distorted. DO NOT GROUP sequences or plant damage states in a non-conservative manner (subsuming of sequences into broader categories not bounded by the worst case accident).	Grouping of sequences into broader plant damage state categories MAY be performed only to the extent that such grouping does not distort realistic CDF and LERF estimation. DO NOT GROUP sequences or plant damage states in a non-conservative manner (subsuming of sequences into broader categories not bounded by the worst case accident).	
AS-B12 [AS-15]	The Accident Sequence Analysis may be modeled using a single top event linked fault tree model. When this option is selected, DEVELOP such models in manner that meets all the technical requirements of this section. PROVIDE justification for any requirements that are not met or do not apply.		

TABLE 4.4-2c SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS <u>HIGH LEVEL REQUIREMENT C</u>
INTERFACE WITH SUCCESS CRITERIA*: Accident Sequence Analysis* shall provide an interface with the success criteria, mission times, and time windows needed to support each key safety function [(2)] represented in the modeled scenarios. (HLR-AS-C)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-C1 [AS-17]	Based on the functional success criteria developed in *Success Criteria*, INCLUDE a reasonably accurate treatment of the functional requirements associated with the plant-specific safety functions, system capabilities and system interactions, procedural guidance to operators, and the timing of events within the *Accident Sequence Analysis* for each modeled initiating event category.		
AS-C2 [AS-18]	IDENTIFY the information sources used as the basis for the *Accident Sequence Analysis* including: (a) system analysis and system dependencies (b) success criteria, plant thermal hydraulics, and plant transient response (c) plant operating procedures and practices.		
AS-C3 [AS-18]	PROVIDE a sequence definition that is based on realistic thermal hydraulic analyses to support the success criteria used in the *Accident Sequence Analysis*. Conservative analyses MAY be used only to the extent that Category I applications are not distorted.	PROVIDE a sequence definition that is based on realistic thermal hydraulic analyses to support the success criteria used in the *Accident Sequence Analysis*. Conservative analyses MAY be used only to the extent that realistic estimates of CDF and LERF are not distorted.	
AS-C4	DEVELOP and SPECIFY the success criteria in a manner that shows an interface with the definition of core damage and PDS, definition of plant safety functions needed to prevent core damage or PDS, and the boundary conditions for the systems analysis. INCLUDE a definition of the success criteria and mission time for each event tree top event. If multiple success criteria and mission times are needed for the same event tree top event, PROVIDE this information for each case.		
AS-C5 [AS-23]	INCLUDE in the definition of success criteria for sequences terminating with no core damage, a mission of at least 24 hours with stable plant conditions or an appropriate representation for accident sequences with unstable conditions that is consistent with the sequence end-state. JUSTIFY and PROVIDE any mission times less than 24 hours for stable sequences and all assumed mission times for all unstable sequences.		

(2) Key safety functions are the minimum set of safety functions that must be maintained to prevent core damage and large early release. These include, at a minimum, reactivity control, core heat removal, reactor coolant inventory control, reactor coolant heat removal, and containment bypass integrity in appropriate combinations to prevent core damage and large early release.

TABLE 4.4-2d SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT D
TREATMENT OF DEPENDENCIES: Dependencies due to initiating events, human interface, functional dependencies, environmental and spatial impacts, and common cause failures shall be addressed. (HLR-AS-D)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-D1 [AS-5] [3.3.2.4.1]	PROVIDE a sequence model development with a clear interface with the system analysis and dependency evaluation tasks of the PRA.		
AS-D2 [AS-10] [3.3.2.4.1]	INCLUDE a visible and a reasonably accurate treatment of dependencies and interfaces among the plant safety functions, system responses, and operator actions needed for accident mitigation in the *Accident Sequence Analysis*. These dependencies include functional, phenomenological, and operational dependencies and interfaces. IDENTIFY dependencies among all modeled event tree top events and INCLUDE these quantitatively in the model.		
AS-D3 [AS-11] [3.3.2.3]	PROVIDE a systematic evaluation of dependencies, such as that provided by dependency matrices. When using dependency matrices for this purpose INCLUDE a matrix or set of matrices that accounts for: a) initiating event to system dependencies b) dependencies among support systems c) dependencies between support and front line systems; d) dependencies among front line systems that support key safety functions [(2)] PROVIDE an event sequence model that realistically treats, and consistently applies, to capture the dependencies among event tree top events.		

(2) Key safety functions are the minimum set of safety functions that must be maintained to prevent core damage and large early release. These include, at a minimum, reactivity control, core heat removal, reactor coolant inventory control, reactor coolant heat removal, and containment bypass integrity in appropriate combinations to prevent core damage and large early release.

TABLE 4.4-2d SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT D
TREATMENT OF DEPENDENCIES: Dependencies due to initiating events, human interface, functional dependencies, environmental and spatial impacts, and common cause failures shall be addressed. (HLR-AS-D)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-D4 [AS-10]	INCLUDE the following types of accident sequence dependencies: Functional: Functional failures, e.g.: a) LOCA initiator causes debris clogging of ECCS Suction b) turbine driven system dependency on SORV, depressurization, and containment heat removal (suppression pool cooling). c) low pressure system injection success dependent on need for RPV depressurization. Intra and Intersystem: Common cause failures and functional dependencies between systems. IDENTIFY system dependencies, dependency matrices, and/or linked fault trees. Human: Adverse environment or sequence timing influences on operator actions. Spatial/Environmental/Phenomenological: Spatial/Environmental dependencies that may result from initiating events and subsequent sequences. Example of Phenomenological dependencies: These dependencies manifest themselves when the environmental conditions generated during an accident sequence influence the operability of equipment or the capability of the operators to implement procedures and recovery actions. Examples of phenomenological impacts include generation of harsh environments that actuate protective trip circuits, loss of pump net positive suction head (NPSH), clogging of flow paths, and consequential effects of other failures.		
AS-D5 [AS-10]	INCLUDE dependencies between the initiating event and mitigating systems as well as dependencies between and among the mitigating systems and operator actions. ACCOUNT for dependencies between the initiating event and mitigating systems, including immediate (e.g. loss of electric power) and delayed responses (e.g., loss of room cooling) in the accident sequence model or reflected in the system logic models. Dependencies among mitigating systems and operator actions MAY also be modeled in the accident sequence model or the system logic models.		
AS-D6 [3.3.2.4.1]	When developing the event sequence structure, ORDER the event tree top events representing the response of systems and post initiator operator actions sequentially according to the timing of the events along the sequence to ensure proper treatment of time dependencies.		
AS-D7 [3.3.2.4.1]	When the event trees with conditional split fraction method is used, if the probability of Event B is dependent on the occurrence or non-occurrence of Event A, PLACE Event A to the left of Event B in the ordering of event tops.		

TABLE 4.4-2d SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT D
TREATMENT OF DEPENDENCIES: Dependencies due to initiating events, human interface, functional dependencies, environmental and spatial impacts, and common cause failures shall be addressed. (HLR-AS-D)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-D8 [3.3.2.4.1]	For the event trees with conditional split fraction method, DEVELOP the event trees to a level of detail sufficient to identify intersystem dependencies and train level interfaces. For the fault tree linking method, DEVELOP fault trees and apply flag settings and mutually exclusive files or comparable method to resolve these same dependencies. If plant configurations and maintenance practices create dependencies among various system alignments, DEFINE and MODEL these configurations and alignments in a manner that reflects these dependencies. PROVIDE one event sequence model or set of event trees that accounts for each initiating event or initiating event category defined in the *Initiating Event Analysis* element so that initiating event dependencies can be properly modeled.		
AS-D9 [AS-12]	PROVIDE an explicit model of the Pump seal LOCA in the *Accident Sequence Analysis* when applicable. PROVIDE the basis for the model.		
AS-D10 [AS-13]	INCLUDE in the *Accident Sequence Analysis* and quantified model an explicit and realistic treatment of dependencies introduced by the time phasing of the event progression. A conservative treatment of time phasing MAY be used to the extent that Category I applications are not distorted.	INCLUDE in the *Accident Sequence Analysis* and quantified model an explicit and realistic treatment of dependencies introduced by the time phasing of the event progression. A conservative treatment of time phasing MAY be used to the extent that realistic estimates of CDF and LERF are not distorted.	

TABLE 4.4-2d SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT D
TREATMENT OF DEPENDENCIES: Dependencies due to initiating events, human interface, functional dependencies, environmental and spatial impacts, and common cause failures shall be addressed. (HLR-AS-D)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-D11 [AS13]	INCLUDE events for which time phased dependencies could be introduced. For SBO/LOOP sequences , INCLUDE key time phased events such as: • AC power recovery • DC battery adequacy (time dependent discharge) • Environmental conditions (e.g., room cooling) for operating equipment and the control room For ATWS/failure to scram events, INCLUDE key time dependent actions such as: • SBLC initiation • RPV level control • ADS inhibit Other events that MAY be subject to explicit time dependent characterization include: • CRD as an adequate RPV injection source • Long term make-up to RWST		

TABLE 4.4-2d SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT D
TREATMENT OF DEPENDENCIES: Dependencies due to initiating events, human interface, functional dependencies, environmental and spatial impacts, and common cause failures shall be addressed. (HLR-AS-D)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-D12 [AS-13]	As part of the time dependence assessment, ADDRESS the following: • Mission time of diesel generators • Mission time of RPT, ARI, scram system • Time to core uncovery		
AS-D13 [AS-15] [3.3.2.4.1]	To model the changing nature of certain sequences, ACCOUNT for operational dependencies. ACCOUNT for interfaces when sequences are modeled in multiple event trees with transfers. Example of event progression: In developing sequences for a transient initiating event in which the reactor coolant boundary is initially intact, event progression may lead to sequences in which reactor coolant system safety or relief valves open such that a transient induced LOCA condition is created.		
AS-D14 [AS-15]	When transfers are being employed, INCLUDE Transfers among event trees explicitly in the quantification except for cases that are noted in the documented descriptions of the sequences to address dependencies properly. PRESERVE the appropriate dependencies, both hardware and human related, from the original event sequence model across the transfer interfaces.		

TABLE 4.4-2e SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT E
DOCUMENTATION: The accident sequence analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed, with assumptions and bases stated. (HLR-AS-E)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-E1 [AS-25]	DOCUMENT the results of the Accident Sequence Analysis consistent with the process that was used for its development. PROVIDE the basis for the accident sequence process.		
AS-E2 [AS-26]	DOCUMENT the results of independent reviews of the *Accident Sequence Analysis* and the qualifications of the reviewers.		
AS-E3 [AS-26]	DOCUMENT the treatment of each initiator and event tree to support reviews and applications.		
AS-E4	DOCUMENT interfaces between *Accident Sequence Analysis* and other PRA tasks. INCLUDE the following interfaces in the documentation: • a link between the definition of initiating event category in the Initiating Event Analysis Task and the event sequence model • the definition of core damage and associated success criteria that is consistent with that documented in the Success Criteria Task • key definitions of operator actions and sequence specific timing and dependencies reflected in the event trees that is traceable to the HRA for these actions • the basis for the sequence and cutset quantification in the Level 1 Quantification And Interpretation of Results Task • a framework for an integrated treatment of dependencies in the initiating events analysis, systems analysis, data analysis, human reliability analysis, Level 1 quantification, and Level 2 LERF quantification PRA elements.		

TABLE 4.4-2e SUPPORTING REQUIREMENTS FOR ACCIDENT SEQUENCE ANALYSIS HIGH LEVEL REQUIREMENT E

DOCUMENTATION: The accident sequence analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed, with assumptions and bases stated. (HLR-AS-E)

Index No. AS	**CATEGORY I APPLICATIONS** Modeling of dominant core damage and large early release accident sequences	**CATEGORY II APPLICATIONS** Modeling of risk significant core damage and large early release accident sequences	**CATEGORY III APPLICATIONS** Modeling of core damage and large early release accident sequences
AS-E5	DOCUMENT a) a description of events and the end states included in the development of the models b) the success criteria for each modeled event c) the actual models.		
AS-E6	DOCUMENT: a) the success criteria established for each initiating event category including the bases for the criteria (i.e., the system capacities required to mitigate the accident and the necessary components required to achieve these capacities); b) the models used (including all sequences) for each initiating event category c) a description of the accident progression for each sequence or group of similar sequences (i.e., descriptions of the sequence timing, applicable procedural guidance, expected environmental or phenomenological impacts, dependencies between systems and operator actions, and other pertinent information required to fully establish the sequence of events); d) any assumptions that were made in developing the accident sequences, as well as the bases for the assumptions and their impact on the final results; e) existing analyses or plant-specific calculations performed to arrive at success criteria and expected sequence phenomena including necessary timing considerations; f) sufficient system operation information to support the modeled dependencies; g) calculations or other bases used to justify equipment operability beyond its "normal" design parameters and for which credit has been taken; and h) description of the interface of the accident sequence models with PDSs. i) how all requirements for *Accident Sequence Analysis* have been satisfied when sequences are modeled using a single top event linked fault tree.		

References

[4.4.2-1] NUREG/CR-4550, Vol. 1 Rev. 1, A Analysis of Core Damage Frequency: Internal Events Methodology, pp 4-1 to 4-22, January 1990

4.4.3 Success Criteria

- A reasonable technical basis is provided to support event timing and success criteria.
- There is fidelity with the as-built, as-operated plant.
- Unique plant features are addressed.
- The technical bases for success criteria are either plant specific or account for plant specific features.
- Known limitations of models are identified and accounted for in the evaluation.
- The criteria for determining success identified (e.g., avoidance of core damage, avoidance of LERF, achieving a safe and stable state)
- The methods and approaches have a firm technical basis.
- The resulting success criteria are referenced to the specific deterministic calculations
- Success criteria are established for critical safety functions, supporting systems, operator actions.
- The documentation for the element clearly describes the methodology, the development process, and the relationship to system and accident sequence success criteria.

Table 4.4-3 HIGH LEVEL REQUIREMENTS FOR SUCCESS CRITERIA AND SUPPORTING ENGINEERING CALCULATIONS (HLR-SC)

A	**Technical Bases:** The success criteria shall be defined and referenced to thermal/hydraulic, structural analysis, or other supporting engineering bases. (HLR-SC-A)
B	**Degree of Realism:** 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. (HLR-SC-B)
C	**Plant Fidelity:** The engineering calculations supporting the success criteria and event sequence timing shall be applicable to the features, procedures, and operating philosophy of the plant. (HLR-SC-C)
D	**Documentation:** The success criteria and supporting engineering analysis shall be documented in a manner that facilitates PRA applications, upgrades, and peer review by describing the processes that were followed, with assumptions and bases stated. (HLR-SC-D)

Table 4.4-3a

SUPPORTING REQUIREMENTS FOR SUCCESS CRITERIA AND OTHER ENGINEERING CALCULATIONS HIGH LEVEL REQUIREMENT A

Scope: The success criteria shall be defined and referenced to thermal/hydraulic, structural analysis, or other supporting engineering bases. (HLR-SC-A)

Index No. **SC**	**CATEGORY I APPLICATIONS** Bases and supporting analyses for establishing success or failure dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic bases and supporting analyses for establishing success or failure in risk-significant accident sequences	**CATEGORY III APPLICATIONS** Realistic bases and supporting analyses for establishing success or failure in accident sequences
SC-A1 [AS-20] [3.3.3.1.1-2]	DEFINE core damage as used in the PRA. SPECIFY the plant parameters (e.g., peak fuel temperature, core collapsed liquid level) and associated acceptance criteria (e.g., temperature limit) to be used in determining core damage.		
SC-A2 [AS-20] [3.3.3.1.1-2]	If core damage has been defined differently than in Section 2 of this standard: · IDENTIFY any substantial differences from the Section 2 definition, and · PROVIDE the bases for the selected definition.		
SC-A3 [AS-17, AS-20] [3.3.3-1] [3.3.3-2] [3.3.3.1-1]	SPECIFY the criteria and bases for reaching a safe, stable state with respect to the minimum set of mitigative systems/functions to prevent core damage or radioactivity release in the accident sequences.		

Table 4.4-3a

SUPPORTING REQUIREMENTS FOR SUCCESS CRITERIA AND OTHER ENGINEERING CALCULATIONS HIGH LEVEL REQUIREMENT A

Scope: The success criteria shall be defined and referenced to thermal/hydraulic, structural analysis, or other supporting engineering bases. (HLR-SC-A)

Index No. **SC**	**CATEGORY I APPLICATIONS** Bases and supporting analyses for establishing success or failure dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic bases and supporting analyses for establishing success or failure in risk-significant accident sequences	**CATEGORY III APPLICATIONS** Realistic bases and supporting analyses for establishing success or failure in accident sequences
SC-A4 [AS-17] [AS-20] [AS-23] [SY-17] [TH-4,-5,-6,-7] [3.3.3-1] [3.3.3-2] [3.3.3.1-1] [3.3.3.2-6] [3.3.3.2-7] [3.3.3.2-9] [3.3.3.2-10] [3.3.3.2-11] [3.3.3.2-12] [3.3.3.2-13] [3.3.3.2-14] [3.3.3.2-15] [3.3.3.3-1]	In specifying success criteria and bases, INCLUDE expected effects of equipment, human actions, sequence timing, and dependencies on sequence and system success, to the extent needed to support Category I applications. *Examples of items to consider for inclusion are:* · *initiating event-specific criteria* · *accident progression dependencies (i.e., differing success criteria for a given system or human action depending on the prior success or failure of other systems or human actions).* · *required system capacities, hardware needed to deliver required capacities, hardware actuation times, times available for human actions, mission times and support system requirements;* · *both safety-related and non-safety-related systems that would be expected to function to prevent core damage or to mitigate radioactive material release*	In specifying success criteria and bases, INCLUDE expected effects of equipment, human actions, sequence timing, and dependencies on sequence and system success. INCLUDE the following items, as appropriate to the plant: · initiating event-specific criteria · accident progression dependencies (i.e., differing success criteria for a given system or human action depending on the prior success or failure of other systems or human actions). · required system capacities, hardware needed to deliver required capacities, hardware actuation times, times available for human actions, mission times and support system requirements; · both safety-related and non-safety-related systems that would be expected to function to prevent core damage or to mitigate radioactive material release	
SC-A5 [AS-20] [3.3.3.1.1-1] [3.3.3.2-18]	PERFORM additional evaluation or modeling for sequences in which a safe, stable state has not been achieved by the end of the mission time defined for the PRA. ADDRESS such sequences by using an appropriate technique. *Examples of appropriate techniques include:* · *assign an appropriate plant damage state for the sequence;* · *extend the mission time, and adjust the affected analyses, to the point at which conditions can be shown to reach acceptable values; or* · *model additional system recovery or operator actions for the sequence, in accordance with requirements stated in the Systems Analysis and Human Reliability sections of this standard, to demonstrate that a successful outcome is achieved.*		

Table 4.4-3a

SUPPORTING REQUIREMENTS FOR SUCCESS CRITERIA AND OTHER ENGINEERING CALCULATIONS HIGH LEVEL REQUIREMENT A

Scope: The success criteria shall be defined and referenced to thermal/hydraulic, structural analysis, or other supporting engineering bases. (HLR-SC-A)

Index No. **SC**	**CATEGORY I APPLICATIONS** Bases and supporting analyses for establishing success or failure dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic bases and supporting analyses for establishing success or failure in risk-significant accident sequences	**CATEGORY III APPLICATIONS** Realistic bases and supporting analyses for establishing success or failure in accident sequences
SC-A6 [3.3.3.2-3] [3.3.3.2-4] [3.3.3.2-5]	For grouped initiating events or for accident sequences that represent multiple possible scenarios: • DEFINE an appropriate process for assigning system and human action success criteria representative of the initiating event or sequence group. Conservative or bounding success criteria covering broad groupings of initiating events or scenarios MAY be used.	For grouped initiating events or for accident sequences that represent multiple possible scenarios: • ASSIGN the success criteria for systems and human actions applicable to the most limiting element in the group of initiators or sequences OR • DEFINE an alternative process • *Examples of acceptable alternative processes include:* ➢ *splitting the group into smaller groups with individual success criteria;* ➢ *redefinition of the event sequence to include additional detail with which to distinguish differences in success criteria for additional scenarios*	
SC-A7 [3.3.3.2-16]	USE consistent analyses to define the time available for each post-initiator action and system response success criterion for the same sequence.		
SC-A8	DEFINE the criteria used to determine structural integrity for piping, vessels, and structures important to the determination of CDF and LERF. EVALUATE ultimate capacity of such equipment on a conservative or realistic basis.		DEFINE the criteria used to determine structural integrity for piping, vessels, and structures important to the determination of CDF and LERF. EVALUATE ultimate capacity of such equipment on a realistic basis.
SC-A9 [ST-4]	EVALUATE reactor pressure vessel ultimate capacity, on a conservative or realistic basis, for the following challenges: • Overpressure • Pressurized thermal shock		EVALUATE reactor pressure vessel ultimate capacity on a realistic basis, for the following challenges: • Overpressure • Pressurized thermal shock
SC-A10 [ST-9]	DETERMINE the pipe ultimate capacity under conditions of exposure to high pressure (*e.g., exposure of low pressure piping to primary reactor coolant system pressure for incipient ISLOCA*) on a conservative or realistic basis. *Examples of acceptable methods are those specified in NUREG/CR-5603 and NUREG/CR--5124.*	DETERMINE the pipe ultimate capacity under conditions of exposure to high pressure (*e.g., exposure of low pressure piping to primary reactor coolant system pressure for incipient ISLOCA*) on a conservative or realistic basis. *Examples of acceptable methods are those specified in NUREG/CR-5603 and NUREG/CR--5124.* USE plant-specific or typical pipe configuration and sizes/schedules in the evaluation.	DETERMINE the pipe ultimate capacity under conditions of exposure to high pressure (*e.g., exposure of low pressure piping to primary reactor coolant system pressure for incipient ISLOCA*) on a realistic basis. *Examples of acceptable methods are those specified in NUREG/CR-5603 and NUREG/CR--5124.* USE plant specific pipe parameters in the evaluation.

<u>References</u>

NUREG/CR-5603 Pressure-Dependent Fragilities for Piping Components. Pilot Study on Davis-Besse Nuclear Power Station.
NUREG/CR-5124 Interfacing Systems Loca: Boiling Water Reactors

Table 4.4-3b

SUPPORTING REQUIREMENTS FOR SUCCESS CRITERIA AND OTHER ENGINEERING CALCULATIONSHIGH LEVEL REQUIREMENT B

Degree of Realism: 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. (HLR-SC-B)

<table>
<tr><th>Index No.
SC</th><th>CATEGORY I APPLICATIONS
Bases and supporting analyses for establishing success or failure in dominant accident sequences</th><th>CATEGORY II APPLICATIONS
Realistic bases and supporting analyses for establishing success or failure in risk-significant accident sequences</th><th>CATEGORY III APPLICATIONS
Realistic bases and supporting analyses for establishing success or failure in accident sequences</th></tr>
<tr><td>SC-B1
[3.3.3-3]
[3.3. 3-4]
[3.3.3.3-5]
[TH-4]
[TH-8]</td><td>When defining success criteria, USE thermal/hydraulic, structural, or other analyses/evaluations appropriate to the event being analyzed.
Conservative (e.g., FSAR) generic or plant-specific analyses/evaluations, or expert judgment (supported by relevant observation, test results, vendor recommendations, or plant experience) MAY BE USED.</td><td>When defining success criteria, USE thermal/hydraulic, structural, or other analyses/evaluations appropriate to the event being analyzed.
Examples include:
· engineering calculations;
· computer codes with detailed plant models;
· results of tests with conditions corresponding to the accident sequences;
· results of generic or plant-specific analyses for similar transients where these are shown to be appropriate.

USE an appropriate combination of realistic generic or plant-specific analyses/evaluations, or expert judgment (supported by relevant observation, test results, vendor recommendations, or plant experience).</td><td>When defining success criteria, USE scenario-specific thermal/ hydraulic, structural, or other analyses/evaluations appropriate to the event being analyzed.
Examples include:
· engineering calculations;
· computer codes with detailed plant models;
· results of tests with conditions corresponding to the accident sequences;
· results of analyses for similar transients where these are shown to be appropriate.
USE realistic, plant specific models (e.g., MAAP, RETRAN, etc.) or equivalent for thermal/hydraulic, structural, and other supporting engineering bases in support of success criteria requiring detailed computer modeling.
If necessary, SUPPLEMENT plant-specific models or analysis with FSAR or generic analysis, but only if such supplemental analyses are applicable to the plant.
EVALUATE impact on risk results of use of conservative, bounding, or generic analyses.</td></tr>
<tr><td>SC-B2
[TH-7]</td><td colspan="3">CHECK the reasonableness and acceptability of the results of the thermal/hydraulic, structural, or other supporting engineering bases used to support the success criteria.
Examples of acceptable means to achieve this include:
· COMPARE with results of the same analyses performed for similar plants, accounting for differences in unique plant features;
· COMPARE with results of similar analyses performed with other plant-specific codes;
· CHECK by other means appropriate to the particular analysis.</td></tr>
</table>

Table 4.4-3b
SUPPORTING REQUIREMENTS FOR SUCCESS CRITERIA AND OTHER ENGINEERING CALCULATIONSHIGH LEVEL REQUIREMENT B
Degree of Realism: 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. (HLR-SC-B)

Index No. **SC**	**CATEGORY I APPLICATIONS** Bases and supporting analyses for establishing success or failure in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic bases and supporting analyses for establishing success or failure in risk-significant accident sequences	**CATEGORY III APPLICATIONS** Realistic bases and supporting analyses for establishing success or failure in accident sequences
SC-B3 [TH-7] [3.3.3.3-2] [3.3.3.3-3]	When performing success criteria analyses, CONSIDER AND EXPLAIN the impacts on CDF/LERF of using significantly conservative or optimistic assumptions.	When performing success criteria analyses, EVALUATE the impacts on CDF/LERF of using significantly conservative or optimistic assumptions.	When performing success criteria analyses, QUANTIFY the impacts on CDF/LERF of using significantly conservative or optimistic assumptions.
SC-B4 [3.3.3.3-8]	PROVIDE the rationale for the use of expert judgment as the basis for specific success criteria. In situations where applicable analysis results exist, or situations where analysis tools exist and can reasonably be employed, MINIMIZE the use of expert judgment.		PROVIDE the rationale for the use of expert judgment as the basis for specific success criteria. In situations where applicable analysis results exist, or situations where analysis tools exist and can reasonably be employed, DO NOT USE expert judgment.

Table 4.4-3c

SUPPORTING REQUIREMENTS FOR SUCCESS CRITERIA AND OTHER ENGINEERING CALCULATIONS HIGH LEVEL REQUIREMENT C

Plant Fidelity: The engineering calculations supporting the success criteria and event sequence timing shall be applicable to the features, procedures, and operating philosophy of the plant. (HLR-SC-C)

Index No. **SC**	**CATEGORY I APPLICATIONS** Bases and supporting analyses for success dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic bases and supporting analyses for risk-significant accident sequences	**CATEGORY III APPLICATIONS** Realistic bases and supporting analyses for accident sequences
SC-C1 [TH-5,-6]	CONFIRM that the thermal/hydraulic, structural, and other supporting engineering bases are current with the plant.		
SC-C2 [TH-5,-6]	For generic analysis models and computer codes, *CONSIDER AND EXPLAIN , to the extent necessary to support Category I applications*, the capability of the analysis or code to provide the necessary information and the degree to which the model is representative of the specific plant to which the results are to be applied.	*EVALUATE* the capability of the analysis or code to provide the necessary information and the degree to which the model is representative of the specific plant to which the results are to be applied. A qualitative evaluation associated with application of codes, models, or analyses that have been used for a similar class of plant *(e.g.,Owners' Group generic studies)* MAY BE USED.	For generic analysis models and computer codes, DETERMINE that the analysis or code is capable of providing the necessary information and that the model is representative of the specific plant to which the results are to be applied.

Table 4.4-3d

SUPPORTING REQUIREMENTS FOR SUCCESS CRITERIA AND OTHER ENGINEERING CALCULATIONS HIGH LEVEL REQUIREMENT D

Documentation: The success criteria and supporting engineering analysis shall be documented in a manner that facilitates PRA applications, upgrades, and peer review by describing the processes that were followed with assumptions and bases stated. (HLR-SC-D)

Index No. **SC**	**CATEGORY I APPLICATIONS** Bases and supporting analyses for success dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic bases and supporting analyses for risk-significant accident sequences	**CATEGORY III APPLICATIONS** Realistic bases and supporting analyses for accident sequences
SC-D1 [TH-9,-10]	DOCUMENT important bases, references, and assumptions for success criteria.	DOCUMENT each of the success criteria and the supporting engineering bases, references, and important assumptions for success criteria and the supporting engineering calculations performed in support of the PRA. • IDENTIFY conservative, optimistic, or simplifying assumptions or conditions • PROVIDE specific justification, based on results of evaluation or quantification, as appropriate to the application Category, for use of conservative, optimistic, or simplifying assumptions or conditions. • PROVIDE the basis for the success criteria development process and the supporting engineering calculations.	
SC-D2 [3.3.3.3-9]	DOCUMENT uses of expert judgment	DOCUMENT uses of and rationale for expert judgement.	
SC-D3 [3.3.3.3-10]	DOCUMENT the rationale used in the application of success criteria for situations in the PRA that are known to involve uncertainty or controversy, where treatment of such situations could distort analysis results.	DOCUMENT the rationale and guidance used in the development and application of success criteria for situations in the PRA that are known to involve uncertainty or controversy.	

Table 4.4-3d

SUPPORTING REQUIREMENTS FOR SUCCESS CRITERIA AND OTHER ENGINEERING CALCULATIONS HIGH LEVEL REQUIREMENT D

Documentation: The success criteria and supporting engineering analysis shall be documented in a manner that facilitates PRA applications, upgrades, and peer review by describing the processes that were followed with assumptions and bases stated. (HLR-SC-D)

<table>
<tr><th>Index No.
SC</th><th>CATEGORY I APPLICATIONS
Bases and supporting analyses for success dominant accident sequences</th><th>CATEGORY II APPLICATIONS
Realistic bases and supporting analyses for risk-significant accident sequences</th><th>CATEGORY III APPLICATIONS
Realistic bases and supporting analyses for accident sequences</th></tr>
<tr><td>SC-D4
[4.3.3-1]
[3.3.3.2-17]
[HR-19]</td><td>DOCUMENT the following:
• definition of core damage;
• definition of large early release;
• summary of success criteria used in the PRA.</td><td colspan="2">DOCUMENT the following:
• the definition of core damage used in the PRA including the bases for any selected parameter value used in the definition (e.g., peak cladding temperature or reactor vessel level);
• the definition of large early release used in the PRA including identification of those parameters used as the basis for defining containment failure or bypass;
• calculations (generic and plant-specific) or other references used to establish success criteria, and identification of cases for which they are used;
• identification of computer codes or other methods used to establish plant-specific success criteria;
• a description of the limitations (e.g., potential conservatisms or limitations that could challenge the applicability of computer models in certain cases) of the calculations or codes;
• identification of important assumptions used in establishing success criteria;
• a summary of success criteria for the available mitigating systems and human actions for each accident initiating group modeled in the PRA;
• the basis for establishing the time available for human actions;
• descriptions of processes used to define success criteria for grouped initiating events or accident sequences.</td></tr>
</table>

4.4 Objectives of the Systems Analysis Element

- Qualitative or quantitative analyses are performed for each plant system represented in the initiating event analysis and sequence development in support of initiating events analysis, sequence development, Level 1 and LERF sequence quantification.
- A reasonably complete set of system failure and unavailability modes for each systemic event represented in the initiating event and accident sequence. definition is identified and modeled, including a reasonably complete coverage of different initial system alignments to the extent needed for CDF and LERF determination.
- Intersystem dependencies and intrasystem 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.
- 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.
- System models reflect as-built and as-operated features of the plant.
- System level success criteria, mission times, time windows for operator actions and assumptions that provide the basis for the system logic models are reflected in the model.

4-4 HIGH LEVEL REQUIREMENTS FOR SYSTEMS ANALYSIS (HLR-SY)

A	FIDELITY: The systems analysis shall reflect the as-built as-operated plant. (HLR-SY-A)
B	MODEL COMPLETENESS: 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-SY-B)
C	DEPENDENCIES: The systems analysis shall provide a reasonably complete treatment of common cause failures and intersystem and intra-system dependencies. (HLR-SY-C)
D	DOCUMENTATION: The systems analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed to select, to model, and to quantify the system unavailability. Assumptions and bases shall be stated. (HLR-SY-D)

TABLE 4.4-4a
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT A
FIDELITY: The systems analysis shall reflect the as-built as-operated plant. (HLR-SY-A)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-A1 3.3.4.1	COLLECT pertinent information to ensure that the system model appropriately reflects the as-built and as-operated system. *Examples of such information include:* *System P&IDs, one-line diagrams, instrumentation and control drawings, spatial layout drawings, system operating procedures, abnormal operating procedures, emergency procedures, success criteria calculations, the Final or Updated SAR, technical specifications, training information, system descriptions and related design documents, actual system operating experience, interviews with system engineers and operators.*		
SY-A2 3.3.4.1	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) procedures for the operation of the system during normal and abnormal conditions; (g) system configuration during normal and abnormal conditions.		
SY-A3 3.3.4.1	CONFIRM that the system models correctly reflect the as-built, as-operated plant using plant walkdowns and interviews with system engineers and plant operators.		

TABLE 4.4-4b

SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT B

MODEL COMPLETENESS: 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-SY-B)

<table>
<tr><th>Index No.
SY</th><th>CATEGORY I APPLICATIONS
Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences</th><th>CATEGORY II APPLICATIONS
Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences</th><th>CATEGORY III APPLICATIONS
Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences</th></tr>
<tr><td>SY-B1</td><td colspan="3">DEVELOP system models for those systems needed to provide or support the safety functions contained in the sequence analyses.</td></tr>
<tr><td>SY-B2
3.3.4.2
[SY-19]</td><td colspan="3">DEVELOP detailed systems models, unless sufficient system-level data are available to quantify the system failure probability, and the omission of a model does not mask contributions to the results of support systems or other dependent-failure modes.

A system model MAY BE DEVELOPED in which several failures are combined into super components or modules. In such a "reduced" model, RETAIN the major contributors to system unavailability, and INCLUDE components or support systems shared with other modeled systems.

A single data value MAY BE USED for systems with no modeled equipment or human-action dependencies, if data exist that sufficiently represent the unreliability or unavailability of the system and account for plant-specific factors that could influence unreliability and unavailability.

Examples of systems that have sometimes not been modeled in detail include the scram system, the power-conversion system, instrument air, and the keep-fill systems.

JUSTIFY the use of limited (i.e., reduced or single data value) modeling.</td></tr>
<tr><td>SY-B3</td><td>In the system model, INCLUDE those conditions that prevent the system from meeting the desired system function. CONSIDER the effects of both normal and alternate system alignments, if alternate alignments are allowed or expected per plant procedures.</td><td colspan="2">In the system model, INCLUDE those conditions that prevent the system from meeting the desired system function. INCLUDE the effects of both normal and alternate system alignments, if alternate alignments are allowed or expected per plant procedures.</td></tr>
<tr><td>SY-B4
3.3.4.4</td><td colspan="3">DEFINE the system model boundary, and INCLUDE within the boundary the components required for system operation, support systems interface required for actuation and operation of the system components, and other components whose failures would degrade or fail the system.</td></tr>
</table>

TABLE 4.4-4b
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT B
MODEL COMPLETENESS: 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-SY-B)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-B5 3.3.4.4.2 [SY-6]	IDENTIFY the boundaries of the components required for system operation. These boundaries should match the definitions used to establish the component failure data. *For example, a control circuit for a pump does not have to be included in the system model if the pump failure data used in quantifying the system model includes control circuit failures.* MODEL SEPARATELY portions of a component boundary that are shared by another component or affect another component, in order to account for the dependent failure mechanism.		
SY-B6 [SY-4]	MODEL SEPARATELY all trains of a multi-train system in the fault tree models.		
SY-B7 3.3.4.6.3	If super components or modules are used to simplify system fault trees, PERFORM the modularization process in a manner that avoids grouping events with different recovery potential, events that are required by other systems, or have probabilities that are dependent on the scenario. *Examples of such events include:* · *hardware failures that are not recoverable versus actuation signals which are recoverable* · *HE events that can have different probabilities dependent on the context of different accident sequences* · *events which are mutually exclusive of other events not in the module* · *events which occur in other fault trees (especially common-cause events)* · *SSCs used by other systems*		
SY-B8 3.3.4.3.2	INCORPORATE the effect of variable success criteria into the system modeling. *Example causes of variable system success criteria are:* • *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 accident initiating event category* • *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 non-critical loads are not isolated)* • *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)*		

TABLE 4.4-4b
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT B
MODEL COMPLETENESS: 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-SY-B)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-B9 [SY-6]	PROVIDE detail to the major component level in the fault tree models. Exceptions for some systems may occur when they are dominated by operator actions, specific phenomenological effects, or are represented by a single data value, such as the scram system.		
SY-B10 3.3.4.4.1 SY(7)	IDENTIFY and INCLUDE in the system model the equipment and components whose failure would affect system operability (as identified in the system success criteria). This equipment includes both active components (e.g., pumps, valves, and air compressors) and passive components (e.g., piping, heat exchangers, and tanks) required for system operation. DO NOT INCLUDE component failures that would be beneficial to system operation in a system model unless omission would distort the results. *Example of a beneficial failure: A failure of an instrument in such a fashion as to generate a required actuation signal*		

TABLE 4.4-4b
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT B
MODEL COMPLETENESS: 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-SY-B)

Index No. SY	CATEGORY I APPLICATIONS Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	CATEGORY II APPLICATIONS Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	CATEGORY III APPLICATIONS Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-B11 4.3.4.5.1	INCLUDE failure modes for components that are to be included in the model. *For example:* *(a) active component fails to start;* *(b) active component fails to continue to run;* *(c) failure of a closed component to open;* *(d) failure of a closed component to remain closed;* *(e) failure of an open component to close;* *(f) failure of an open component to remain open;* *(g) active component spurious operation;* *(h) failure of an active component (e.g., battery charger) to operate;* *(i) plugging of an active or passive component* *(j) leakage of an active or passive component;* *(k) rupture of an active or passive component;* *(l) internal leakage of a component* *(m) (m)internal rupture of a component* *(n) electrical short circuit* *(o) electrical open circuit* *(p) electrical short to power* *(q) failure to provide signal/operate (e.g., instrumentation); and* *(r) spurious signal/operation*		

TABLE 4.4-4b
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT B
MODEL COMPLETENESS: 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-SY-B)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-B12 3.3.4.4.1 [SY-8,-15]	Contributors to system unavailability and unreliability (i.e., components and specific failure modes) MAY BE EXCLUDED from the model if one of the following screening criteria is met: (a) A component may be excluded from the system model if the total failure probability of the component failure modes resulting in the same effect on system operation is at least two orders of magnitude lower than the highest failure probability of the other components in the same system train that results in the same effect on system operation. (b) The aggregate failure probability for the failure modes of a given component is less than 1% of the sum of the probabilities for the failure modes of the component that result in the same effect on system operation, or (c) The screened contributors are position faults for components (such as those that occur during or following test and maintenance activities) for which the component receives an automatic signal to place it in its required state and no other position faults exists (e.g., pulled breakers) that would preclude the component from receiving the signal, or (d) It can be shown that the omission of the contributor does not have a significant impact on the results. DO NOT SCREEN components or failure modes using criteria (a) (b), or (c) if they could fail multiple systems or multiple trains of a system. INCLUDE in the model support systems that are required for a component that is screened.		
SY-B13 3.3.4.5.5	INCLUDE human error (HE) events that cause the system or component to be inoperable when demanded in the systems analysis. These events are referred to as pre-initiator human events. (See also *Human Reliability Analysis*)		INCLUDE human error (HE) events that cause the system or component to be inoperable when demanded in the systems analysis. These events are referred to as pre-initiator human events. To avoid double counting, EXCLUDE any pre-initiator human errors from the equipment failure rate. (See also *Human Reliability Analysis*)
SY-B14 3.3.4.5.5	INCLUDE in the system model HE events that are expected during the operation of the system or component or that are accounted for in the final quantification of accident sequences*. These HE events are referred to as post-initiator human actions. (See also *Human Reliability Analysis*) *Except for those already included in the sequence development element.		

TABLE 4.4-4b
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT B
MODEL COMPLETENESS: 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-SY-B)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-B15 3.3.4.4.5	IDENTIFY and 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, or SHOW their exclusion does not to impact the results. *For example, conditions that isolate or trip a system include:* • *system-related parameters such as a high temperature within the system* • *external parameters used to protect the system from other failures (e.g., the high reactor pressure vessel (RPV) water level isolation signal used to prevent water intrusion into the turbines of the RCIC and HPCI pumps of a BWR)* • *adverse environmental conditions.*		
SY-B16 3.3.4.5.3	INCLUDE out of service unavailability for components in the system model, unless screened. MODEL the type of testing and maintenance consistent with the actual practices and history of the plant for removing equipment from service. *Examples of out of service unavailability to be modeled:* • *Train outages during a work window for preventive/corrective maintenance* • *A functional equipment group (FEG) removed from service for preventive/corrective maintenance* • *A relief valve taken out of service to adjust its lift set point*	INCLUDE out of service unavailability for components in the system model, unless screened. MODEL the type of testing and maintenance consistent with the actual practices and history of the plant for removing equipment from service. MODEL unavailability caused by testing when a component or system train is reconfigured from its required accident mitigating position such that the component can not function as required. MODEL maintenance events at the train level when procedures require isolating the entire train for maintenance MODEL maintenance events at a sub-train level (i.e., between tagout boundaries, such as a functional equipment group) when directed by procedures. MODEL component-level maintenance events when specific components only are removed from service *Examples of out of service unavailability to be modeled:* • *Train outages during a work window for preventive/corrective maintenance* • *A functional equipment group (FEG) removed from service for preventive/corrective maintenance* • *A relief valve taken out of service to adjust its lift set point*	

TABLE 4.4-4b
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT B
MODEL COMPLETENESS: 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-SY-B)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-B17 3.3.4.3.1 3.3.4.4.7	EXPLICITLY MODEL system conditions that cause a loss of desired system function by using realistic functional requirements that are supported with engineering analysis. *For example: flow diversion or insufficient inventories of air, water, or power (e.g., battery depletion) to support continued operation of the system for the required mission time that are based on plant-specific or acceptable generic analyses.* If engineering analyses are not available, ASSUME that the equipment/system fails with a probability of 1.0.	EXPLICITLY MODEL system conditions that cause a loss of desired system function by using realistic functional requirements that are supported with engineering analysis. *For example: flow diversion or insufficient inventories of air, water, or power (e.g., battery depletion) to support continued operation of the system for the required mission time that are based on plant-specific or acceptable generic analyses.* If engineering analyses are not available, ASSUME that the equipment/system fails with a probability of 1.0 or JUSTIFY the assumed failure probability.	EXPLICITLY MODEL system conditions that cause a loss of desired system function by using realistic functional requirements that are supported with engineering analysis. *For example: flow diversion or insufficient inventories of air, water, or power (e.g., battery depletion) to support continued operation of the system for the required mission time that are based on plant-specific or acceptable generic analyses.*
SY-B18 3.3.4.4.6 [SY-11]	Credit for system or component operability beyond design basis conditions MAY BE INCLUDED based on an appropriate combination of: · test or operational data · calculations · vendor input · expert judgement JUSTIFY the basis for credit taken.		
SY-B19 3.3.4.6.1 [SY-18]	DEVELOP system model nomenclature in a consistent manner to allow model manipulation and to represent the same designator when a component failure mode is used in multiple systems or trains.		
SY-B20 3.3.4.6.2	Fault tree linking may result in circular logic that must be broken before the model is solved. BREAK circular logic at a location in the linked fault tree such that incorrect cut sets are not generated. Guidance for breaking logic loops is provided in NUREG/CR-2728 (Reference [4.4.4-1]).		
SY-B21 3.3.4.6.2	In the support state approach, ASSIGN support states to properly account for system dependencies on other systems.		

TABLE 4.4-4b
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT B
MODEL COMPLETENESS: 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-SY-B)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-B22 3.3.4.5.2	DO NOT MODEL the repair of hardware faults, unless the probability of repair is justified through an adequate recovery analysis or examination of data.		

References

4.4.4-1 NUREG/CR-2728 Interim Reliability Evaluation Program Procedures Guide, March 3, 1983.

TABLE 4.4-4c
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT C
DEPENDENCIES: The systems analysis shall provide a reasonably complete treatment of common cause failures and intersystem and intra-system dependencies. (HLR-SY-C)

<table>
<tr><th>Index No.
SY</th><th>CATEGORY I APPLICATIONS
Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences</th><th>CATEGORY II APPLICATIONS
Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences</th><th>CATEGORY III APPLICATIONS
Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences</th></tr>
<tr><td>SY-C1
3.3.4.5.4</td><td>MODEL intra-system common-cause failures or SHOW they do not impact the results.</td><td colspan="2">MODEL intra-system common-cause failures.</td></tr>
<tr><td>SY-C2
3.3.4.5.4</td><td>MODEL inter-system common-cause failures (i.e., across systems performing the same function) when supported by generic or plant-specific data or show they do not impact the results.</td><td colspan="2">MODEL inter-system common-cause failures (i.e., across systems performing the same function) when supported by generic or plant-specific data.</td></tr>
<tr><td>SY-C3
3.3.4.5.4</td><td colspan="3">INCLUDE common-cause failures for identical components that provide redundancy. An acceptable method is represented in NUREG/CR-5485 [Reference 4.4.4-2].

Candidates for common-cause failures include, for example:
• motor-operated valves
• pumps
• safety-relief valves
• air-operated valves
• solenoid-operated valves
• check valves
• diesel generators
• batteries
• inverters and battery charger
• circuit breakers</td></tr>
<tr><td>SY-C4
3.3.4.5.4
[DA-10]</td><td colspan="3">ESTABLISH common cause groups by using a logical, systematic process that considers similarity in:
· service conditions
· environment
· design
· maintenance
Justify the basis for the common cause component groups. (See also Data Analysis)</td></tr>
</table>

References

[4.4.4-2] NUREG/CR-5485 Guidelines on Modeling Common-Cause Failures in Probabilistic Risk Assessment, November 20, 1998.

TABLE 4.4-4c
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT C
DEPENDENCIES: The systems analysis shall provide a reasonably complete treatment of common cause failures and intersystem and intra-system dependencies. (HLR-SY-C)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-C5 3.3.4.4.4 [SY-12]	Explicitly ACCOUNT for the modeled system's dependency on support systems in the modeling process unless it is shown that their omission does not impact Category I Applications. This may be accomplished by: • fault tree linking • dependency matrices that are translated into event tree structure, event tree logic rules, or conditional split fraction rules. Support system modeling MAY BE BASED on the use of conservative success criteria and timing if use of such criteria does not impact Category I Applications.	Explicitly ACCOUNT for the modeled system's dependency on support systems in the modeling process unless it is shown that their omission does not impact Category II Applications. This may be accomplished by: • fault tree linking • dependency matrices that are translated into event tree structure, event tree logic rules, or conditional split fraction rules. BASE support system modeling on realistic success criteria and realistic timing unless use of conservative success criteria and timing does not impact Category II Applications.	Explicitly ACCOUNT for the modeled system's dependency on support systems in the modeling process. This may be accomplished by: • fault tree linking • dependency matrices that are translated into event tree structure, event tree logic rules, or conditional split fraction rules BASE support system modeling on realistic success criteria and realistic timing.
SY-C6 3.3.4.4.4	PERFORM engineering analyses of support systems that are plant-specific and reflect the variability in the conditions present during the postulated accidents for which the system is required to function. Bounding or generic engineering analyses MAY BE USED (i.e., tests, operational experience, or calculations) when these analyses do not interfere with realistic quantification of CDF or LERF.		
SY-C7 3.3.4.4.5 [SY-10]	IDENTIFY spatial and environmental hazards that may impact system operation and ACCOUNT FOR them in the system fault tree or the accident sequence evaluation. *For Example: Use results of plant walkdowns as a source of information and resolution of issues in the evaluation of their impacts.*		
SY-C8 3.3.4.4.5 [SY-10]	INCLUDE explicit treatment of containment vent effects (BWRs) and containment failure effects on system operation in the consideration of possible hazards.		

TABLE 4.4-4c
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT C
DEPENDENCIES: The systems analysis shall provide a reasonably complete treatment of common cause failures and intersystem and intra-system dependencies. (HLR-SY-C)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-C9 3.3.4.4.4	When modeling a system, INCLUDE the support systems required for successful operation of the system for a required mission time. *Examples:* • *actuation logic,* • *support systems required for control of components,* • *component motive power,* • *cooling of components* • *any other identified support function (e.g., heat tracing) necessary to meet the success criteria and associated systems.* Exceptions: The treatment of circular logic may require approaches that do not strictly comply with this criteria.		
SY-C10 3.3.4.4.4	INCLUDE support systems required to supply motive power for continuous and successful operation of components in accordance with the success criteria in the system model (e.g., AC power to a motor-driven pump).		
SY-C11 3.3.4.4.3	IDENTIFY those systems that are required for initiation and actuation of a system. INCLUDE the presence of the conditions needed for automatic actuation (e.g., low vessel water level) in the model quantification and ADDRESS permissive and lockout signals that are required to complete actuation logic unless their exclusion would not impact Category I applications.	IDENTIFY and MODEL those systems that are required for initiation and actuation of a system. INCLUDE the presence of the conditions needed for automatic actuation (e.g., low vessel water level) in the model quantification. ADDRESS permissive and lockout signals that are required to complete actuation logic.	
SY-C12 [SY-13]	IDENTIFY the inventories of air, power, and cooling sufficient to support the mission time (or potential deficiencies) and INCLUDE in the model unless justification is provided. Do not allow conservative evaluations to distort the CDF, LERF, or the risk profile.		
SY-C13 3.3.4.4.4	DO NOT USE proceduralized recovery actions as the sole basis for eliminating a support system from the model. However, include these recovery actions in the model quantification.		
SY-C14 3.3.4.4.1	Some systems use components and equipment that are required for operation of other systems. INCLUDE components that may otherwise be screened from a system model when their failure affects more than one system *(e.g., a common suction pipe feeding two separate systems).*		

TABLE 4.4-4c
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT C
DEPENDENCIES: The systems analysis shall provide a reasonably complete treatment of common cause failures and intersystem and intra-system dependencies. (HLR-SY-C)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-C15 3.3.4.4.5 [SY-11]	IDENTIFY SSCs that may be required to operate in conditions beyond their environmental qualifications. INCLUDE dependent failures of multiple SSCs that result from operation in these adverse conditions. *Examples of degraded environments include:* • *LOCA inside containment with failure of containment heat removal,* • *RV Operability (small LOCA, drywell spray, severe accident) (for BWRs)* • *Steamline breaks outside containment* • *Debris that could plug screens/filters (both internal and external to the plant),* • *heating of the water supply (e.g., BWR suppression pool, PWR containment sump) that could affect pump operability* • *Loss of NPSH for pumps* • *Steam binding of pumps*		
SY-C16 3.3.4.5.5	INCLUDE operator interface dependencies across systems or trains, where applicable.		

TABLE 4.4-4d
SUPPORTING REQUIREMENTS FOR SYSTEMS ANALYSIS HIGH LEVEL REQUIREMENT D
DOCUMENTATION: The systems analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed to select, to model, and to quantify the system unavailability. Assumptions and bases shall be stated. (HLR-SY-D)

Index No. SY	**CATEGORY I APPLICATIONS** Modeling of key components and failure modes contributing to the function of systems expected to operate in dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic modeling of major components and failure modes contributing to the reliability and availability of systems expected to operate in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of components and failure modes contributing to the reliability and availability of systems expected to operate in modeled sequences
SY-D1 4.3.4	DOCUMENT the system model used in the PRA system functions and boundary, the associated success criteria, the modeled components and failure modes including human actions, and a description of modeled dependencies including support system and common cause failures. *This documentation typically includes:* *(a) system function and operation under normal and emergency operations* *(b) system model boundary* *(c) system schematic illustrating all equipment and components necessary for system operation* *(d) information and calculations to support equipment operability considerations and assumptions* *(e) actual operational history indicating any past problems in the system operation* *(f) system success criteria and relationship to accident sequence models* *(g) human actions necessary for operation of system* *(h) reference to system-related test and maintenance procedures* *(i) system dependencies and shared component interfaces documented using a dependency matrix or dependency diagram indicating all dependencies for all components among all systems (front-line and support)* *(j) component spatial information* *(k) assumptions or simplifications made in development of the system models* *(l) a list of all components and failure modes included in the model, along with justification for any exclusion of components and failure modes* *(m) description of the modularization process (if used)* *(n) records of resolution of logic loops developed during fault tree linking (if used)* *(o) the results of the system model evaluations* *(p) results of sensitivity studies (if used)* (q) *the sources of the above information, (e.g., completed checklist from walkdowns, notes from discussions with plant staff)*		
SY-D2 4.3.4 [SY-9]	DOCUMENT basic events in the system fault trees so that they are traceable to modules and to cutsets.		
SY-D3 4.3.43	DOCUMENT the nomenclature used in the system models.		

4.4.5 Objectives of the Human Reliability Analysis Element

- HRA modeling addresses the actions that can affect the risk profile for CDF and LERF
- The methodologies for HEP development are consistently applied and described.
- Representations of operator response are realistic considering the postulated system failures.
- A reasonably complete set of operator errors is included to support the intended applications.
- Diagnosis and manipulation errors are addressed for those HEPs in the model.
- Performance shaping factors that may influence the HEP are addressed (e.g., time critical actions, complex actions, adverse environment, location dependencies)
- Errors not explicitly addressed in equipment failure rates (e.g., design errors, construction errors, installation errors) are addressed in the
- Pre-initiator human errors that may impact multiple trains of a system or systems are addressed.
- Important quantitative errors identified for similar plants are identified and addressed.
- Dependencies among operator actions are explicitly treated.
- The output from this element is a set of well defined operating crew errors and associated failure probabilities.
- The documentation clearly describes the methodology, development process, and the resulting HEPs.

Table 4.4-5 HIGH LEVEL REQUIREMENTS FOR HUMAN RELIABILTY ANALYSIS (HLR-HR)

	PRE-INITIATOR HRA
A	SCOPE -The HRA shall address those pre-initiator human activities required to operate the plant in a safe manner. (HLR-HR-A)
B	QUALITATATIVE ASSESSMENT - A systematic process shall be used to identify the human failure events associated with pre-initiator human actions associated with each system modeled in the PRA. (HLR-HR-B)
C	QUANTIFICATION -The evaluation of errors in pre-initiator human actions shall be performed using a well-defined process that recognizes plant-specific nature of the human failure events. (HLR-HR-C)
	POST-INITIATOR HRA
D	SCOPE -The HRA shall address those post-initiator human actions required of plant personnel to operate the plant in a safe manner as a result of an upset condition. (HLR-HR-D)
E	QUALITATIVE ASSESSMENT -A systematic process shall be used to identify the human failure events associated with the post-initiator human actions. (HLR-HR-E)
F	QUANTIFICATION -The quantification of errors associated with the post-initiator human actions shall be performed using a well defined process that recognizes the plant-specific and scenario-specific nature of the human failure events. (HLR-HR-F)
G	DOCUMENTATION -The HRA of the pre- and post-initiator human actions shall be documented in a manner that facilita PRA applications, updates, and peer review by describing the processes that were used, with assumptions and bases stated. (HLR-HR-G)

Table 4.4-5a
SUPPORTING REQUIREMENTS FOR HUMAN RELIABILITY ANALYSIS HIGH LEVEL REQUIREMENT A
SCOPE -The HRA shall address those *pre-initiator* human activities required to operate the plant in a safe manner (HLR-HR-A)

Index No. HR	**CATEGORY I APPLICATIONS** Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs	**CATEGORY II APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences
HR-A1 3.3.6.1 [HR-5]	INCLUDE an assessment of test, maintenance, and calibration activities on each SSC modeled in the PRA that leave the SSC in an unavailable state as a result of a human error in performing these activities.		
HR-A2 3.3.6.2 [HR-4]	INCLUDE in the SSC quantification those pre-initiator human errors with the possibility of adversely impacting the baseline CDF or LERF. CHARACTERIZE the principal methods of disabling a system, train or function due to latent or unrevealed failures caused by human intervention.		
HR-A3 3.3.6.2 [HR-4, HR-5]		IDENTIFY a reasonably complete set of human failure events that result from: ▪ Failure to restore equipment to the desired standby status, ▪ Failure to restore initiation signal or set point for starting or realigning, and ▪ Failure to restore automatic realignment controls and power	IDENTIFY a reasonably complete set of human failure events that result from: ▪ Failure to restore equipment to the desired standby status, ▪ Failure to restore initiation signal or set point for starting or realigning, and ▪ Failure to restore automatic realignment controls and power ADD any failure modes discovered through the review of plant specific or generic operating experience that leave systems unavailable for response in accident sequences.

Table 4.4-5b
SUPPORTING REQUIREMENTS FOR HUMAN RELIABILITY ANALYSIS HIGH LEVEL REQUIREMENT B
QUALITATATIVE ASSESSMENT - A systematic process shall be used to identify the human failure events associated with *pre-initiator* human actions associated with each system modeled in the PRA (HLR-HR-B)

Index No. HR	CATEGORY I APPLICATIONS Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs	CATEGORY II APPLICATIONS Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences	CATEGORY III APPLICATIONS Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences
HR-B1 3.3.6.2 [HR-5]	By review of procedures, operating experience and plant practices, IDENTIFY those activities that lead to equipment realignment and can leave equipment outside its normal operation or standby status. INCLUDE the physical and cognitive requirements involved in performing maintenance testing and calibration activities.		
HR-B2 3.3.6.2			IDENTIFY the important human failure events even though their contribution may be included in the component hardware failure data.
HR-B3 3.3.6.2.2 [HR-6]	Rules MAY be established and used to screen pre-initiator human failure events (HFEs).	ESTABLISH rules to screen pre-initiator human failure events. Pre-initiator human failure events, including dependencies and interfaces between HFEs and the capability of the operator to affect more than one component, train or system, MAY be screened from further consideration if: ▪ Equipment can be successfully re-aligned on system demand, or ▪ A post-maintenance functional test is performed that reveals failures, or ▪ Equipment position is monitored to ensure that the error will be detected and corrected.	ESTABLISH plant specific rules to screen human failure events. Pre-initiator human failure events, including dependencies and interfaces between HFEs and the capability of the operator to affect more than one component, train or system, MAY be screened from further consideration when plant specific operation shows there are no causes of system unavailability and if: ▪ Equipment can be successfully re-aligned on system demand, or ▪ A post-maintenance functional test is performed that reveals failures, or ▪ Equipment position is monitored to ensure that the error will be detected and corrected

Table 4.4-5c
SUPPORTING REQUIREMENTS FOR HUMAN RELIABILITY ANALYSIS HIGH LEVEL REQUIREMENT C
QUANTIFICATION -The evaluation of errors in *pre-initiator* human actions shall be performed using a well defined process that recognizes plant-specific nature of the human failure events (HLR-HR-C)

Index No. HR	**CATEGORY I APPLICATIONS** Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs	**CATEGORY II APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences
HR-C1 3.3.6.2.3	SUPPORT pre-initiator HEPs with reference HEP databases. Acceptable methods include THERP or ASEP. The assessments MAY be supplemented with industry and plant specific data.		
HR-C2 3.3.6.2.3	If a qualitative screening analysis is performed, QUANTIFY the modeled human failure events that survive the pre-initiator screening analysis.		
HR-C3 3.3.6.2.3	Operating experience MAY be used to support quantification of impact that test, maintenance and calibration activities have on overall system unavailability. Screening estimates MAY be included in the quantification of the pre-initiator HEPs	USE best estimates in the quantification of pre-initiator HEPs for dominant system contributors. Screening values MAY be used in the quantification of the pre-initiator HEPs for systems that don't appear in the dominant sequences. For each human error probability assessment, CONSIDER in the evaluation process the following plant-specific relevant information: • The quality of written procedures (for performing tasks) and administrative controls (for independent review) , and • The quality of the human-machine interface.	USE best estimates in the quantification of pre-initiator HEPs for each system. For each human error probability assessment, INCLUDE in the evaluation process the following plant-specific relevant information: • The quality of written procedures (for performing tasks) and administrative controls (for independent review), and • The quality of the human-machine interface, and • Explicit models for instrumentation and control systems.

Table 4.4-5c
SUPPORTING REQUIREMENTS FOR HUMAN RELIABILITY ANALYSIS HIGH LEVEL REQUIREMENT C
QUANTIFICATION -The evaluation of errors in *pre-initiator* human actions shall be performed using a well defined process that recognizes plant-specific nature of the human failure events (HLR-HR-C)

Index No. HR	**CATEGORY I APPLICATIONS** Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs	**CATEGORY II APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences
HR-C4 3.3.6.2.3 [HR-4]	ASSESS the dependency of pre-initiator human actions among multiple systems or trains, including whether the work process itself introduces a mechanism for dependency.		
HR-C5 3.3.6.2.3 [HRA-11]	VERIFY that use of pre-initiator recovery models is consistent with selected HRA methodology.	If pre-initiator error recovery credit is given: - ESTABLISH the maximum credit given when multiple recoveries (total recovery credit) occur for given human actions, and - DEFINE plant specific assumptions about minimum probabilities to be used for the joint probability of multiple HEPs occurring in a given cutset. USE the following information to assess the potential for recovery of pre-initiator errors (e.g., NUREG/CR-4772 [Reference 4.4.5-1]): ▪ post-maintenance or post-calibration tests required and performed by procedure, ▪ independent verification, using a written check-off list, which verify component status following maintenance/testing; ▪ original performer, using a written check-off list, makes a separate check of component status at a later time and place, and ▪ work shift or daily checks of component status, using a written check-off list.	
HR-C6	USE mean values in the quantification of the HEPs.		
HR-C7	CHECK the reasonableness of the final HEPs in light of the plant's history, procedures, operational practices, and experience.		
HR-C8 [HR-5]	USE an explicit and traceable process for deriving pre-initiator human failure probabilities.		

<u>References</u>

[4.4.5-1] NUREG/CR-4772 Accident Sequence Evaluation Program Human Reliability Analysis Procedure, February 28, 1987.

Table 4.4-5d

SUPPORTING REQUIREMENTS FOR HUMAN RELIABILITY ANALYSIS HIGH LEVEL REQUIREMENT D

SCOPE - The HRA shall address those post-initiator human actions required of plant personnel to operate the plant in a safe manner as a result of an upset condition (HLR-HR-D).

Index No. HR	**CATEGORY I APPLICATIONS** Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs	**CATEGORY II APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences
HR-D1 3.3.6.1 3.3.6.3 [HR-9]	ASSESS post-initiator human response actions that are required to prevent or mitigate CDF or LERF as a result of an upset condition in key sequences including those actions required to manually initiate, operate, control , isolate, or terminate systems and components used in preventing or mitigating core damage as defined by the success criteria (e.g., operator manually opens a required valve) Recovery actions performed in recovering a failed function, system or component that is used in the performance of a response action (e. g., recovery of a standby pump) MAY be included.	ASSESS post-initiator human response and recovery actions that prevent or mitigate CDF or LERF as a result of an upset condition, including : - those risk significant actions required to manually initiate, operate, control, isolate, or terminate those systems and components used in preventing or mitigating core damage as defined by the success criteria (e.g., operator manually opens a required valve), and - those actions performed in recovering a failed function, system or component that is used in the performance of a response action in dominant sequences (e. g., recovery of a standby pump).	ASSESS post-initiator human response and recovery actions that prevent or mitigate CDF or LERF as a result of an upset condition in analyzed sequences, including: - those actions required to manually initiate, operate, control, isolate, or terminate those systems and components used in preventing or mitigating core damage as defined by the success criteria (e.g., operator manually opens a required valve) - those actions performed in recovering a failed function, system or component that is used in the performance of a response action (e. g., recovery of a standby pump). CONSIDER modeling local repair actions addressed in plant specific emergency, local, or accident management procedures when time dependent statistical data or plant specific models can be developed.

Table 4.4-5e
SUPPORTING REQUIREMENTS FOR HUMAN RELIABILITY ANALYSIS HIGH LEVEL REQUIREMENT E
QUALITATIVE ASSESSMENT -A systematic process shall be used to identify the human failure events associated with the *post-initiator* human actions (HLE-HE-E).

Index No. HR	**CATEGORY I APPLICATIONS** Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs	**CATEGORY II APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences
HR-E1	ESTABLISH processes for assessment of post-initiator actions.		
HR-E2	For each initiator, IDENTIFY and INCLUDE those human response failures that would adversely impact the CDF and LERF.		
HR-E3 3.3.6.3.1 [HR-13, HR-14, HR-16]	When identifying the human response actions: • DEFINE the response action in the context of the accident scenarios by review of the plant-specific emergency operating procedures, and ▪ VERIFY that the interpretation of the procedures is consistent with plant operational and training practices for response and recovery actions through review from operations or training Simulator observations MAY be used on key scenarios to validate the response models	When identifying and developing the key human response and recovery actions: • DEFINE the response action in the context of the accident scenarios by review of the plant-specific emergency operating procedures, and other relevant procedures (AOPs, etc.), and • REVIEW system operation such that an understanding of how the system(s) functions and the human interfaces with the system is obtained, and • VERIFY that the interpretation of the procedures is consistent with plant operational and training practices by talk throughs or table top discussions with operations or training. Simulator observations MAY be used on key scenarios to validate the response models.	When identifying and developing the key human response, recovery and repair actions: • DEFINE the response and recovery in the context of the accident scenarios by review of the plant-specific emergency operating procedures, AOPs, and SAMGs, and • REVIEW plant specific history for control room and local operations to identify specific error modes and conditions, and • VERIFY that the interpretation of the procedures is consistent with plant operational and training practices by talk throughs or table top discussions with operations and training, and • VALIDATE the response models on key scenarios using simulator observations.
HR-E4 3.3.6.3.1 [HR-11]	Human recovery actions that have the potential to restore the modeled functions, systems, or components MAY be included in the HRA analysis, including: • recovery actions based on plant-specific and scenario-specific information, and • “cues” (e.g., alarms) that alert the operator to the recovery action provided procedure, training, or skill of the craft exist .		
HR-E5 3.3.6.3.1 [HR-19]	When restoration and repair actions are included, SUPPORT them by relevant actuarial data or analysis.		

Table 4.4-5e
SUPPORTING REQUIREMENTS FOR HUMAN RELIABILITY ANALYSIS HIGH LEVEL REQUIREMENT E
QUALITATIVE ASSESSMENT -A systematic process shall be used to identify the human failure events associated with the *post-initiator* human actions (HLE-HE-E).

Index No. HR	**CATEGORY I APPLICATIONS** Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs	**CATEGORY II APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences
HR-E6 3.3.6.3.3 [HR-17, [HR-19]	DEVELOP logic models for post-initiator HEPs that accurately reflect: ▪ Accident sequence specific timing, and ▪ Accident sequence specific procedural guidance (e. g., AOPs, and EOPs), and ▪ Training. These factors support sequence specific HEPs. In the HRA assessment, ACCOUNT for competing effects of multiple actions when multiple failures have occurred	DEVELOP logic models for post-initiator HEPs that accurately reflect: ▪ Accident sequence specific timing, and ▪ Accident sequence specific procedural guidance (e. g., AOPs, and EOPs), and ▪ Training ,and ▪ The availability of cues and other indications for detection and evaluation errors, and ▪ The complexity and sequencing in performing the action when evaluating errors.	DEVELOP logic models for post-initiator HEPs that accurately reflect: ▪ Accident sequence specific timing,and ▪ Accident sequence specific procedural guidance (e. g., AOPs, EOPs, and SAMGs),and ▪ Training including simulator responses, and ▪ The availability of cues and other indications for detection and evaluation errors, and ▪ The complexity and sequencing in performing the action when evaluating errors. These factors support sequence specific HEPs. In the HRA assessment, ACCOUNT for the complexity of competing effects of multiple actions when multiple failures have occurred DETERMINE the best estimate post-initiator HEP according to the modeling process selected.
HR-E7 3.3.6.3.3 [HR-23]	CREDIT operator response actions including recovery only if 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.		

Index No. HR	**CATEGORY I APPLICATIONS** Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs	**CATEGORY II APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences	**CATEGORY III APPLICATIONS** Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences
HR-E8 3.3.6.3.3 [HR-17]	The assessment MAY INCLUDE performance shaping factors formulated for the specific accident sequence and the associated HEP.	For each human error probability, EVALUATE the following plant-specific factors that impact the error probability: • the quality (type (classroom or simulator) and frequency) of the operator training or experience, and • the quality of the written procedures and administrative controls, and • the environment (e.g., lighting, heat, radiation) under which the operator is working, and • the accessibility of the equipment requiring manipulation, and • Time Available (t_a) and Time Required (t_r) • the necessity, adequacy, and availability of special tools, parts, clothing, etc., and • the quality of the human-machine interface including the availability of instrumentation needed to take corrective actions and the control room layout.	For each human error probability, EVALUATE the following plant-specific factors that impact the error probability: • The quality (type (classroom or simulator) and frequency) of the operator training or experience, and • The quality of the written procedures and administrative controls, and • The environment (e.g., lighting, heat, radiation) under which the operator is working, and • The accessibility of the equipment requiring manipulation, and • Time Available (t_a) and Time Required (t_r), and • The necessity, adequacy, and availability of special tools, parts, clothing, etc., and • The quality of the human-machine interface including the availability of instrumentation needed to take corrective actions and the control room layout. ASSESS performance shaping factors formulated for the specific accident sequence and the associated HEP (including stress, complexity, and resource limitations)
HR-E9 3.3.6.3.3 [HR-20]	BASE the time available for actions on engineering analysis, simulations or plant specific event data. BASE the required time on actual time measurements in either walkthroughs or simulator observations. INCLUDE the point in time at which operators receive relevant indications. Observations of simulator exercises relevant to the modeled accident sequences MAY be used to provide additional information regarding control room operational practices and crew performance, if documented.		

Table 4.4-5f

SUPPORTING REQUIREMENTS FOR HUMAN RELIABILITY ANALYSIS HIGH LEVEL REQUIREMENT F

QUANTIFICATION -The quantification of errors associated with the post-initiator human actions shall be performed using a well defined process that recognizes the plant-specific and scenario-specific nature of the human failure events (HLR-HR-F)

Index No. HR	CATEGORY I APPLICATIONS Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs	CATEGORY II APPLICATIONS Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences	CATEGORY III APPLICATIONS Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences
HR-F1 3.3.6.3.3	QUANTIFY post-initiator human failure events in the dominant cutsets or sequences.		
HR-F2 3.3.6.3.3	Feasible response and recovery actions MAY be quantified	QUANTIFY feasible response and recovery actions when they are consistent with the failure modes (e.g., where the equipment to be manipulated is available).	
HR-F3 3.3.6.3.3 [HR-13]	INCLUDE either bounding assessments, (e.g., HEPs=1.0), screening, or best estimate of time dependent HEPs for initiation, control, isolation, and alignment of required prevention and mitigation systems in dominant accident sequences.		INCLUDE best estimate time dependent HEPs for initiation, control, isolation, and alignment of prevention and mitigation systems in accident sequences analyzed in detail, and bounding assessments for HEPs not analyzed in detail.
HR-F4 3.3.6.3.3	Generic quantitative data to support assessments MAY be used	Generic error data with generic simulator data and models to support quantification MAY be used.	Generic error data, plant specific simulator measures to support, and event reviews to support the quantification MAY be used.
HR-F5 3.3.6.3.3 [HR-26]	For multiple human actions in the same sequence or cut set, QUANTIFY the influence of success or failure in previous human actions and system performance on the human event under consideration including: • the time required to complete all actions of the time available to perform the actions, and • factors that could lead to increased failure probability (e.g., common instrumentation, common procedures, increased stress, etc.)		
HR-F6 3.3.6.3.3		TEST for consistency the post-initiator HEP quantifications.	
HR-F7 3.3.6.3.3		REVIEW the human action and their final HEPs relative to each other to check their reasonableness given the plant history, procedures, operational practices and experience: ▪ DEFINE the maximum credit to be given when recoveries from human errors modeled for a post-initiator action (e. g., operator recognizing his error, new plant status information, or a shift technical advisor), and ▪ JUSTIFY error reduction factors (total credit) greater than 10, and ▪ DEFINE the minimum probability to be used for the joint probability of multiple human errors occurring in a given cutset.	
HR-F8 3.3.6.3.3	USE mean values in the quantification of the HEPs.		

Table 4.4-5g

SUPPORTING REQUIREMENTS FOR HUMAN RELIABILITY ANALYSIS HIGH LEVEL REQUIREMENT G

DOCUMENTATION -The HRA of the *pre-* and *post-initiator* human actions shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were used, with assumptions and bases stated (HLR-HR-G).

<table>
<tr><th>Index No. HR</th><th>CATEGORY I APPLICATIONS
Modeling of major human actions (i.e. latent, response and recovery) with screening HEPs</th><th>CATEGORY II APPLICATIONS
Realistic modeling of human actions (i.e., latent, response and recovery) with plant specific HEPs for human actions in risk significant sequences</th><th>CATEGORY III APPLICATIONS
Realistic modeling of human actions (i.e., latent, response and recovery) with plant-specific HEPs in modeled sequences</th></tr>
<tr><td>HR-G1
[HR-1]</td><td>DOCUMENT the following :
• the process used
• the basis for the HRA estimates

MAINTAIN traceability to plant specific or generic analysis

CONSIDER INCLUDING an independent review of the documented HRA results</td><td colspan="2">DOCUMENT the HRA in enough detail to reproduce results and permit reviewers to understand limitations imposed by the models, assumptions, and data, including the following:

▪ HRA methodology and process used to identify pre- and post-initiator HEPs
▪ generic and plant specific assumptions that were made in the HRA, including the bases for the assumptions and their impact on the CDF and LERF results
▪ factors used in the quantification of the human action, how they were derived (their bases), and how they were incorporated into the quantification process
▪ source(s) of data used to quantify human actions, including screening values and best estimates with uncertainties and their bases
▪ the method and treatment of dependencies for post-initiator actions
▪ all pre-and post-initiator human actions evaluated by model, system, initiating event and function, and all HEPs for each post-initiator human action and significant dependency effects

DOCUMENT any independent reviews of the analysis by operations and training departments, or independent outside reviewers.</td></tr>
</table>

4.4.6 Data Analysis

Appendix A describes the top down approach used in this standard to develop the High Level and Supporting Requirements for Data Analysis contained in Table 4.4-6. These requirements were developed to meet the following objectives:

- Data analysis is intended to characterize the current operation of the plant and uses plant specific data where appropriate.
- Data are collected from both generic and plant-specific sources in an organized process and analyzed where needed to quantify the frequencies and probabilities of all events modeled in the PRA to the extent needed to estimate CDF and LERF.
- Event data include number of component failures over time, number of system failures over time, number of common cause events relative to independent failures, and events that are quantified based on the evaluation of experience data.
- Parameter data include measures of component or system train unavailability due to maintenance and repair, data supporting estimates of common cause failure parameters, and other modeling parameters that are developed based on the evaluation of generic and plant specific data bases.
- Plant specific data are collected and analyzed to account for time trends when appropriate.
- Relevant generic industry and plant specific evidence is incorporated into the analysis to the extent needed for plant specific estimates of CDF and LERF.
- The grouping of data is performed among similar equipment with similar operating environments and service conditions.
- The grouping of data does not mask poor performing groups of components.
- The source of the information used to support numerical estimation, including expert opinion assessments where data are unavailable, is documented.
- Appropriate statistical methods are used to apply parameter estimators, test hypotheses regarding the interpretation of data, and to characterize uncertainties in the parameter estimates.
- Bayesian methodology can be used to update estimates when additional data become available.

Table 4.4-6 HIGH LEVEL REQUIREMENTS FOR DATA ANALYSIS (HLR-DA)

A	**Scope:** A systematic process for data collection shall be used to provide a technical basis for estimating the frequencies and probabilities of the various events modeled in the PRA. (HLR-DA-A)
B	**Realism:** 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. (HLR-DA-B)
C	**Parameter Estimation:** The basic events for which a common parameter are to be used shall be selected, grouped, and quantified in a manner that provides model-plant fidelity. The groups shall consist of similar components that operate under similar environmental and service conditions. (HLR-DA-C). Uncertainty intervals shall be addressed for key parameters as needed for each category of application. (HLR-DA-C)
D	**Documentation:** The data analysis shall be documented in a manner that facilitates PRA applications, upgrades, and peer reviews with processes, assumptions and bases stated. (HLR-DA-D)

Table 4.4-6a

SUPPORTING REQUIREMENTS FOR DATA ANALYSIS HIGH LEVEL REQUIREMENT A
Scope: A systematic process for data collection shall be used to provide a technical basis for estimating the frequencies and probabilities of the various events modeled in the PRA. (HLR-DA-A)

Index No. **DA**	**CATEGORY I APPLICATIONS** Quantification of point estimates for basic events and associated parameters with generic data for dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic quantification of mean values for basic events and associated parameters in a manner that accounts for relevant generic and plant-specific data for risk-significant sequences	**CATEGORY III APPLICATIONS** Realistic quantification of risk significant basic events and associated parameters in a manner that quantifies impacts of uncertainties
DA-A1	IDENTIFY components, systems and structures (SSC) for which failure data and parameters are needed to support basic event data.		
DA-A2 [3.3.5.3.3, 3.3.5.5.4]	COLLECT generic data to establish SSC failure rate data, equipment maintenance unavailabilities, common cause failure rates, and other PRA parameters. IDENTIFY plant specific demands, operating time periods, and the frequency of planned outage periods for testing and preventive maintenance. IDENTIFY outage periods needed for corrective maintenance according to HR-D1. DO not mask temporal trends nor exclude specific events nor bias plant-specific or generic data to obtain lower failure rates.	COLLECT generic data and plant specific event data to establish SSC failure rate data, common cause failure parameters, and other PRA parameters on basic events that impact the dominant risk sequences. IDENTIFY plant specific demands, operating time periods, and the frequency of planned outage periods for testing and preventive maintenance. IDENTIFY outage periods needed for corrective maintenance according to HR-D1. DO not mask temporal trends nor exclude specific events nor bias plant-specific or generic data to obtain lower failure rates.	
DA-A3 [DA-5] [3.3.5.3.4]	For collection of failure data, GROUP SCCs according to the characteristics of their usage. For Example: • Size/Type of component • Service condition, • Frequency of demands, • Environmental conditions, • Maintenance practices • Any other appropriate characteristic		

Table 4.4-6a

SUPPORTING REQUIREMENTS FOR DATA ANALYSIS HIGH LEVEL REQUIREMENT A

Scope: A systematic process for data collection shall be used to provide a technical basis for estimating the frequencies and probabilities of the various events modeled in the PRA. (HLR-DA-A)

Index No. **DA**	**CATEGORY I APPLICATIONS** Quantification of point estimates for basic events and associated parameters with generic data for dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic quantification of mean values for basic events and associated parameters in a manner that accounts for relevant generic and plant-specific data for risk-significant sequences	**CATEGORY III APPLICATIONS** Realistic quantification of risk significant basic events and associated parameters in a manner that quantifies impacts of uncertainties
DA-A4 [3.3.5.5]	COLLECT data on maintenance and testing outage times at the component, train, or system level.	COLLECT plant-specific data on maintenance and testing outage times at the component, train, or system level.	

Table 4.4-6b

SUPPORTING REQUIREMENTS FOR DATA ANALYSIS HIGH LEVEL REQUIREMENT B

Realism: 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. (HLR-DA-B)

Index No. **DA**	**CATEGORY I APPLICATIONS** Quantification of point estimates for basic events and associated parameters with generic data for dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic quantification of mean values for basic events and associated parameters in a manner that accounts for relevant generic and plant-specific data for risk-significant sequences	**CATEGORY III APPLICATIONS** Realistic quantification of risk significant basic events and associated parameters in a manner that quantifies impacts of uncertainties
DA-B1 [3.3.5.3.2, 3.3.5.3.4(d), 3.3.5.7, 3.3.5.8]	DEFINE SSC boundaries, failure modes, and success criteria consistent with corresponding definitions in *Systems Analysis* (SY-B5, SY-B11, SY-C1, SY-C2) for failure rates and common cause failure parameters. DEVELOP a rationale for distinguishing between functional failures, incipient failures, and degraded states.		
DA-B2 [3.3.5.1.1, 3.3.5.1.2]	Generic data MAY BE USED.	UPDATE generic data with plant specific data except for components whose importance can be shown to be sufficiently low so as to not impact applications.	
DA-B3 [DA-4] [3.3.5.3.1]	USE an accepted generic data source, such as NUREG/CR-4639 [Reference 4.4.6-1], to estimate component failure probabilities. IDENTIFY the derivation process and/or source of the generic data.		
DA-B4 [3.3.5.1]	USE data appropriate for the event, component, and the plant type being modeled. If appropriate data are not available, USE data from similar events, components, or the plant type. If no data are available, USE estimates based on models of the events. If modeling of events is not feasible, USE expert judgment.		
DA-B5 [3.3.5.3.5]	When screening (censoring) data, DO NOT LOSE important information and thereby bias the estimated parameters. JUSTIFY the rationale for any screened data (e.g., plant design modifications, changes in operating practices).		
DA-B6 [DA-6, DA-7] [3.3.5.5.4]	USE maintenance and testing data that are consistent with plant-specific practices and Maintenance Rule goals. USE the actual time period that the equipment was unavailable for the maintenance duration.		
DA-B7 [DA-8]	USE accepted generic sources for common cause data, such as, NUREG/CR-5497 [Reference 4.4.6-2].		

<u>References</u>

[4.4.6-1] NUREG/CR-4639 Nuclear Computerized Library for Assessing Reactor Reliability, January 31, 1989
[4.4.6-2] NUREG/CR-5497 Common Cause Failure Parameter Estimations, October 31, 1998

Table 4.4-6b
SUPPORTING REQUIREMENTS FOR DATA ANALYSIS HIGH LEVEL REQUIREMENT B
Realism: 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. (HLR-DA-B)

Index No. **DA**	**CATEGORY I APPLICATIONS** Quantification of point estimates for basic events and associated parameters with generic data for dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic quantification of mean values for basic events and associated parameters in a manner that accounts for relevant generic and plant-specific data for risk-significant sequences	**CATEGORY III APPLICATIONS** Realistic quantification of risk significant basic events and associated parameters in a manner that quantifies impacts of uncertainties
DA-B8 [DA-9] [3.3.5.4.1, 3.3.5.4.3]	Generic common cause failure probabilities MAY BE USED.	To the extent possible, USE realistic common cause probabilities consistent with available plant-specific data.	USE realistic common cause failure probabilities consistent with available plant-specific data, supported by plant-specific screening and mapping of common-cause events, as described in NUREG/CR-5485 (Reference 4.4.6-3).
DA-B9 [DA-14] [3.3.5.4]	USE one of the following models for estimating CCF parameters (Reference 4.4.6-3) · Alpha Factor Model · Multiple Greek Letter Model • Basic Parameter Model • Binomial Failure Rate Model JUSTIFY the use of alternative methods.		
DA-B10 [DA-10, DA-13] [new]	ESTABLISH common cause groups by using a logical, systematic process that considers similarity in: · service conditions · environment • design • maintenance JUSTIFY the basis for the common cause component groups. (See SY-C4)		
DA-B11 [new]	IDENTIFY and JUSTIFY assumptions made in modifying or applying common cause models that assume symmetry among the components in the common cause group to groups of asymmetrical components.		
DA-B12 [DA-9] [3.3.5.4.4]	DO NOT USE limited plant-specific common cause data to claim that rare failure modes are impossible.		

References

[4.4.6-3] NUREG/CR-5485 Guidelines on Modeling Common-Cause Failures In Probabilistic Risk Assessment, November 30, 1998

Table 4.4-6c
SUPPORTING REQUIREMENTS FOR DATA ANALYSIS HIGH LEVEL REQUIREMENT C
Parameter Estimation: The basic events for which a common parameter are to be used shall be selected, grouped, and quantified in a manner that provides model-plant fidelity. The groups shall consist of similar components that operate under similar environmental and service conditions. Uncertainty intervals shall be addressed for key parameters as needed for each category of application. (HLR-DA-C)

Index No. **DA**	**CATEGORY I APPLICATIONS** Quantification of point estimates for basic events and associated parameters with generic data for dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic quantification of mean values for basic events and associated parameters in a manner that accounts for relevant generic and plant-specific data for risk-significant sequences	**CATEGORY III APPLICATIONS** Realistic quantification of risk significant basic events and associated parameters in a manner that quantifies impacts of uncertainties
DA-C1 [3.3.5]	ESTIMATE point values of parameters used to determine the frequencies or probabilities of events modeled in the PRA.	ESTIMATE mean values of parameters used to determine the frequencies or probabilities of events modeled in the PRA. Acceptable systematic methods include: Bayesian updating, [Reference 4.4.64], [Reference 4.4.6-5], frequentist method, [Reference 4.4.6-6] or expert judgment	
DA-C2 [DA-4] [3.3.5.1.1, 3.3.5.1.2]	Conservative estimates of parameters MAY BE USED as long as Category I applications are not distorted.	ACCOUNT for relevant sources of generic and plant-specific evidence in the development of realistic parameter estimates for dominant contributors.	ACCOUNT for relevant sources of generic and plant-specific evidence in the development of realistic parameter estimates for basic events. EXAMINE trends in the failure data to support special applications
	Examples of inappropriate application of data sources include: • *Development of failure rates for motor operated valves (MOVs) in systems with very high boron concentration (which leads to fouling of the mechanisms and significantly elevated failure rates) from data bases corresponding to MOVs in systems with clean water; or* ▪ *Development of failure probabilities for small check valves using data from check valves in desiccant air dryer units that must operate many times an hour for data on check values that operate on a monthly basis (This misapplication of data can result in failure probabilities two orders of magnitude lower than for check valves in other systems that operate perhaps once a month).*		
DA-C3 [3.3.5.1.4]	VERIFY the reasonableness of each parameter assessment	When updating generic data using any method: • COMPARE the derived parameter value to that obtained from generic data. • USE appropriate hypothesis tests to ensure that data from grouped components are from compatible populations (Reference [4.4.6-6], [4.4.6-4], [4.4.6-7], and [4.4.6-8].	
DA-C4 [3.3.5.1.3]	CONSIDER USING plant specific data to support the parameter assessments	When the Bayesian approach is used in developing the prior distribution, ACCOUNT for relevant generic data and plant-to-plant variability. INCLUDE in the plant-specific data all relevant and recent operating experience.	

Table 4.4-6c

SUPPORTING REQUIREMENTS FOR DATA ANALYSIS HIGH LEVEL REQUIREMENT C

Parameter Estimation: The basic events for which a common parameter are to be used shall be selected, grouped, and quantified in a manner that provides model-plant fidelity. The groups shall consist of similar components that operate under similar environmental and service conditions. Uncertainty intervals shall be addressed for key parameters as needed for each category of application. (HLR-DA-C)

Index No. **DA**	**CATEGORY I APPLICATIONS** Quantification of point estimates for basic events and associated parameters with generic data for dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic quantification of mean values for basic events and associated parameters in a manner that accounts for relevant generic and plant-specific data for risk-significant sequences	**CATEGORY III APPLICATIONS** Realistic quantification of risk significant basic events and associated parameters in a manner that quantifies impacts of uncertainties
DA-C5	CONSIDER UPDATING parameter assessments as needed.	When the Bayesian approach is used to derive a distribution and mean value of a parameter, PERFORM the following tests to ensure that the updating is accomplished correctly and that the generic data is consistent with the plant-specific application: • VERIFY that the Bayesian updating does not produce a posterior distribution with a single bin histogram; • IDENTIFY inconsistencies between the prior distribution and the plant-specific evidence; • VERIFY that the Bayesian updating algorithm provides valid results over the range of values being considered; • VERIFY the reasonableness of the posterior distribution mean value.	
DA-C6 [3.3.5.1]	VERIFY that uncertainties are addressed in assessing of point values for data parameters.	VERIFY that uncertainties are addressed in estimating the mean values of the data parameters to allow the *estimation* of the mean values of CDF and LERF.	VERIFY that the impacts of uncertainties in data parameters are quantified to allow the *calculation* of uncertainty intervals for values of CDF and LERF.
DA-C7 [DA-15] [3.3.5.6.1, 3.3.5.6.3]	CONSIDER BASING AC power non-recovery probabilities on available and applicable data that is traceable to its source. Lacking strong site-specific data, CONSIDER USING generic data for recovery of loss of off-site power. JUSTIFY application of alternative data.	BASE AC power non-recovery probabilities on available and applicable data that is traceable to its source. Lacking strong site-specific data, USE generic data for recovery of loss of off-site power.	

Table 4.4-6d

SUPPORTING REQUIREMENTS FOR DATA ANALYSIS HIGH LEVEL REQUIREMENT D
Documentation: The data analysis shall be documented in a manner that facilitates PRA applications, upgrades, and peer reviews with processes, assumptions and bases stated. (HLR-DA-D)

Index No. **DA**	**CATEGORY I APPLICATIONS** Quantification of point estimates for basic events and associated parameters with generic data for dominant accident sequences	**CATEGORY II APPLICATIONS** Realistic quantification of mean values for basic events and associated parameters in a manner that accounts for relevant generic and plant-specific data for risk-significant sequences	**CATEGORY III APPLICATIONS** Realistic quantification of risk significant basic events and associated parameters in a manner that quantifies impacts of uncertainties
DA-D1 [DA-17, DA-19, DA-20] [3.3.5.1.2, 4.3.5]	DOCUMENT the following: (a) the plant-specific sources of data (component failures, demands, operating time periods, and frequency and outage periods for maintenance and testing) ; (b) sources for generic data (component failures, demands, operating time periods, and frequency and outage periods for maintenance and testing); (c) system and component boundaries used to establish component failure probabilities; (d) models used to estimate data parameters (e.g., fault trees used to estimate an initiating event frequency); (e) the time periods from which plant-specific data were gathered; (f) key assumptions made in the data analysis; (g) justification for exclusion of any data; (h) the rationale for any distributions used as priors for Bayesian updates, where applicable; (i) the distribution parameters for each modeled component failure mode, including common cause failures, where applicable; (j) the distribution parameters for component out of service events, where applicable; and (k) the basis for common cause screening, grouping, generic and plant-specific data.		

4.4.7 Objectives of the Internal Flooding Element

- A reasonable evaluation of the sources of potential flooding, the propagation pathways, and the targets susceptible to flooding is performed for buildings and critical equipment locations.
- The frequency of potential flood initiators is based on data, evaluation of maintenance practices, or pipe and component rupture frequencies.
- Failure of equipment by submergence, jet impingement, spray, pipe whip, humidity, condensation, and temperature concerns is addressed.
- The process for screening internal flood initiating events does not eliminate potential significant accident sequences.
- Flooding rates have reasonable technical bases.
- The spectrum of flooding rates is addressed (e.g., high frequency/low flooding rates and low frequency/high flooding rates).
- Significant operator actions in response to internal flood events include performance shaping factors reflecting the time constraints, stress, available indications, accessibility, and adverse environmental conditions.
- The internal flooding accident sequence modeling addresses the accident scenarios that can affect the risk profile for CDF and LERF.
- The internal flooding accident sequences address all critical safety functions of affected equipment for the modeled internal flood initiators.
- Accident sequence end states are clearly defined as leading to core damage or to a safe stable state.
- There is fidelity with the as-built as-operated plant.
- Unique plant features are addressed.
- The output from this element is a set of well defined internal flooding accident scenarios that lead to core damage.

TABLE 4.4-7 HIGH LEVEL REQUIREMENTS FOR INTERNAL FLOODING (HLR-IF)

A	AREAS AND SSCs: Different flood areas of the plant and the SSCs located within the areas shall be identified. (HLR-IF-A)
B	SOURCES AND MECHANISMS: The potential flood sources in the plant and their associated flooding mechanisms shall be identified. (HLR-IF-B)
C	SCENARIOS: The potential flooding scenarios shall be developed for each flood source by identifying the propagation path(s) of the water and the affected SSCs. (HLR-IF-C)
D	INITIATING EVENTS: Flooding-induced initiating events and their frequencies shall be identified and estimated. (HLR-IF-D)
E	QUANTIFICATION: Flood-induced accidents sequences shall be quantified. (HLR-IF-E)
F	DOCUMENTATION: The internal flooding analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed, with assumptions and bases stated. (HLR-IF-F)

TABLE 4.4-7a
SUPPORTING REQUIREMENTS FOR INTERNAL FLOODING HIGH LEVEL REQUIREMENT A
AREAS AND SSCs: Different flood areas of the plant and the SSCs located within the areas shall be identified. (HLR-IF-A)

Index No. IF	**CATEGORY I APPLICATIONS** Modeling of dominant flood sequences	**CATEGORY II APPLICATIONS** Realistic modeling of risk significant flood contributors	**CATEGORY III APPLICATIONS** Realistic and thorough modeling of flooding contributors
IF-A1 **3.3.7.2**	DEFINE flood areas by dividing the plant into physically separate areas where a flood area is a "single room" or combination of adjacent connected rooms generally on the same elevation. DEFINE flood areas by using: • the presence of physical barriers (e.g., walls, floors, dikes), • mitigation features (e.g., sumps, drains), and • propagation pathways (e.g., open hatches or doors),		
IF-A2	IDENTIFY the SSCs located in each flood area including their spatial location in the area and any flooding mitigative features (e.g., shielding) INCLUDE SSCs modeled in the PRA as part of the success criteria and SSCs that can challenge normal plant operation requiring successful mitigation to prevent core damage		
IF-A3 **3.3.7.1-1**	USE plant information sources to support development of flood areas and to identify the SSCs located within each flood area.		
IF-A4 **3.3.7.1-2**	CONDUCT a plant walkdown to verify the accuracy of information obtained from plant information sources and to OBTAIN or VERIFY: • spatial information needed for the development of flood areas, and • the SSCs located within each flood area.		

TABLE 4.4-7b
SUPPORTING REQUIREMENTS FOR INTERNAL FLOODING HIGH LEVEL REQUIREMENT B
SOURCES AND MECHANISMS: The potential flood sources in the plant and their associated flooding mechanisms shall be identified. (HLR-IF-B)

Index No.	CATEGORY I APPLICATIONS Modeling of dominant flood sequences	CATEGORY II APPLICATIONS Realistic modeling of risk significant flood contributors	CATEGORY III APPLICATIONS Realistic and thorough modeling of flooding contributors
IF-B1 **3.3.7.3-1**	For each flood area, IDENTIFY the potential sources of flooding water which include: • equipment (e.g., piping, valves, pumps) from fluid systems in the area (e.g., circulating water system, service water system, component cooling water system, feedwater system, and reactor coolant system), • plant internal sources of water (e.g., tanks or pools) located in the area, and • plant external sources of water (e.g., reservoirs or rivers) that are connected to the area through some system or structure.		
IF-B2 **3.3.7.3-2**	For each potential source of flooding water, IDENTIFY the flooding mechanisms that would result in the release of water. INCLUDE: • failure modes of components such as pipes, tanks, gaskets, expansion joints, fittings, seals, etc.; • human-induced mechanisms that could lead to overfilling tanks, diversion of flow through openings created to perform maintenance; inadvertent actuation of fire suppression system; and • other events releasing water into the area.		
IF-B3 **3.3.7.3-3**	For each source and its identified failure mechanism, IDENTIFY the type of water release and capacity INCLUDE: • breach (e.g., leak, rupture, spray), • flow rate of water, • capacity (e.g., gallons of water source), and • a characterization of the water out of the breach (e.g., a five foot cone-shaped spray discharging to the northeast).		
IF-B4 **3.3.7.3-1**	In each flood area, IDENTIFY any floor drains (i.e., any physical structure that can function as a drain) or sumps (i.e., any physical structure that allows for the accumulation and retention of water). IDENTIFY or DETERMINE the capacity of the drains and the amount of water retained by the sumps. If these are larger than a flood source in the area and the flood source cannot cause additional equipment damage or failure (see IF-C1), then the flood source MAY BE ELIMINATED as a flood source.		

TABLE 4.4-7c
SUPPORTING REQUIREMENTS FOR INTERNAL FLOODING HIGH LEVEL REQUIREMENT C
SCENARIOS: The potential flooding scenarios shall be developed for each flood source by identifying the propagation path(s) of the water and the affected SSCs. (HLR-IF-C)

Index No. **IF**	**CATEGORY I APPLICATIONS** Modeling of dominant flood sequences	**CATEGORY II APPLICATIONS** Realistic modeling of risk significant flood contributors	**CATEGORY III APPLICATIONS** Realistic and thorough modeling of flooding contributors
IF-C1 **3.3.7.4-1** **3.3.7.4-3**	For each flood source, IDENTIFY the propagation path from the flood source area to its accumulation point INCLUDE: • the normal flow path from one area to another via drain lines, • areas connected via back flow through drain lines involving failed check valves • pipe and cable penetrations (including cable trays), • doors, • stairwells, • hatchways, • the structural failure of doors or walls, and • HVAC ducts. INCLUDE potential for structural failure due to flooding loads.		
IF-C2 **3.3.7.4-4**	IDENTIFY plant design features or operator actions that have the ability to terminate the flood propagation. INCLUDE the availability of flood dikes, curbs, drains, sump pumps, spray shields, water tight doors, and operator actions. JUSTIFY any credit given, particularly any credit given for non-flood proof doors or barriers and credit for isolation of a flood source including the method of detection, accessibility to the isolation device, and time available to perform actions.		
IF-C3 **3.3.7.5**	IDENTIFY the susceptibility of each SSC in a flood area to flood-induced failure mechanisms. INCLUDE failure by submergence, jet impingement, spray, pipe whip, humidity, condensation, temperature concerns, and any other identified failure modes in the identification process. JUSTIFY exclusion of any SSC's susceptibility to a flood-induced environment based on appropriate documented criteria such as test or experimental data, equipment qualification data, or other analyses. If susceptibility information cannot be ascertained, ASSUME the equipment will fail in the presence of the associated flood-induced environment.		
IF-C4 **3.3.7.4-1**	DEVELOP flood scenarios by examining potential propagation paths, giving credit for appropriate flood mitigation systems or operator actions, and identifying susceptible SSCs. VERIFY any information used from documents during plant walkdown.		

TABLE 4.4-7c
SUPPORTING REQUIREMENTS FOR INTERNAL FLOODING HIGH LEVEL REQUIREMENT C
SCENARIOS: The potential flooding scenarios shall be developed for each flood source by identifying the propagation path(s) of the water and the affected SSCs. (HLR-IF-C)

<table>
<tr><th>Index No.
IF</th><th>CATEGORY I APPLICATIONS
Modeling of dominant flood sequences</th><th>CATEGORY II APPLICATIONS
Realistic modeling of risk significant flood contributors</th><th>CATEGORY III APPLICATIONS
Realistic and thorough modeling of flooding contributors</th></tr>
<tr><td>IF-C5
3.3.7.7-1</td><td colspan="3">CONSIDER SCREENING flood scenarios using one or more of the following:
• an area (including adjacent zones where flood sources can propagate) with no mitigating equipment modeled in the PRA, or does not cause an initiating event, including a manual scram,
• an area with no significant flood sources (i.e., an area whose flood sources have volumes insufficient to cause significant impacts--cause failure of equipment) that is not in the propagation path from another source,
• an area with mitigation systems (e.g., drains or sump pumps) capable of preventing unacceptable flood levels and other flooding effects are expected to be insignificant.
JUSTIFY any other qualitative screening criteria.</td></tr>
<tr><td>IF-C6
3.3.7.7-1
(3rd bullet)</td><td>CONSIDER SCREENING flood scenarios using human mitigative actions if all the following can be shown:
• an area that has small or modest flood sources that is not in a propagation path from small or modest sources
• the time to the damage of safe shutdown equipment is greater than 2 hours for the worst flooding initiator
• flood indication is available in the control room, and
• the flood sources in the area can be isolated.</td><td>CONSIDER SCREENING flood scenarios using human mitigative actions if all the following can be shown:
• an area that has small or modest flood sources that is not in a propagation path from small or modest sources
• the mitigate action can be performed with high reliability for the worst flooding initiator
• flood indication is available in the control room, and
• the flood sources in the area can be isolated.</td><td>DO NOT SCREEN flood scenarios that rely on operator action to prevent challenges to normal plant operations.</td></tr>
</table>

TABLE 4.4-7d
SUPPORTING REQUIREMENTS FOR INTERNAL FLOODING HIGH LEVEL REQUIREMENT D
INITIATING EVENTS: Flooding-induced initiating events and their frequencies shall be identified and estimated. (HLR-IF-D)

Index No. IF	**CATEGORY I APPLICATIONS** Modeling of dominant flood sequences	**CATEGORY II APPLICATIONS** Realistic modeling of risk significant flood contributors	**CATEGORY III APPLICATIONS** Realistic and thorough modeling of flooding contributors
IF-D1 [IE-7]	USE a structured, systematic process to identifying those flood scenarios that challenge normal plant operation and that require successful mitigation to prevent core damage. INCLUDE the potential for a flooding induced transient or LOCA.		
IF-D2 [IE-10]	In searching for flood-induced initiating events, REVIEW the impact of plant-specific initiating event precursors and system alignments, INCLUDING alignments of supporting systems.		
IF-D3 [IE-4]	Flooding induced initiating events MAY BE GROUPED: • Events can be considered similar in terms of plant response, success criteria, and timing, *OR* • Events can be subsumed into a group and bounded by the worst case impacts within the "new" group. DO NOT INTRODUCE excessive conservatism within the grouping process which would impact Category I applications.	Flooding induced initiating events MAY BE GROUPED: • Events can be considered similar in terms of plant response, success criteria, and timing, *OR* • Events can be subsumed into a group and bounded by the worst case impacts within the "new" group. DO NOT INTRODUCE excessive conservatism within the grouping process which would impact Category II applications.	Flooding induced initiating events MAY BE GROUPED when: • Events can be considered similar in terms of plant response, success criteria, and timing, *OR* • Events can be subsumed into a group and bounded by the worst case impacts within the "new" group. DO NOT INTRODUCE excessive conservatism within the grouping process which would impact Category III applications.
IF-D4 [IE-6]	For multi-unit sites with shared systems, PERFORM a qualitative evaluation to ensure that the relative risk significance of modeled SSCs is not distorted if dual unit internal flood initiators are excluded from the analysis. If the qualitative evaluation cannot show that the relative risk significance of modeled SSCs is not distorted, then INCLUDE dual unit initiators.	For multi-unit sites with shared systems, TREAT and QUANTIFY dual unit internal flood initiators explicitly.	

TABLE 4.4-7d
SUPPORTING REQUIREMENTS FOR INTERNAL FLOODING HIGH LEVEL REQUIREMENT D
INITIATING EVENTS: Flooding-induced initiating events and their frequencies shall be identified and estimated. (HLR-IF-D)

Index No. IF	**CATEGORY I APPLICATIONS** Modeling of dominant flood sequences	**CATEGORY II APPLICATIONS** Realistic modeling of risk significant flood contributors	**CATEGORY III APPLICATIONS** Realistic and thorough modeling of flooding contributors
IF-D5 **3.3.7.6-1**	DETERMINE the flood initiating event frequency by using the HLR-DA-A supporting requirements and one or more of the following: • an assessment of applicable generic operating experience of internal flooding, • an evaluation of pipe, component, and tank rupture failure rates from generic data sources, • a probabilistic fracture mechanics evaluation of the probability of pipe leaks or ruptures representative of plant-specific conditions, • a combination of operating experience and generic pipe and component failure rates, or • a combination of one of the above approaches with expert judgment.	DETERMINE the flood initiating event frequency by using the HLR-DA-A supporting requirements and one or more of the following: • an assessment of generic and plant-specific operating experience of internal flooding, • an evaluation of pipe, component, and tank rupture failure rates from generic data sources enhanced by any plant-specific information, • a probabilistic fracture mechanics evaluation of the probability of pipe leaks or ruptures using plant-specific information, • a combination of operating experience and generic pipe and component failure rates, or • a combination of one of the above approaches with expert judgment.	

TABLE 4.4-7e
SUPPORTING REQUIREMENTS FOR INTERNAL FLOODING HIGH LEVEL REQUIREMENT E
QUANTIFICATION: Flood-induced accidents sequences shall be quantified. (HLR-IF-E)

Index No. IF	**CATEGORY I APPLICATIONS** Modeling of dominant flood sequences	**CATEGORY II APPLICATIONS** Realistic modeling of risk significant flood contributors	**CATEGORY III APPLICATIONS** Realistic and thorough modeling of flooding contributors
IF-E1 **3.3.6.7-3**	REVIEW the accident sequence results obtained by following the requirements described in *Accident Sequence Analysis* and MODIFY as necessary to account for any flood-induced phenomena.		
IF-E2	PERFORM any necessary engineering calculations for flood rate, time to reach vulnerable equipment, and the structural capacity of SSCs according to the requirements described in *Success Criteria*.		
IF-E3 **3.3.6.7-3**	MODIFY the systems analysis results obtained by following the requirements described in 4.4.4 to include flood-induced failures identified by HLR IF-C.		
IF-E4	PERFORM any additional data analysis to the requirements described in *Systems Analysis*.		
IF-E5 **3.3.6.7-4** **3.3.6.7-5**	PERFORM any human reliability analysis to the requirements described in *Human Reliability Analysis*, and INCLUDE the following scenario specific PSFs for control room and ex-control room actions as appropriate: • additional workload and stress (above that for similar sequences not caused by internal floods) • uncertainties in event progression (e.g., cue availability and timing concerns caused by flood) • effect of flood on mitigation, required response, and recovery activities (e.g., accessibility restrictions, possibility of physical harm) • flooding-specific job aids and training (e.g., procedures, training exercises) JUSTIFY the use of extraordinary recovery actions that are not proceduralized.		
IF-E6 **3.3.6.7-6**	PERFORM internal flood sequence quantification in accordance with the requirements described in *Quantification*, including any quantitative screening. INCLUDE the combined effects of failures caused by flooding and those coincident with the flooding due to independent causes including equipment failures, unavailability due to maintenance, and other credible causes. INCLUDE both the direct effects of the flood (e.g., loss of cooling from a service water train due to an associated pipe rupture) and indirect effects such as submergence, jet impingement, and pipe whip.		
IF-E7 **3.3.6.7-3**	REVIEW the Level 2/LERF results obtained by following the requirements described in *Level 2 Analysis* and MODIFY as necessary to account for any flood-induced phenomena.		

TABLE 4.4-7f
SUPPORTING REQUIREMENTS FOR INTERNAL FLOODING HIGH LEVEL REQUIREMENT F
DOCUMENTATION: The internal flooding analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review by describing the processes that were followed, with assumptions and bases stated. (HLR-IF-F)

Index No. IF	**CATEGORY I APPLICATIONS** Modeling of dominant flood sequences	**CATEGORY II APPLICATIONS** Realistic modeling of risk significant flood contributors	**CATEGORY III APPLICATIONS** Realistic and thorough modeling of flooding contributors
IF-F1 **4.3.7**	DOCUMENT the process used to identify flood sources, flood zones, flood pathways, flood scenarios, and their screening, and internal flood model development and quantification.		
IF-F2 **4.3.7**	In addition to the information documented in IF-F1, DOCUMENT the following: • flood sources identified in the analysis, any rules used to screen out these sources, and the resulting list of sources to be further examined; • flood zones used in the analysis and the reason for eliminating any of these areas from further analysis; • propagation pathways between flood zones and any assumptions, calculations, or other bases for eliminating or justifying any of these propagation pathways; • accident mitigating features and barriers credited in the analysis, the extent to which they were credited, and associated justification; • component fragilities and any associated assumptions or calculations used in the determination of the impacts of submergence, spray, temperature, or other flood-induced effects on equipment operability; • screening criteria used in the analysis; • flooding scenarios considered, screened, and the remaining scenarios as well as how the internal event analysis models were modified to model these remaining scenarios for the internal flooding analysis; • flood frequencies, component unreliabilities/unavailabilities, and HE probabilities used in the analysis (i.e., the data values unique to the flooding analysis); • any calculations or other analyses used to support or refine the flooding evaluation; and • results of the internal flooding analysis including results from each accident sequence, results from the combined accident sequence model (i.e., the total plant model), results from sensitivity and uncertainty analyses, and results from importance measure calculations.		

4.4.8 Objectives of the Quantification Element

- A realistic estimate of the core damage frequency that captures plant specific and unique factors important to risk is developed.
- A clear understanding of the principal contributors to CDF is developed. These include accident sequences, accident classes, accident sequence end states, and importance of operator actions, systems, components, and basic events in the PRA.
- Accepted methods and computer programs are used for the quantification (e.g., use of approximate solutions for probability models, use of justified truncation values, treatment of success in accident sequence logic).
- A quantitative analysis of uncertainties, or an assessment of sensitivities in the CDF to data and modeling uncertainties, is provided.
- PRA updates account for significant changes in CDF due to changes in plant design, procedure, equipment performance, modeling assumptions, and other changes in the models and database.
- Significant dependencies are accounted for, including functional, phenomenological, human, common cause, success logic, logic loops, state of knowledge, and other dependencies that could influence the estimation of CDF.
- A clear interface with the Level 2/LERF PRA models and quantification process is provided to support the quantification of LERF for each sequence involving core damage. This interface includes a clear definition of plant damage states which define important conditions of the plant at the time of core damage, and pass-through of important dependencies between events in the Level 1 and Level 2 accident sequence and sequence quantification models, at least to the extent needed to trace key contributors to LERF through the integrated Level 1 to LERF PRA models.

TABLE 4.4-8 HIGH LEVEL REQUIREMENTS FOR QUANTIFICATION (HLRs-QU)

A	**SCOPE**: The Level 1 Quantification Methodology shall quantify core damage frequency in a way that captures plant specific and unique factors important to risk. (HLR-QU-A)
B	**COMPLETENESS IN DETAIL**: The Level 1 Quantification Methodology shall be traceable and shall describe the relationship of the PRA technical elements to the quantification process (including the model assumptions). (HLR-QU-C)
C	**COMPLETENESS IN DETAIL**: The Level 1 Quantification Methodology shall be traceable and shall describe the relationship of the PRA technical elements to the quantification process (including the model assumptions). (HLR-QU-C)
D	**REALISM AND TREATMENT OF DEPENDENCIES**: The Level 1 Quantification Uncertainty Analysis shall address uncertainties and sensitivities in the quantification of CDF in a manner that is sufficient to support intended applications. (HLR-QU-D)
E	**MODEL PLANT FIDELITY**: The Level 1 Quantification Interface shall provide traceability with the LERF PRA analysis that is sufficient to identify the important contributors to LERF. (HLR-QU-E)
F	**DOCUMENTATION**: The Level 1 Quantification Documentation shall be performed in a manner that facilitates PRA applications, updates, and peer review, with assumptions and bases stated. (HLR-QU-F)

TABLE 4.4-8a
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT A
SCOPE: The Level 1 Quantification Methodology shall quantify core damage frequency in a way that captures plant specific and unique factors important to risk. (HLR-QU-A)

Index No. QU	**CATEGORY I APPLICATIONS** Quantification of CDF contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-A1 3.3.8.1	ESTIMATE the CDF for each of the accident sequences resulting in the onset of core damage that are not truncated. ASSESS the physical logic of each sequence. ESTIMATE the overall CDF from internal events, the CDF for each accident sequence modeled, and the importance of each major contributor included in the model. The estimates MAY be accomplished by using either fault tree linking or event trees with conditional split fractions.		
QU-A2 3.3.8.1 3.3.8.1.1	System model dependencies MAY be treated through either the process of fault tree linking or event trees with conditional split fractions. ACCOUNT FOR sequence-specific impacts or requirements for system operation. Examples: · conditions that would lead to an automatic actuation signal are present in one sequence but not in another · long-term support system operation is required in one sequence, while short-term operation is required in another · feedback of accident phenomenon on system operation is sequence dependent		
QU-A3 [QU-4]	DO NOT TRUNCATE cutsets based on the order of the cutset.		
QU-A4 [QU-4] 3.3.8.1.2	The rare event approximation MAY be used when event probabilities are below 0.1. When event probabilities are above 0.1, USE the minimal cutset upper bound or an exact solution. When conditional core damage probabilities greater than 0.5 are obtained for an accident, USE an exact solution. ACCOUNT FOR situations for which the rare event approximation does not apply.		
QU-A5 [QU-4] 3.3.8.1.2	If using an event tree with conditional split fractions, the same truncation limit used in evaluating system failures MAY be used in the complementary success branches.		If using an event tree with conditional split fraction approach, USE the same truncation limit used in evaluating system failures in the complementary success branches.
QU-A6 [QU-4] 3.3.8.1.2	DO NOT USE independent modules to increase the truncation limit. When modules or independent subtrees are used to reduce the model size and facilitate the quantification, USE the same truncation level or a lower value in solving the modules as is used in the accident sequence quantification.		
QU-A7 [QU-14]	The methods of eliminating circular logic may result in incorrect quantitative results, (e.g., non-conservative). JUSTIFY the cutting of circular logic in the model and DO NOT INTRODUCE significant conservatisms or non-conservatisms in the model.		
QU-A8 [QU-21] [QU-23] 3.3.8.1.2	TRUNCATE accident sequences at a sufficiently low cutoff value that significant dependencies are not eliminated. JUSTIFY truncation of entire groups of sequences (e.g., ATWS, LOOP). Accident sequences may have been eliminated from the quantified model <u>before</u> the truncation test is applied. DO NOT eliminate certain sequences (e.g., LOCA and failure to scram, or breaks outside containment) using the GL 88-20 type screening (or equivalent) without considering the impact on CDF and LERF.		

TABLE 4.4-8a
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT A
SCOPE: The Level 1 Quantification Methodology shall quantify core damage frequency in a way that captures plant specific and unique factors important to risk. (HLR-QU-A)

Index No. QU	**CATEGORY I APPLICATIONS** Quantification of CDF contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-A9 3.3.8.1.2		TRUNCATE accident sequences at a sufficiently low cutoff value so that importance calculations are understood and consistent with system design and dependencies. For example, components in series for a train of equipment normally produce the same RAW value.	
QU-A10 [QU-22,QU-24] 3.3.8.1.2	Accident sequences and cutsets MAY be eliminated based on low frequency of occurrence (i.e., truncation). If used, then CONSIDER truncation effects both before and after recovery actions are applied in order to avoid discarding important cutsets and sequences. ESTABLISH the final truncation limits by an iterative process of demonstrating that the overall model results are not significantly changed and that no important accident sequences are inadvertently eliminated. In setting the screening values for final quantification, ACHIEVE convergence towards a stable result. CONTINUE the process until the change in CDF is less than 1% for an order of magnitude decrease in the truncation limit. Exception. - If only point estimate quantification is completed, then USE the mean. Recognize that when a strong state of knowledge dependence exists in the same cutset, the mean cutset probability could be elevated.		
QU-A11 3.3.8.1.2	CONSIDER estimating the magnitude of the truncated sequences or cutsets and compare to the CDF value to ensure that the magnitude of the truncated sequences or cutsets is not greater than the CDF value.	ESTIMATE the magnitude of the truncated sequences or cutsets and compare to the CDF value to ensure that the magnitude of the truncated sequences or cutsets is not greater than the CDF value.	
QU-A12	When truncating cutsets or sequences, USE screening values no greater than as follows: < 1E-4 * CDF Base AND < 1E-4 * LERF Base	When truncating cutsets or sequences, USE screening values no greater than as follows: < 1E-5 * CDF Base AND < 1E-5 * LERF Base	When truncating cutsets or sequences, USE screening values no greater than as follows: < 1E-6 * CDF Base AND < 1E-6 * LERF Base
QU-A13 3.3.8.1.2	For event trees with conditional split fractions, truncation MAY generally be performed at two levels: at the cutset level during the evaluation of each conditional split fraction, where all cutsets of a frequency less than the selected truncation limit are eliminated, and at the sequence level, where all sequences entering a particular plant state at a frequency less than the selected truncation limit are eliminated.		
QU-A14 3.3.8.3.1	If system equations are combined to quantify accident sequences, then the same truncation limit MAY be used for solving each system and the overall sequence CDF.		If system equations are combined to quantify accident sequences, USE the same truncation limit for solving each system and the overall sequence CDF.
QU-A15 3.3.8.3.1	For linked fault tree models, truncation MAY be performed at a cutset level during the evaluation of each accident sequence where cutsets of a frequency less than the selected truncation limit are eliminated.		

TABLE 4.4-8a
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT A
SCOPE: The Level 1 Quantification Methodology shall quantify core damage frequency in a way that captures plant specific and unique factors important to risk. (HLR-QU-A)

Index No. QU	**CATEGORY I APPLICATIONS** Quantification of CDF contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-A16 3.3.8.1.2	The same truncation limits used in evaluating the system failures in an accident sequence MAY be used for a complement equation if used in modeling the system successes in the accident sequence.	USE the same truncation limits used in evaluating the system failures in an accident sequence for a complement equation if used in modeling the system successes in the accident sequence, to avoid erroneous results due to truncation.	
QU-A17 [QU-4, QU-25] 3.3.8.1.2	USE computer codes for quantification that are capable of accounting for system successes in addition to system failures, in the evaluation of accident sequences to the extent needed for realistic estimation of CDF and LERF. This MAY be accomplished using numerical quantification of success probability, complimentary logic, or a delete term approximation (used in many existing codes). If success branches of event trees are less than 0.9, USE the numerically correct estimate If the fault tree linking approach is used, USE “delete” terms (cutset complements) to account for the successes in event sequences as appropriate to assure that the correct cut sets are generated. This includes the treatment of transfers among event trees where the “successes” may not be transferred between event trees.		
QU-A18 [QU-26] 3.3.8.2.2	IDENTIFY and DELETE in the quantification process mutually exclusive cutsets. DELETE any cutset containing mutually exclusive events in the results. CORRECT sequences containing mutually exclusive events by either: (a) designing path-dependent fault trees to eliminate mutually exclusive situations, or (b) deleting cutsets containing mutually exclusive events from supporting fault tree analysis results. Examples of ways in which fault tree codes generate cutsets containing mutually exclusive events include cases where: the same component fails in different modes, a cutset that reflects a plant condition that cannot physically occur, or a cutset contains planned maintenance unavailability events for redundant trains that would violate Technical Specifications and has been shown not to voluntarily occur at the plant.		
QU-A19 3.3.8.3.1	If used, SET logic flag events to either TRUE or FALSE (instead of setting the event probabilities to 1.0 or 0.0), as appropriate for each accident sequence, prior to the generation of cutsets. DO NOT MANIPULATE flag events after generation of sequence cutsets or setting event probabilities to 1.0 or 0.0, when used as a means to change systems failure logic, unless it can be demonstrated that such manipulations are performed correctly.		
QU-A20 [QU-4]	PERFORM a review and confirmation of the house event file and the disallowed maintenance file to ensure the absence of logical errors.		

TABLE 4.4-8b
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT B
COMPLETENESS IN DETAIL: The Level 1 Quantification Methodology shall be traceable and shall describe the relationship of the PRA technical elements to the quantification process (including the model assumptions). (HLR-QU-B)

Index No. QU	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-B1 3.3.8.1.2	INTEGRATE the system models, data, and HRA in the quantification process accounting for system dependencies to arrive at accident sequence frequencies.		
QU-B2 3.3.8.1.2	IDENTIFY dependencies among multiple Human Error (HE) events, which occur in individual sequences or cutsets so that the combined HE probability is realistically evaluated. USE sequence or cutset-specific timing and conditional information in the calculation and application of post-initiator operator actions and recovery actions.		
QU-B3	The quantification MAY combine models and sensitivity studies of integrated performance of equipment and personnel under conditions modeled in the PRA.		COMBINE models and sensitivity studies of integrated performance of equipment and personnel under conditions modeled in the PRA.
QU-B4 3.3.8.2.1	When using event tree with conditional split fraction approach, in a support system event tree USE a combinatorial model describing the status of support system trains. USE support system state definitions to break logic loops, such as the dependence of emergency diesel generators on Service Water systems. In a front-line mitigating systems event tree, USE an event sequence model of the plant response to each initiating event category.		
QU-B5 3.3.8.2.2	When using event tree with conditional split fraction approach, CALCULATE path dependent split fractions using system models that are requantified conditional on each initiating event category and each path through the event trees, including each support system state. Also INCORPORATE in the conditional calculation changes in success criteria and timing as well as other dependencies associated with each particular accident sequence.		
QU-B6 3.3.8.2.2	Post-initiator HE events MAY be included as event tree top events to ensure that dependencies among multiple human actions can be appropriately modeled and to permit quantification on a sequence-by-sequence basis, accounting for path dependent differences in timing and success criteria. If these HE events are included in the system fault trees, ACCOUNT FOR dependencies among human actions in the quantification.	INCLUDE post-initiator HE events as event tree top events to ensure that dependencies among multiple human actions can be appropriately modeled and to permit quantification on a sequence-by-sequence basis, accounting for path dependent differences in timing and success criteria. If these HE events are included in the system fault trees, ACCOUNT FOR dependencies among human actions in the quantification.	
QU-B7 [QU-18,QU-18]	Recovery actions credited in the evaluation MAY be either proceduralized or have reasonable likelihood of success assuming that trained and qualified personnel are performing the recovery action(s). INCLUDE credited recovery actions in the quantification process in all applicable sequences and cut sets.		

TABLE 4.4-8b
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT B
COMPLETENESS IN DETAIL: The Level 1 Quantification Methodology shall be traceable and shall describe the relationship of the PRA technical elements to the quantification process (including the model assumptions). (HLR-QU-B)

Index No. QU	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-B8	When using the event tree with conditional split fraction approach, STRUCTURE the event tree rules to select split fraction values based on event tree path dependencies.		
QU-B9	When using the event tree with conditional split fraction approach, if modules or independent subtrees are used to facilitate the quantification, USE a process of modularization that: (a) allows identification of shared events, (b) allows correct formation of modules that are truly independent, (c) allows results interpretation based on individual events within modules (e.g., risk significance).		
QU-B10 3.3.8.3.1	The requirements for a system's operation can vary from one accident sequence to another. The failure of the system in each circumstance MAY be represented by a separate fault tree or a single fault tree that utilizes logic flag events to remove logic for particular accident sequences. Example: A system that does not require a pump room HVAC system to operate for short-term operation of the pump but does require the HVAC system operation for long-term operation of the pump.		
QU-B11 3.3.8.3	Accident sequences using linked fault trees often result in cutsets with multiple HE events that can be dependent. To avoid premature truncation of such cutsets, USE screening HEPs values of 0.5 or greater in the initial quantification of accident sequences. The final quantification of these post-initiator HEs MAY be done at the cutset or saved sequence level. CONSIDER the dependency with other HEs in the cutset as well as timing requirements.		
QU-B12	When using event tree with conditional split fraction approach, QUANTIFY accident sequences for a specific initiator that are represented by transfers to event trees for other initiators by calculating the transfer event tree sequences using the logic flags, timing, and recovery events that are appropriate for the transferring initiator. However, the frequencies of partial sequences leading into a second event tree MAY be added and used in the event tree quantification if the sequences leading into the new event tree have identical responses and impacts on the subsequent accident sequence behavior.		
QU-B13	When using the linked fault tree approach, COMBINE front-line mitigating system fault trees with their required support systems, and operator action probabilities according to event tree sequence logic.		

TABLE 4.4-8c
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT C
COMPLETENESS IN DETAIL: The Level 1 Quantification Methodology shall be traceable and shall describe the relationship of the PRA technical elements to the quantification process (including the model assumptions). (HLR-QU-C)

Index No. QU See 3.3.8.4 for C1 through C10	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-C1 [QU-8]	REVIEW the dominant cutsets or sequences to demonstrate the reasonableness of the cutset or sequence results and to identify that there are no anomalies in the results.		
QU-C2 [QU-9]	INCLUDE common cause failure probabilities and all identified common cause component groups.	INCLUDE common cause failure probabilities and all identified common cause component groups. USE updated common cause data, if available.	
QU-C3 [QU-11]	CONSIDER reviewing the sequences and cutsets from similar plants to ensure that the results observed at other plants are generally consistent and that significant differences are understood.	REVIEW the sequences and cutsets from similar plants to ensure that the results observed at other plants are generally consistent and that significant differences are understood.	
QU-C4 [QU-15]	REVIEW non-dominant accident cutsets or sequences to ensure they are reasonable and have physical meaning.		
QU-C5 [QU-15]	Conservatism in the search for plant vulnerabilities MAY be used.	ELIMINATE overly conservative assumptions (even in non-dominant sequences) for PRAs that are to be used for risk-informed applications in order to avoid biasing the results.	
QU-C6 [QU-10, QU-17]	EVALUATE the dependence among human actions in the PRA process. INCLUDE as a test of modeling adequacy, identification of sequences that, but for low human error rates, would have been dominant contributors to core damage frequency. Equivalent techniques that achieve this objective MAY also be used		
QU-C7		REVIEW the results of the data analysis and individual systems analyses. For Bayesian analyses, EXAMINE priors, evidence, and posteriors for consistency. INVESTIGATE unusual results for reasonableness. QUANTIFY and REVIEW individual system fault trees.	
QU-C8	EXAMINE each sequence that is a significant contributor to CDF frequency and VERIFY that it is a valid core damage scenario.	EXAMINE each sequence that is a significant contributor to CDF or Plant Damage State (PDS) frequency and VERIFY that it is a valid core damage scenario. If the reason that a significant portion of the core damage sequences goes to core damage is because of conservative success criteria, PERFORM calculations to refine the success criteria. If the success criteria were uncertain, then PERFORM sensitivity studies to identify the potential impact on the results. DECOMPOSE significant sequences to understand the low level contributors and to ensure the sequences make logical sense.	

TABLE 4.4-8c
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT C
COMPLETENESS IN DETAIL: The Level 1 Quantification Methodology shall be traceable and shall describe the relationship of the PRA technical elements to the quantification process (including the model assumptions). (HLR-QU-C)

Index No. QU See 3.3.8.4 for C1 through C10	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-C9	PERFORM importance measure calculations to determine the contributions of various components and basic events to the total CDF. Typical importance measures are Fussell-Vesely (FV), risk achievement worth (RAW), risk reduction worth (RRW), and Birnbaum.	PERFORM importance measure calculations to determine the contributions of various components and basic events to the total CDF. Typical importance measures are Fussell-Vesely (FV), risk achievement worth (RAW), risk reduction worth (RRW), and Birnbaum. EXAMINE the importance of SSCs that contribute to initiating event frequencies. REVIEW the importance values for components and basic events to ensure they make logical sense. For example, components in series in a system train normally have equal RAWs.	
QU-C10	REVIEW the results of the PRA for consistency (e.g., event sequence models consistency with systems models and success criteria) and reasonableness.	REVIEW the results of the PRA for consistency (e.g., event sequence models consistency with systems models and success criteria) and reasonableness. In the review, QUESTION modeling assumptions, asking, under certain sequences or cutsets, if conditions outside those modeled could occur and, if so, could success criteria or other assumptions change. In the review, also QUESTION modeled human actions for consistency with plant procedures and the range of conditions that would be obtained in the associated PRA sequence.	

TABLE 4.4-8d
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT D
REALISM AND TREATMENT OF DEPENDENCIES: **The Level 1 Quantification Uncertainty Analysis shall address uncertainties and sensitivities in the quantification of CDF in a manner that is sufficient to support intended applications. (HLR-QU-D)**

Index No. QU See 3.3.8.1.3 for D2 through D14	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-D1 [QU-29] 3.3.8.1	PROVIDE the capability to perform sensitivity studies to support PRA applications.		
QU-D2 [QU-30]	The calculation of the CDF MAY consider the effects of uncertainties in establishing that the point estimate is a reasonable indicator of the mean value.	INCLUDE an assessment of parameter (aleatory) and modeling (epistemic) uncertainty. PERFORM a quantification of parametric and modeling uncertainties, or ESTIMATE the impact of selected uncertainties on PRA figures-of-merit via sensitivity studies. If modeling uncertainty is not included in the quantification, PERFORM sensitivity studies for modeling assumptions that impact the dominant contributors to the resulting CDF.	
QU-D3		IDENTIFY the sources of model uncertainty that can impact the sequence frequencies and evaluate their impact on the results either quantitatively or qualitatively.	IDENTIFY the sources of model uncertainty that can impact the sequence frequencies and evaluate their impact on the results.
QU-D4		EVALUATE the impact of parameter uncertainties by propagating the probability distributions that characterize uncertainty on input parameters through the calculation, USE Monte Carlo uncertainty propagation or other comparable means.	
QU-D5		PROPAGATE uncertainties in such a way that the “state-of-knowledge” correlation between event probabilities is taken into account. USE, in the Monte Carlo approach, the same uncertain value for a parameter drawn from the probability distribution for all basic events whose probabilities are evaluated using that parameter.	

TABLE 4.4-8d
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT D
REALISM AND TREATMENT OF DEPENDENCIES: The Level 1 Quantification Uncertainty Analysis shall address uncertainties and sensitivities in the quantification of CDF in a manner that is sufficient to support intended applications. (HLR-QU-D)

Index No. QU See 3.3.8.1.3 for D2 through D14	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-D6		When model uncertainty is calculated, all sources of reliable information MAY be incorporated into the assessment, including deterministic calculations, sensitivity studies, experimental results, and observations of operational events. DESCRIBE the uncertainties and EXPLAIN the significance of the uncertainties that significantly impact the results.	When model uncertainty is calculated, INCORPORATE all sources of reliable information into the assessment, including deterministic calculations, sensitivity studies, experimental results, and observations of operational events. DO NOT give more weight to deterministic calculations based on narrowly defined plant conditions than less rigorous information that applies to a more realistic range of conditions. DESCRIBE the uncertainties and explain the significance of the uncertainties that significantly impact the results. EXPLAIN the effects of these key uncertainties on potential decisions based on the PRA results.

TABLE 4.4-8d
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT D
REALISM AND TREATMENT OF DEPENDENCIES: The Level 1 Quantification Uncertainty Analysis shall address uncertainties and sensitivities in the quantification of CDF in a manner that is sufficient to support intended applications. (HLR-QU-D)

Index No. QU See 3.3.8.1.3 for D2 through D14	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-D7		If model uncertainty is not evaluated in the uncertainty quantification, EVALUATE the sensitivity of the results to uncertain model boundary conditions and other key assumptions using sensitivity analyses. In the sensitivity analyses, EXAMINE key assumptions or parameters both individually or in logical combinations. CHOOSE the combinations analyzed such that interactions among the variables affected by the sensitivities is represented. CONSIDER for a sensitivity analysis modeling assumptions, HE probabilities, CCF probabilities, and safety function success criteria.	EVALUATE the sensitivity of the results to uncertain model boundary conditions and other key assumptions using sensitivity analyses. In the sensitivity analyses, EXAMINE key assumptions or parameters both individually or in logical combinations. CHOOSE the combinations analyzed such that interactions among the variables affected by the sensitivities is represented. CONSIDER for a sensitivity analysis modeling assumptions, HE probabilities, CCF probabilities, and safety function success criteria unless such sources of uncertainties have been adequately treated in the quantitative uncertainty analysis.
QU-D8		In performing sensitivity analyses that only lowers a data value, the analyses MAY be performed by manipulating (requantifying) the original accident sequences and cutsets. However, for data sensitivities that increase a data value and for modeling sensitivities, the sequences and cutsets that were truncated could potentially be impacted and significantly influence the results (e.g., dominant accident sequences and contributors). Therefore, PERFORM these types of sensitivity analyses by requantifying the entire model unless it can be shown that only the retained accident sequences or cutsets are impacted.	
QU-D9		If modeling uncertainties are not amenable to quantification, ANALYZE sources of incompleteness as an important characterization of the results. IDENTIFY known omissions established by scope or other known limitations of the PRA.	
QU-D10		If a full quantitative propagation of uncertainties is not performed. JUSTIFY why the mean value of the sequence frequency or CDF is not affected by state-of-knowledge correlation.	

TABLE 4.4-8d
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT D
REALISM AND TREATMENT OF DEPENDENCIES: The Level 1 Quantification Uncertainty Analysis shall address uncertainties and sensitivities in the quantification of CDF in a manner that is sufficient to support intended applications. (HLR-QU-D)

Index No. QU See 3.3.8.1.3 for D2 through D14	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-D11		If the event tree with conditional split fraction method is employed, PERFORM parameter uncertainty analysis on the sequences that represent at least 90% of the mean point estimate CDF. JUSTIFY any alternative criteria used.	
QU-D12		If the fault tree linking method is employed, PERFORM parameter uncertainty analysis on the cutsets that represent at least 95% of the mean point estimate CDF. JUSTIFY any alternative criteria used. If modules or super components are used in the fault tree linking approach, directly PROPOGATE the uncertainty of individual basic events contained in the modules through the modules contained in the cutsets (i.e., DO NOT USE estimates of module uncertainty distributions as this can mask potential important state of knowledge dependencies).	
QU-D13		EXAMINE the PRA's boundary conditions and success criteria to determine the sensitivity of the results to those conditions. VERIFY that modeling decisions are still appropriate. VERIFY that truncation has not adversely affected results, and that sensitivity studies performed to set success criteria are appropriate for the current results and the range of sequences affected.	
QU-D14 [QU-27]	If there are unusual sources of uncertainty, then special sensitivity evaluations or quantitative uncertainty assessments MAY be performed to support the base conclusion and future applications.	IDENTIFY unique or unusual sources of uncertainty not present in the typical or generic plant analysis. If there are unusual sources of uncertainty, PERFORM special sensitivity evaluations to support the base conclusion and future applications.	

TABLE 4.4-8e
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT E
MODEL PLANT FIDELITY: The Level 1 Quantification Interface shall provide traceability with the LERF PRA analysis that is sufficient to identify the important contributors to LERF. (HLR-QU-E)

Index No. QU See 3.3.8.5	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-E1	IDENTIFY the plant damage states leading to LERF.		
QU-E2	ESTIMATE the frequency of plant damage states leading to LERF and associated contributors.		
QU-E3		ESTIMATE the frequency of plant damage states leading to radiological releases resulting from core damaging events.	IDENTIFY and ESTIMATE the plant damage states and associated contributors which are necessary to provide a reasonable estimate of all radiological release categories.

TABLE 4.4-8f
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT F
DOCUMENTATION: The Level 1 Quantification Documentation shall be performed in a manner that facilitates PRA applications, updates, and peer review, with assumptions and bases stated. (HLR-QU-F)

Index No. QU	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-F1	When using the linked fault tree approach "cutset" model, or any other simplified model, IDENTIFY limitations that would impact applications. When using the event tree with conditional split fraction approach "saved sequence" model, or any other simplified model, IDENTIFY limitations that would impact applications.		
QU-F2 [QU-31]	IDENTIFY and DESCRIBE the key contributors to CDF in the PRA results summary.	IDENTIFY and DESCRIBE the key contributors to CDF in the PRA results summary. PROVIDE a detailed description of at least the Top 100 accident cutsets for fault tree linking and the top 100 sequences for event tree with conditional split fractions. DESCRIBE the dominant accident sequences or functional failure groups	
QU-F3 [QU-13]	Asymmetries in quantitative modeling MAY be explained and examined to provide an understanding why such asymmetries are present in the model.	IDENTIFY asymmetries in quantitative modeling to provide application users the necessary understanding regarding why such asymmetries are present in the model.	
QU-F4	DOCUMENT the model integration process. INCLUDE any recovery analysis, computer codes used to perform the quantification, and the results of the quantification including uncertainty and sensitivity analyses. DOCUMENT: *(a)* records of the process/results when adding non-recovery terms as part of the final quantification; and *(b)* records of the cut set review process and any manipulations therein such as eliminating invalid cut sets, requantifying multiple but dependent HEs in the same cut set, etc. *(c)* a general description of the quantification process including accounting for systems successes, the truncation values used, how recovery and post-initiator HEs 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 initiating events and accident classes; *(f)* a list of the dominant accident sequences and their contributing cut sets (a dominant accident sequence, from a frequency perspective, rather than a risk perspective, is defined here as one whose contribution to the total CDF is greater than 1%); *(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 and for each dominant accident sequence; *(j)* importance measure results, including at least FV, risk reduction, and risk achievement; *(k)* a list of mutually exclusive events eliminated from the resulting cut sets and their bases for elimination		

TABLE 4.4-8f
SUPPORTING REQUIREMENTS FOR QUANTIFICATION HIGH LEVEL REQUIREMENT F
DOCUMENTATION: The Level 1 Quantification Documentation shall be performed in a manner that facilitates PRA applications, updates, and peer review, with assumptions and bases stated. (HLR-QU-F)

Index No. QU	**CATEGORY I APPLICATIONS** Quantification of CDF and key contributors supported by an understanding of the impact of key uncertainties	**CATEGORY II APPLICATIONS** Realistic quantification of CDF and key contributors supported by a sound understanding of the impact of uncertainties	**CATEGORY III APPLICATIONS** Realistic quantification of CDF and risk significant contributors supported by a sound understanding and quantification of the impact of uncertainties
QU-F5			DOCUMENT causes of uncertainty, such as: possible optimistic or conservative success criteria, suitability of the reliability data, possible modeling uncertainties (asymmetry or other modeling limitations due to the method selected), degree of completeness in the selection of initiating events, possible spatial dependencies, etc.
QU-F6 [QU-34]	DOCUMENT the computer code(s) used to perform the quantification process.		

4.4.9 Objectives of the Level 2/LERF Analysis Element

- The potential Level 2/LERF accident scenarios, including phenomena for radionuclide releases that are early and large, are identified and included in the model. The frequencies of these scenarios are identified.
- Pathways and release mechanisms that can be probabilistically evaluated are included in the analysis, or a basis for screening them is established.
- The methodology is clear and consistent with the Level 1 evaluation, and creates an adequate transition from Level 1.
- The adequacy of mitigation systems is established and accounts for adverse conditions and previous failures.
- Dependencies are reflected in the accident sequence model structure, if necessary (e.g., Level 2/LERF sequence dependencies on Level 1 event sequence, functional, common cause, operator action, spatial and environmental factors).
- End states are clearly defined to be LERF or non-LERF.
- Success criteria are available to support the individual function successes for each accident sequence.
- Containment event trees are adequate to support LERF development and quantification.
- Event trees reflect operating and emergency procedures.
- There is fidelity with the as-built, as-operated plant.
- Unique plant features are addressed.
- Transfers of accident sequences between event trees, if performed, are explicitly treated.
- The methodology for LERF sequence development is consistently applied and described.
- The output from this element is a set of well-defined accident scenarios that lead to LERF.
- Documentation clearly describes the methodology, the development process, and the resulting event trees.

TABLE 4.4-9 HIGH LEVEL REQUIREMENTS FOR LEVEL 2 ANALYSIS (HLR-L2)

A	ACCIDENT SEQUENCE METHODOLOGY: The LERF accident sequences shall include the dominant contributors (including containment bypass) to LERF and represent a reasonably complete set of accident progressions that lead to Large Early Release of radionuclides to the environment (HLR-L2-A)
B	INTERFACES: The interface with definition and quantification of Level 1 accident sequences, HRA, and LERF, as well as other relevant success criteria shall be defined. (HLR-L2-B)
C	DEPENDENCIES: Dependencies due to Level 1 Accident Sequences, human interface, functional, spatial, environmental dependencies, and common cause failures shall be addressed in the definition and quantification of LERF sequences. (HLR-L2-C)
D	CONTAINMENT PERFORMANCE / STRUCTURAL ANALYSIS: The containment structural analysis and bypass assessment shall represent failure conditions of systems, structures and components operating during severe accidents, as needed to support realistic LERF. (HLR-L2-D)
E	LERF QUANTIFICATION: LERF shall be quantified in a manner that captures factors important to risk and supports an understanding of sources of uncertainty (HLR-L2-E)
F	DOCUMENTATION: The LERF accident sequence analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review, with assumptions and bases stated. (HLR-L2-F)

TABLE 4.4-9a
SUPPORTING REQUIREMENTS FOR LEVEL 2 ANALYSIS HIGH LEVEL REQUIREMENT A
ACCIDENT SEQUENCE METHODOLOGY: The LERF accident sequences shall include the dominant contributors (including containment bypass) to LERF and represent a reasonably complete set of accident progressions that lead to Large Early Release of radionuclides to the environment (HLR-L2-A)

Index No. L2	**CATEGORY I APPLICATIONS** Quantification of LERF with an understanding of the impact of key uncertainties for the dominant LERF contributors	**CATEGORY II APPLICATIONS** Realistic quantification of LERF with a sound understanding of the impact of uncertainties for risk significant accident sequences	**CATEGORY III APPLICATIONS** Realistic quantification of LERF supported by a sound understanding and quantification of the impact of uncertainties
L2-A1 [L2-8,-9,-10]	INCLUDE containment challenges from the set identified in Table 4.4-9(a). This is the minimum set to be considered. For PWR LERF calculations, INCLUDE thermally induced SGTR (TI-SGTR) within the category of SGTR. An acceptable approach for identifying failure modes is outlined in the LERF event trees contained in NUREG/CR-6595. ADD as appropriate, unique plant issues as determined by expert judgement and/or past plant analyses.		INCLUDE challenges sufficient to support a realistic containment event tree. CONSIDER INCLUDING all postulated failure modes identified by IDCOR [Reference 4.4.9-1 and 4.4.9-2] or in NUREG-1150. Known plant specific failure modes, not included in the preceding evaluations, should also be included.
L2-A2 [L2-8,-9,-10, -21,-24,-25] 3.4.1	DEVELOP containment event tree (CET) or equivalent structure to establish LERF in a manner consistent with the containment challenges and failure modes and intended level of detail (category).		
L2-A3 [L2-8,-9,-10]	INCLUDE those decision points necessary to provide a conservative LERF estimation. It is acceptable to selectively consider mitigating actions by operating staff, effect of fission product scrubbing on radionuclide release and expected beneficial failures. PROVIDE technical justification to support the inclusion of these features.	INCLUDE those decision points necessary to provide a realistic LERF estimation. It is acceptable to selectively consider mitigating actions by operating staff, effect of fission product scrubbing on radionuclide release and expected beneficial failures. PROVIDE technical justification to support the inclusion of these features.	INCLUDE those decision points necessary to provide a realistic LERF calculation. CONSIDER INCLUDING risk significant mitigating actions by operating staff, effect of fission product scrubbing on radionuclide release and expected beneficial failures. PROVIDE technical justification to support the inclusion of these features. INCLUDE (1) the systems and HEPs necessary for the determination of LERF, (2) reasonable operator recovery actions and (3) effects of in vessel melt retention. When including recovery actions, VERIFY that these actions are consistent with the plant specific EOPs/SAMGs

<u>References</u>

[4.4.9-1] Nuclear Power Plant Response to Severe Accidents, IDCOR Technical Summary Report, Atomic Industrial Forum, November, 1984

[4.4.9-2] Nuclear Power Plant Response to Severe Accidents: Supplement to the Technical Summary Report, IDCOR Technical Summary Report Update, Tenera, Knoxville, TN, December 1988

Table 4.4-9(a): Dominant Contributors to be Considered in LERF Assessment

Containment Design	Large Dry and Subatmospheric CTMTs	Ice Condenser Containments	BWR Mark I	BWR Mark II	BWR Mark III
LERF Contributor					
Loss of Containment Isolation	✓	✓	✓	✓	✓ (1)
Containment Bypass					
-ISLOCA	✓	✓	✓	✓	✓
-SGTR	✓	✓			
Energetic Containment Failures					
-Induced RV Failure (e.g., DCH , containment failures)	✓	✓	✓	✓	✓
-Hydrogen Combustion		✓	✓	✓	✓
-Corium Impingement			✓		
ATWS			✓	✓	✓
Steam Explosion			✓	✓	✓
Shell Melt-through			✓		

(1) Dry Well (DW) Isolation Failure

TABLE 4.4-9b
SUPPORTING REQUIREMENTS FOR LEVEL 2 ANALYSIS HIGH LEVEL REQUIREMENT B
INTERFACES: The interface with definition and quantification of Level 1 accident sequences, HRA, and LERF, as well as other relevant success criteria shall be defined. (HLR-L2-B)

Index No. L2	**CATEGORY I APPLICATIONS** Quantification of LERF with an understanding of the impact of key uncertainties for the dominant LERF contributors	**CATEGORY II APPLICATIONS** Realistic quantification of LERF with a sound understanding of the impact of uncertainties for risk significant accident sequences	**CATEGORY III APPLICATIONS** Realistic quantification of LERF supported by a sound understanding and quantification of the impact off uncertainties
L2-B1 [L2-22,-23]	DEFINE LERF consistent with the definition in Section 2 of this Standard and the facility Emergency Plan USE a definition of LERF that captures the contributions to the risk of early health effects during the time interval to implement the associated emergency plan protective actions.	DEFINE LERF consistent with the definition in Section 2 of this Standard and the facility Emergency Plan. Credit for plant specific emergency plan and available Level 3 insights MAY be used, as appropriate. JUSTIFY use of plant specific considerations with particular emphasis on the relationship of release magnitude and timing on the definition of *LARGE* and *EARLY*, respectively. USE a definition of LERF that captures the contributions to the risk of early health effects during the time interval to implement the associated emergency plan protective actions Note: *EARLY* refers to a time frame prior to effective evacuation of the inhabitants in the Exclusion Area Boundary. Thus, events where the Emergency Action Level will define a General Emergency sufficiently in advance of a large release to allow effective evacuation MAY be excluded from consideration within LERF. The timing associated with this definition MAY be site specific. *LARGE* refers to a release magnitude that would significantly exceed the 10 CFR PART 100 siting criteria and could result in early fatalities. *LARGE* releases will typically release greater than 10% of the initial core inventory of iodine into the environment. In defining LARGE, the analyst MAY CONSIDER mitigating factors such as the degree of core damage, plateout or deposition of fission products released from the fuel, and release pathway characteristics. Use of Level 3 insights MAY be used if applicable to the site. JUSTIFY mitigation factors by use of applicable data or relevant analyses.	
L2-B2 [L2-7] 3.3.9 3.4..2	GROUP/BIN challenges based on Level 1 conditions. It is acceptable to subsume lower consequence events within higher consequence categories, provided the grouping does not distort PRA insights.		DEVELOP the LERF model with limited use of grouping/binning and phenomena blending. In grouping events realistically, CONSIDER the severity of the release and plant actions.

TABLE 4.4-9b
SUPPORTING REQUIREMENTS FOR LEVEL 2 ANALYSIS HIGH LEVEL REQUIREMENT B
INTERFACES: The interface with definition and quantification of Level 1 accident sequences, HRA, and LERF, as well as other relevant success criteria shall be defined. (HLR-L2-B)

Index No. L2	**CATEGORY I APPLICATIONS** Quantification of LERF with an understanding of the impact of key uncertainties for the dominant LERF contributors	**CATEGORY II APPLICATIONS** Realistic quantification of LERF with a sound understanding of the impact of uncertainties for risk significant accident sequences	**CATEGORY III APPLICATIONS** Realistic quantification of LERF supported by a sound understanding and quantification of the impact off uncertainties
L2-B3 [L2-4,5,6]	DEFINE containment integrity success criteria consistent with structural analyses. INCLUDE plant specific uniqueness when defining containment integrity success criteria		USE realistic and plant specific containment success criteria that accommodate a thorough phenomenological assessment of containment challenges included in the LERF model. DEFINE containment integrity success criteria consistent with structural analyses. CONSIDER plant specific uniqueness.
L2-B4 [L2-11] [L2-4,5,6] 3.3.3.1.2	Conservative system success criteria MAY be used.	A blend of conservative and realistic system success criteria MAY be used. EXPLAIN the degree of conservatism as it may affect Category II applications.	USE realistic system success criteria when possible. Conservative system success criteria MAY be used for non-dominant LERF contributors, if their use does not distort insights.

TABLE 4.4-9c
SUPPORTING REQUIREMENTS FOR LEVEL 2 ANALYSIS HIGH LEVEL REQUIREMENT C
DEPENDENCIES: Dependencies due to Level 1 Accident Sequences, human interface, functional, spatial, environmental dependencies, and common cause failures shall be addressed in the definition and quantification of LERF sequences. (HLR-L2-C)

Index No. L2	**CATEGORY I APPLICATIONS** Quantification of LERF with an understanding of the impact of key uncertainties for the dominant LERF contributors	**CATEGORY II APPLICATIONS** Realistic quantification of LERF with a sound understanding of the impact of uncertainties for risk significant accident sequences	**CATEGORY III APPLICATIONS** Realistic quantification of LERF supported by a sound understanding and quantification of the impact off uncertainties
L2-C1 [L2-12] [L2-24,25] 3.3.9.1.5	CONSIDER INCLUDING operator actions following the onset of core damage When human actions are credited beyond those defined in Level 1, INCLUDE bounding values for the HEP. VERIFY that HEPs are consistent with EOPs/SAMGs, proceduralized actions or Technical Support Center guidance and event timings for high stress conditions.	INCLUDE operator actions following the onset of core damage for SGTR bypass events. CONSIDER INCLUDING other operator actions that may cause a LERF sequence to be averted (e.g. delayed PORV operation for some PWRs). When human actions are credited beyond those defined in Level 1, INCLUDE HEP dependency with post initiator HEPs which have occurred in Level 1 sequences. VERIFY that HEPs are consistent with EOPs/SAMGs, proceduralized actions or Technical Support Center guidance and event timings for high stress conditions.	INCLUDE operator recovery actions and actions for equipment restoration, as appropriate. USE systems restoration probabilities and HEPs that are consistent with the event progression, environmental conditions and plant procedures (EOPs, AOPs and SAMGs), as needed for realistic LERF determination. INCLUDE HEP dependency with post initiator HEPs which have occurred in Level 1 sequences.

TABLE 4.4-9d
SUPPORTING REQUIREMENTS FOR LEVEL 2 ANALYSIS HIGH LEVEL REQUIREMENT D
CONTAINMENT PERFORMANCE/STRUCTURAL ANALYSIS: The containment structural analysis and bypass assessment shall represent failure conditions of systems, structures and components operating during severe accidents, as needed to support realistic LERF. (HLR-L2-D)

Index No. L2	**CATEGORY I APPLICATIONS** Quantification of LERF with an understanding of the impact of key uncertainties for the dominant LERF contributors	**CATEGORY II APPLICATIONS** Realistic quantification of LERF with a sound understanding of the impact of uncertainties for risk significant accident sequences	**CATEGORY III APPLICATIONS** Realistic quantification of LERF supported by a sound understanding and quantification of the impact off uncertainties
L2-D1 ST-5, 3.4.3	DEFINE the containment ultimate capacity for the dominant challenges that result in LERF.		
L2-D2 [L2-14,-15,-16,-17,18,19,20] 3.4.3	Evaluation of containment capacity MAY include conservatisms. CONSIDER dominant failure mode(s). Generic assessments formulated for similar plants MAY be used. USE generic calculations consistent with the plant being evaluated. Quasi static containment capability evaluations MAY be used unless hydrogen concentrations are expected to result in potential detonations.	PERFORM a realistic containment capacity assessment and CONSIDER significant containment failure modes. Evaluation of containment capacity MAY include conservatisms. CONSIDER USING plant specific calculations. USE generic calculations consistent with the plant being evaluated. Quasi static containment capability evaluations MAY be used unless hydrogen concentrations are expected to result in potential detonations. When failure location affects the event classification as a LERF, DEFINE failure location based upon realistic plant specific containment assessment.	PERFORM a realistic containment capacity assessment and CONSIDER significant containment failure modes. EVALUATE the containment capacity using plant specific input CONSIDER behavior of containment seals, penetrations, and hatches beyond the design basis temperature and pressure conditions. PROVIDE static and dynamic failure capabilities, as appropriate.
L2-D3 ST-6,7,8,9	RETAIN the containment isolation failure assessment in the model unless the reliability of containment isolation does not impact applications.		
L2-D4	PROVIDE a conservative estimate of the dominant failure modes contributing to LERF.	PROVIDE a realistic estimate of failure modes contributing to LERF.	PROVIDE a realistic estimate of failure modes contributing to LERF. CONSIDER INCLUDING postulated containment failure modes identified by IDCOR [References 4.4.9-1 and 4.4.9-2] or in NUREG-1150. INCLUDE known plant specific failure modes, not included in the preceding evaluations.

TABLE 4.4-9d
SUPPORTING REQUIREMENTS FOR LEVEL 2 ANALYSIS HIGH LEVEL REQUIREMENT D
CONTAINMENT PERFORMANCE/STRUCTURAL ANALYSIS: The containment structural analysis and bypass assessment shall represent failure conditions of systems, structures and components operating during severe accidents, as needed to support realistic LERF. (HLR-L2-D)

<table>
<tr><th>Index No. L2</th><th>CATEGORY I APPLICATIONS
Quantification of LERF with an understanding of the impact of key uncertainties for the dominant LERF contributors</th><th>CATEGORY II APPLICATIONS
Realistic quantification of LERF with a sound understanding of the impact of uncertainties for risk significant accident sequences</th><th>CATEGORY III APPLICATIONS
Realistic quantification of LERF supported by a sound understanding and quantification of the impact off uncertainties</th></tr>
<tr><td>L2-D5
[L2-13], ST-6,7,8,9</td><td colspan="3">PROVIDE the failure capacity and failure probability of the Interfacing Systems structures whose failure would result in a containment bypass. VERIFY that this assessment SHOULD be consistent with Level 1 evaluation.</td></tr>
<tr><td>L2-D6

[L2-13]</td><td>PERFORM an assessment of the capacity of RCS interfacing systems. Interfacing system capacity assumptions MAY include conservatisms in the evaluation.

Quasi-static piping capability evaluations MAY be used.</td><td>PERFORM a realistic or conservative plant specific assessment of the capacity of RCS interfacing systems. Interfacing system capacity assumptions MAY include conservatisms in the evaluation.

Quasi-static piping capability evaluations MAY be used.</td><td>PERFORM a realistic plant specific assessment of the capacity of RCS interfacing systems. CONSIDER evaluating the behavior of pump seals, heat exchangers, and safety valves for contributing failure modes and failure pathways.

PROVIDE static and dynamic failure capabilities, as appropriate. ESTIMATE failure sizes.

When possible, INCLUDE a best estimate evaluation of piping structural capability when assessing the potential impacts of Water Hammer.</td></tr>
<tr><td>L2-D7

3.4.3</td><td>For BWR containment designs, USE available containment analyses from generic or plant specific sources.</td><td colspan="2">For BWR containment designs, USE plant specific containment thermal hydraulic analyses to model containment or RPV response under severe accident progression.

For BWR containment designs, USE plant specific containment thermal hydraulic analyses to model containment or RPV response under severe accident progression.</td></tr>
</table>

TABLE 4.4-9e
SUPPORTING REQUIREMENTSFOR LEVEL 2 ANALYSIS HIGH LEVEL REQUIREMENT E
LERF QUANTIFICATION :
LERF shall be quantified in a manner that captures factors important to risk and supports an understanding of sources of uncertainty (HLR-L2-E)

Index No. L2	**CATEGORY I APPLICATIONS** Quantification of LERF with an understanding of the impact of key uncertainties for the dominant LERF contributors	**CATEGORY II APPLICATIONS** Realistic quantification of LERF with a sound understanding of the impact of uncertainties for risk significant accident sequences	**CATEGORY III APPLICATIONS** Realistic quantification of LERF supported by a sound understanding and quantification of the impact off uncertainties
L2-E1 [L2-7] 3.3.9 3.4..2	TRANSFER information between Level 1 and Level 2. USE plant damage states to characterize groups with similar characteristics and impacts on severe accident melt progression, as appropriate. INCLUDE dependent failure effects (system or HRA) in the quantification, as appropriate. Coarse conservative groupings/BINS MAY be used.	TRANSFER information between Level 1 and Level 2. USE plant damage states to characterize groups with similar characteristics and impacts on severe accident melt progression, as appropriate. INCLUDE dependent failure effects (system or HRA) in the quantification, as appropriate. GROUP BINS to ensure LERF insights not distorted. INCLUDE dependent failure effects (system or HRA) in the quantification, as appropriate.	TRANSFER information between Level 1 and Level 2. USE plant damage states to characterize groups with similar characteristics and impacts on severe accident melt progression, as appropriate. INCLUDE dependent failure effects (system or HRA) in the quantification, as appropriate. MINIMIZE grouping in assessing releases. For dominant / risk significant LERF precursor sequences, CONSIDER direct transfer of sequences or cutsets to ensure dependencies are properly treated
L2-E2	DO NOT TRUNCATE Level 1 sequences to avoid transfer to LERF unless they meet the truncation limits or can be otherwise justified.		
L2-E3	SOLVE LERF tree consistent with modeling approach. The use of multipliers (conditional probabilities) (see NUREG/CR-6595) to obtain LERF MAY be used. RETAIN the containment isolation failure assessment in the model unless the reliability of containment isolation does not impact applications		SOLVE the LERF model (i.e., CET) reflecting appropriate interfaces.
L2-E4	USE conservative data for determination of CET branch points. A conservative data set for some key parameters is included in NUREG/CR-6595. JUSTIFY applicability of, and variations from NUREG/CR-6595, using plant specific assessments, applicable generic data or new research findings.	USE of a blend between realistic and conservative data for branch point is acceptable.	USE realistic data for branch point probabilities, as available from relevant severe accident research findings and plant specific analyses.
L2-E5		PROVIDE uncertainty assessment or sensitivity study for dominant contributors to LERF.	PROVIDE uncertainty assessment or sensitivity study, as needed to support a realistic assessment of LERF.

TABLE 4.4-9f
SUPPORTING REQUIREMENTS FOR LEVEL 2 ANALYSIS HIGH LEVEL REQUIREMENT F
DOCUMENTATION: The LERF accident sequence analysis shall be documented in a manner that facilitates PRA applications, updates, and peer review, with assumptions and bases stated. (HLR-L2-E)

Index No. **L2**	**CATEGORY I APPLICATIONS** Quantification of LERF with an understanding of the impact of key uncertainties for the dominant LERF contributors.	**CATEGORY II APPLICATIONS** Realistic quantification of LERF with a sound understanding of the impact of uncertainties for risk significant accident sequences	**CATEGORY III APPLICATIONS** Realistic quantification of LERF supported by a sound understanding and quantification of the impact off uncertainties.
L2-F1 [L2-26,27,28]	DOCUMENT success criteria for Level 2/LERF. Include: -RPV ultimate capacity due to core melt progression and debris attack -Core cooling adequacy for in-vessel recovery -Timing for in-vessel recovery -Prevention of RPV breach due to core melt progression -Hydrogen deflagration survivability -Hydrogen burn impact for steam inerted containment prior to spray initiation. -Containment boundary survivability DEFINE those parameters (e.g., containment leakage rate) to be used as the basis for assigning containment bypass or failure .		
L2-F2	DOCUMENT Containment Capacity Assessment.		
L2-F3	**For Ice Condenser and BWR Mark III containments only**: DOCUMENT geometric details impacting the hydrogen related phenomena (i.e., heat sink distribution, circulation paths, ignition sources, water availability, and gravity drain paths) in a readily comprehensible form.		

4.5 Process Check

Analyses and/or calculations used directly by the PRA (e.g., HRA, data analysis) or used to support the PRA (e.g., thermal-hydraulics calculations to support mission success definition) shall be reviewed 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.

4.6 Use of Expert Judgment

This Subsection provides requirements for the use of expert judgment outside of the PRA analysis team to resolve a specific technical issue.

NUREG/CR-6372 (Reference 4.6-1) and NUREG-1563 (Reference 4.6-2) may be used to meet the requirements in this Subsection. Other approaches, or a mix of these, may also be used.

4.6.1 Objective of Using Expert Judgment
The PRA analysis team shall explicitly and clearly define the objective of the information that is being sought through the use of outside expert judgment, and shall explain this objective and the intended use of the information to the expert(s).

4.6.2 Identification of the Technical Issue. The PRA analysis team shall explicitly and clearly define the specific technical issue to be addressed by the expert or experts.

4.6.3 Determination of the Need for Outside Expert Judgment. The PRA analysis team may elect to resolve a technical issue using their own expert judgment, or the judgment of others within their organization.

The PRA analysis team shall use outside experts when the needed expertise on the given technical issue is not available within the analysis team or within the team's organization. The PRA analysis team should use outside experts, even when such expertise is available inside, if there is a need to obtain broader perspectives, for any of the following or related reasons:

- complex experimental data exist that the analysts know have been interpreted differently by different outside experts;

- more than one conceptual model exists for interpreting the technical issue, and judgment is needed as to the applicability of the different models;

- judgments are required to assess whether bounding assumptions or calculations are appropriately conservative;

- uncertainties are large and significant, and judgments of outside technical experts are useful in illuminating the specific issue.

4.6.4 Identification of Expert Judgment Process. The PRA analysis team shall determine:

- the degree of importance and the level of complexity of the issue; and

- whether the process will use a single entity (individual, team, company, etc.) that will act as an evaluator and integrator and will be responsible for developing the community distribution, or will use a panel of expert evaluators and a facilitator/integrator.

The facilitator/integrator shall be responsible for aggregating the judgments and community distributions of the panel of experts so as to develop the composite distribution of the informed technical community.

4.6.5 Identification and Selection of Evaluator Experts. The PRA analysis team shall identify one or more experts capable of evaluating the relative credibility of multiple alternative hypotheses to explain the available information. These experts shall evaluate all potential hypotheses and bases of inputs from the literature, and from proponents and resource experts, and shall provide:
a) their own input; and
b) their representation of the community distribution.

4.6.6 Identification and Selection of Technical Issue Experts. If needed, the PRA analysis team shall also identify other technical issue experts such as:

a) experts who advocate particular hypotheses or technical positions, for example, an individual who evaluates data and develops a particular hypothesis to explain the data.
b) technical experts with knowledge of a particular technical area of importance to the issue.

4.6.7 Responsibility for the Expert Judgment. The PRA analysis team shall assign responsibility for the resulting judgments, either to an integrator or shared with the experts. Each individual expert shall accept responsibility for his individual judgments and interpretations.

References

[4.6-1] R.J. Budnitz, G. Apostolakis, D.M. Boore, L.S. Cluff, K.J. Coppersmith, C.A. Cornell, and P.A. Morris, "Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on the Use of Experts", U.S. Nuclear Regulatory Commission and Lawrence Livermore National Laboratory, Report NUREG/CR-6372, 1997

[4.6-2] J.P. Kotra, M.P. Lee, N.A. Eisenberg, and A.R. DeWispelare, "Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program", U.S. Nuclear Regulatory Commission, Office of Nuclear Materials Safety and Safeguards, Report NUREG-1563, 1996

5 PRA CONFIGURATION CONTROL

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5 PRA CONFIGURATION CONTROL

5.1 Purpose

This Section provides requirements for configuration control of a PRA to be used with this Standard in risk-informed decisions for nuclear power plants.

5.2 PRA Configuration Control Program

The Configuration Control Program shall contain the following key elements:

- a process for monitoring PRA inputs and collecting new information
- a process that maintains and upgrades the PRA to be consistent with the as-built, as operated plant
- a process that ensures that the aggregate impact of pending changes is considered when applying the PRA
- a process that evaluates the impact of changes on previous PRA applications
- a process that maintains configuration control of computer codes used to support PRA quantification

5.3 Monitoring PRA Inputs and Collecting New Information

The PRA Configuration Control Program shall include a process to monitor changes in the design, operation, maintenance, and industrywide operational history that could affect the 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 PRA technology and industry experience that could change the results of the PRA model.

5.4 PRA Maintenance And Upgrades

The 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 PRA inputs or discovery of new information identified pursuant to Section 5.3 shall be evaluated to determine whether such information warrants PRA Maintenance or PRA Upgrade (See Section 2 for the distinction between PRA Maintenance and PRA Upgrade.) Changes that would impact risk-informed decisions should be prioritized to ensure that the most significant changes are incorporated as soon as practical. Changes that are relevant to a specific application shall meet the Supporting Requirements provided in Section 4.

Changes to a PRA due to PRA Maintenance shall be reviewed, but do not require a peer review. Upgrades of a PRA shall satisfy the peer review requirements specified in Section 6, but limited to aspects of the PRA that have been upgraded.

5.5 Pending Changes

This Standard recognizes that immediately following a plant change, or upon identification of a subject for model improvement, a PRA may not represent the plant until the change is incorporated. Therefore, the PRA configuration control process shall address the aggregate impact of pending changes on the application being performed. These changes should be addressed in a fashion similar to the approach used in Section 3 to address Elements that are determined to be inadequate.

5.6 Previous PRA Applications

A process shall exist to review the impact of a PRA change on previous risk-informed decisions that have used the PRA.

5.7 Use Of Computer Codes

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

5.8 Documentation

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

Specifically, the documentation shall include:

- a description of the process used to monitor PRA inputs and new information
- evidence of the scope and frequency of the PRA inputs and new information monitoring process
- descriptions of potential changes
- a discussion of resolutions used to address the potential changes
- scope of changes included in a PRA update due to a PRA Upgrade or PRA Maintenance
- evidence of the performance of the appropriate PRA reviews
- a description of the process used to address the aggregate impact of pending changes
- a description of the process used to evaluate changes on previous PRA applications
- a description of the process used to maintain software configuration control

6 PEER REVIEW

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6 PEER REVIEW

6.1 Purpose

This section provides requirements for peer review of a PRA to be used with this Standard in risk-informed decisions for nuclear power plants. PRAs used for applications applying this Standard shall be peer reviewed. The peer review shall assess the PRA Elements contained in Section 4 to the extent necessary to determine if the methodology and its implementation meet the requirements of this Standard. The peer review need not assess all aspects of the PRA against all Section 4 requirements; however, enough aspects of the PRA shall be reviewed for the reviewers to achieve consensus on the adequacy of methodologies and their implementation for each PRA Element.

6.1.1 Frequency. Only a single peer review is necessary. Section 5 of this Standard provides requirements for PRA Maintenance and Upgrades of the PRA. If additional peer reviews are conducted on 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 PRA that have occurred since the previous review.

6.1.2 Methodology. The review shall be performed using a written methodology that assesses the requirements of Section 4 and Section 6. Reference [6.1.2-1] provides an acceptable review methodology.

The peer review methodology shall consist of the following elements:

(a) an approach to be used by the peer review team for assessing if the PRA meets the requirements of this Standard for the application categories in Subsection 1.5;
(b) a process by which differing professional opinions are to be addressed and resolved;
(c) an approach for reviewing the PRA configuration control; and
(d) a method for documenting the review.

<u>References</u>

[6.1.2-1] Probabilistic Risk Assessment (PRA) Peer Review Process Guidance NEI-00-02.

6.2 Peer Review Team Composition And Personnel Qualifications

The peer review team shall consist of personnel whose qualifications cover all the PRA Elements of Section 4 and the interfaces between those elements.

6.2.1 General. The peer review team members shall:

(a) be knowledgeable of the requirements in this Standard for their area of review;
(b) have demonstrated experience performing PRA activities related to their area of review; and
(c) have collective knowledge of the plant NSSS design, containment design, and plant operation .

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

The peer review team members shall:

(a) not be allowed to review their own work; and
(b) not be allowed to review a PRA for which they have a conflict of interest, such as a financial or career path incentive or disincentive that may influence the outcome of the peer review.

6.2.2 Specific. Each peer reviewer shall be experienced in performing the activities related to the PRA Elements to that the reviewer is assigned to review, and shall be knowledgeable of the requirements in this

Standard for their area of review. 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 PRA Element assigned for review. Understanding and competence in the assigned area shall be demonstrated by the range of the individual's experience in the number of different,, independent activities performed in the assigned area, as well as the different levels of complexity of these activities.

One member of the peer review team (the technical integrator) shall be familiar with all the PRA Elements identified in this Standard and shall have demonstrated the capability to integrate these PRA Elements.

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.

The team members assigned to review the HRA and Level 2 Analysis shall have experience specific to these areas and be capable of recognizing the impact of plant specific features on the analysis.

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 PRA Element, such as a review of an upgrade of a PRA Element, then the peer review should be conducted by a team with a minimum of two members, performed over a time necessary to address the specific PRA Element.

Exceptions to the requirements of this subsection may be taken based on the availability of appropriate personnel to develop a team. All such exceptions shall be documented in accordance with Subsection 6.6 of this Standard.

6.3 Review Of PRA Elements To Confirm The Methodology

The peer review team shall use the requirements of this Subsection for the PRA Elements being reviewed to determine if the methodology and the implementation of the methodology for each PRA Element meets the requirements of this Standard. The judgment of the reviewer shall be used to determine the specific depth of the review in each PRA Element.

The results of the overall PRA and the results of each PRA Element shall be reviewed to determine their reasonableness given the design and operation of the plant (e.g., investigation of cutset or sequence combinations for reasonableness).

The High Level Requirements of Section 4 shall be used by the peer review team in assessing the completeness of a PRA Element.

6.3.1 Initiating Event Analysis (IE). The entire initiating event analysis shall be reviewed.

6.3.2 Accident Sequence Analysis (AS). A review shall be performed on selected accident sequences.

The review of selected accident sequences should include:

- one accident sequence model balance-of-plant transient the accident sequence model containing LOOP/Station Blackout considerations model
- one accident sequence model for a loss of a support system initiating event
- one LOCA accident sequence model
- one ISLOCA accident sequence model
- the SGTR accident sequence model (for PWRs only)
- one ATWS accident sequence model

Additional accident sequence models should be reviewed depending on the results of the review of the event trees for the required accident sequence models.

6.3.3 Success Criteria (SC). A review shall be performed on success criteria definitions and evaluations.

The review of selected success criteria definitions and evaluations should include:

- the definition of core damage used in the success criteria evaluations and the supporting bases
- the core and containment response conditions used in defining LERF and supporting bases
- the core and containment system success criteria used in the PRA for mitigating each modeled initiating event

- the generic bases (including assumptions) used to establish the success criteria of systems credited in the PRA and the applicability to the modeled plant
- the plant-specific bases (including assumptions) used to establish the system success criteria of systems credited in the PRA
- one calculation, performed specifically for the PRA, for each computer code used to establish core cooling or decay heat removal success criteria and accident sequence timing
- one calculation, performed specifically for the 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 a SBO)
- the containment response calculations, performed specifically for the PRA, for the dominant plant damage states
- all expert judgments used in establishing success criteria used in the PRA

6.3.4 Systems Analysis (SA). A review shall be performed on the systems analysis.

The selected system models reviewed should include:

- dominant systems contributing to the CDF or LERF calculated in the PRA
- a number of different models reflecting different levels of detail
- one front-line system for each mitigating function (e.g., reactivity control, coolant injection, and decay heat removal)
- one of each major type of support system, (e.g., electrical power, cooling water, instrument air, and HVAC)
- any complex system 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)

Additional system models should be reviewed depending on the results of the review of the systems delineated above.

6.3.5 Human Reliability Analysis (HR). A review shall be performed on the human reliability analysis.

The portion of the HRA selected for review should include:

- HEPs for dominant human actions contributing to the CDF or LERF calculated in the PRA
- the selection and implementation of any screening HEPs used in the PRA
- two post-accident HEPs
- two pre-accident HEPs for both instrumentation miscalibration and failure to recover equipment
- HEPs for the same human action but with different times required for success
- two HEPs for dependent human actions
- any HEPs less than 1E-6
- any HEPs involving remote actions in harsh environments

6.3.6 Data Analysis (DA). A review shall be performed on the data analysis.

The portion of the data analysis selected for review should include:

- data values for dominant component failure modes contributing to the CDF or LERF calculated in the PRA
- all common cause failure values
- 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)
- all probabilities that do not fit into the basic event data base for plant specific or generic sources
- all equipment repair and recovery data.

6.3.7 Internal Flooding (IF). A review shall be performed on the internal flooding analysis.

The portion of the internal flooding analysis selected for review should include:

- dominant internal flooding contributors to the CDF or LERF calculated in the PRA
- the screening of any flood areas
- all internal flood initiating event frequencies
- one internal flooding scenario involving each identified flood source
- two internal flooding scenarios involving flood propagation to adjacent flood areas
- one internal flooding scenario that involves each of the flood-induced component failure mechanisms (i.e., one flood scenario for each mechanism)

- one internal flooding scenario involving each type of identified accident initiator (e.g., transient and LOCA)

6.3.8 Quantification (QU). Level 1 Quantification results shall be reviewed.

The portion of Level 1 quantification process selected for review should include:

- appropriateness of the computer codes used in the quantification
- the truncation values and process
- the recovery analysis
- model asymmetries and sensitivity studies
- the process for generating modules (if used)
- several examples of fault tree linking (if used)
- all logic flags (if used)
- the solution of several logic loops (if appropriate)

6.3.9 Level 2 Analysis (L2). The Level 2/LERF analysis and the Level 1/Level 2 interface process shall be reviewed.

The portion of Level 1/Level 2 interface process selected for a detailed review should include:

- accident characteristics chosen for carryover to Level 2 analysis (and for binning of Plant Damage States if PDS methods were used)
- interface mechanism used
- CDF carryover

The portion of the Level 2 analysis should include:

- the Level 2 analysis method
- demonstration that the phenomena considered impact the LERF radionuclide release characterization
- human action and system success consider adverse conditions
- the sequence mapping
- evaluation of containment performance under severe accident conditions
- the definition and bases for LERF
- inclusion in the containment event tree of the functional events necessary to achieve a safe stable containment endstate

6.4 Expert Judgment

The use of expert judgment to implement requirements in this Standard shall be reviewed.

6.5 PRA Configuration Control

The peer review team shall review the process, including implementation, for updating the PRA against the configuration control requirements of this Standard.

6.6 Documentation

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 PRA reviewed;

(b) the names of the peer review team and identification of their roles;

(c) a brief resume for each team member describing the individual's employer, education, PRA training, and PRA and PRA Element experience and expertise;

(d) the elements of the PRA reviewed by each team member;

(e) a discussion of the extent to which each PRA Element was reviewed;

(f) results of the review identifying any differences between the requirements in Sections 4 and 5 of this Standard and the methodology implemented and defined to a sufficient level of detail that will allow the resolution of the differences;

(g) recommended alternatives for resolution of any differences; and

(h) at the request of any peer reviewer, differences or dissenting views among peer reviewers.

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.