Proprietary Markings Regarding the Safety Evaluation (by NRO) for Licensing Topical Report WCAP-17203-P/WCAP-17203-NP, Revision 0-2, "Fast Transient and ATWS Methodology"

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SAFETY EVALUATION BY THE OFFICE OF NEW REACTORS FOR LICENSING TOPICAL REPORT WCAP-17203-P, REVISION 0-2, "FAST TRANSIENT AND ATWS METHODOLOGY"

1. INTRODUCTION

By letter dated June 30, 2010, South Texas Project Nuclear Operating Company (STPNOC) submitted the Westinghouse Electric Company (WEC) licensing topical report (LTR) WCAP-17203-P, Revision 0, "Fast Transient and ATWS Methodology," for Nuclear Regulatory Commission (NRC) review and approval (Ref. 1). The LTR is to support a future fuel license amendment for South Texas Project (STP) Units 3 and 4. During review of the LTR, the staff sent several requests for additional information (RAIs) to Nuclear Innovation North America LLC (NINA), the applicant for STP Units 3 and 4. By letter dated October 20, 2014, NINA submitted Revision 0-2 of the LTR (Ref. 2) that addresses many of these RAIs and their responses.

The purpose of the LTR is to augment the existing methodology for fast transients and anticipated transients without scram (ATWS) described in LTR CENPD-300-P-A, "Reference Safety Report for Boiling Water Reactor Reload Fuel" (Ref. 3). While the methodology in CENPD-300-P-A is applicable for the analysis of anticipated operational occurrences (AOOs) including ATWS for boiling-water reactor (BWR) product lines 2-6 (BWR/2-6), it does so within the context of reload analysis and not first cores. The objective of this LTR is to establish a methodology for analyzing both limiting and non-limiting fast transients in initial and reload cores for currently operating BWRs and the advanced boiling-water reactor (ABWR) design. This report also establishes the acceptability of using a revised statistical approach for the evaluation of figures of merit (FOM) that are important to the analysis of fast transients and ATWS. LTR Section 1.4 specifically requests NRC review and approval of:

- The ranking designations in the phenomena identification and ranking table (PIRT)
- The analysis methodology for evaluating fast transients
- The Monte Carlo-based uncertainty analysis methods

According to the LTR, the final EM that will be used to perform analysis for a particular plant will reference the subject LTR, a code-specific topical report, and other licensing documents, thereby providing a complete submittal for the use of the EM.

Even though the submitted LTR is applicable to BWR/2-6 and ABWR, the Office of New Reactors (NRO) review focused on the aspects of the LTR pertinent to the consideration of future submittals related to fuel amendments regarding the ABWR design. Therefore, this safety evaluation report (SER) addresses the application of the methodology only to the ABWR design. Evaluation of the methodology for application to BWR/2-6 will be issued by the Office of Nuclear Reactor Regulation (NRR) separately.

This SER documents the staff's review of the LTR. Section 1.1 of this SER discusses the scope of the review, and Section 2 discusses the regulatory criteria used to guide the review. Section 3 of this SER provides a brief summary of the technical information provided by the applicant. Section 4 describes the staff's technical evaluation, including a discussion of the RAIs. Section 5 of this SER provides the applicable conditions and limitations resulting from the review, and Section 6 presents the staff's conclusions.

1.1 Background

Prior to submittal of the subject LTR, the NRC had not reviewed fast transient and ATWS analysis methodology in the context of the ABWR design. The LTR intends to establish a methodology for both limiting and non-limiting fast transients in initial and reload cores for ABWR and BWR/2-6, though the scope of this review covers the ABWR only.

The distinction between fast and slow events is described in the LTR as follows:

> *These events are grouped into fast and slow transients based on the dynamic characteristics of the transient. "Fast transients" are those events of relatively short duration such that the impact of the spatial and temporal dynamics on the system nuclear and thermal-hydraulics is important to the overall plant response. "Slow transients" are defined as those transients for whom the dynamic changes during the transient are sufficiently slow that the assumption that steady state conditions are achieved at each time step is either realistic or conservative.*

The LTR cites Regulatory Guide (RG) 1.203, "Transient and Accident Analysis Methods" (Ref. 4), as the guidance used to analyze AOOs including ATWS events. Since ATWS events are considered AOOs followed by a failure of the reactor protection system to scram, they are discussed separately in the LTR.

The LTR presents a PIRT for fast transients relating to BWR/2-6 and ABWR. The phenomena identified in the PIRT are grouped into eight categories and are each assigned an importance ranking corresponding to its influence on a FOM. The PIRT provides the rationale for each ranking. The LTR defines separate importance rankings for different AOOs and ATWS events.

The LTR proposes a transient analysis statistical methodology that accounts for uncertainties and biases in the models, inputs, and parameters to ensure that operating limits and safety margins meet the required acceptance criteria. To do this, the LTR proposes a statistical analysis method using 95 percent probability with a 95 percent confidence level (95/95) for calculating uncertainties associated with operating limits and safety margins.

The LTR is only a portion of the documentation required to support revision of an EM. As stated in LTR Section 1.1:

> *"The methodology described in this topical report applies to fast transients; the methodology documented in Reference 1* [CENPD-300-P-A] *continues to be valid for slow transients. As such, the complete evaluation model will utilize this document, a code dependent topical and other supporting licensing basis documents."*

Furthermore, LTR Section 7.1 describes the limitations of the code capability assessment (CCA) and data uncertainty assessment (DUA):

> "*The following sections contain the description of CCA and DUA on an overall process level. Neither CCA nor DUA is performed for any particular code in this topical report."*

Since the methodology in this LTR will eventually be utilized in conjunction with an approved EM, the staff notes that the extent of the documentation supplied is limited. Consequently, the scope of this review is limited to applicable portions of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition" (Standard Review Plan [SRP]) (Ref. 5), Section 15.0.2, "Review of Transient and Accident Analysis Methods." The staff also used the guidance in RG 1.203 for its review.

The SRP identifies six areas of review for AOO and ATWS analysis methods: documentation; evaluation model; accident scenario identification process; code assessment; uncertainty analysis; and quality assurance plan. Each of these areas is discussed below.

Documentation

The guidance in SRP Section 15.0.2.II.1 states:

> *... The evaluation model documentation must be scrutable, complete, unambiguous, accurate, and reasonably self-contained... The code documentation must be sufficiently detailed that a qualified engineer can understand the documentation without recourse to the originator as required of any design calculation that meets the design control requirements of Appendix B to 10 CFR Part 50, and the documentation requirement in Appendix K to 10 CFR Part 50.*

As stated in the submittal, the LTR will supplement an EM submittal.

Evaluation Model

The SRP recommends that the EM include all computational and non-computational elements, including field equations, constitutive and closure relations, and simplifying assumptions used to perform accident or transient analyses, and it needs to be reviewed to determine its applicability and adequacy.

The LTR provides an uncertainty analysis methodology that can be used with an approved EM.

Accident Scenario Identification Process

The SRP recommends the applicant/licensee/vendor to supply a complete description of the accident scenarios. This includes initial plant conditions, the transient initiating event, and all subsequent events and phases of the accident and the important physical phenomena and systems and/or component interactions that influence the outcome of the accident. The SRP also recommends that the applicant use a structured process for the identification and ranking of phenomena relevant to accident scenarios to which the analysis methodology will be applied to determine their importance and impact on the selected FOM. The predictive fidelity of the models present in the EM should be commensurate with the levels of importance attached to their associated phenomena.

The LTR provides a structured identification and ranking process discussed in detail in the following sections. The balance of information recommended by the SRP, including plant-specific transients and EMs, is to be provided as part of a licensing submittal.

Code Assessment

The SRP guidance recommends that all code models, or changes to such models, that will be used in the EM shall be evaluated.

LTR Section 7.2.1 states that the transient methodology presented is code-independent and therefore can be applied regardless of the computer code used. The LTR therefore does not present a complete code assessment; the assessment performed in the LTR is for demonstration purposes only.

Since the LTR introduces no models, this portion of the guidance is only applicable in that the RAIs and responses discuss the performance or acceptability of certain models to address issues related to scope of applicability changes by the LTR (e.g., ABWR). The separate effects test (SET), integral effects test (IET), and scaling aspects of the guidance are also similarly applicable.

Uncertainty Analysis

The SRP guidance states that the review methods will either estimate the uncertainty associated with the computation of accident and transient behavior, as is performed for best-estimate loss-of-coolant accidents (LOCAs), or will provide a demonstrably conservative evaluation.

The currently approved EM for BWR/2-6 (Ref. 3) allows only the use of suitably conservative values for AOOs and ATWS. The proposed methodology implements a combination of conservative and statistically chosen values, as detailed in the LTR and RAI responses.

The uncertainty analysis must address all important sources of code uncertainty, including the mathematical models in the code and the user-selected inputs, such as model nodalization. The major sources of uncertainty should be assessed in a manner consistent with the results of the accident sequence identification process. The LTR describes a process for addressing uncertainties.

SRP guidance also states that when a code is used in a licensing calculation, the combined code and application uncertainty must be less than the design margin for the safety parameter of interest. Examples of safety parameters typically applicable to ABWR analysis are reactor vessel pressure (RVP), linear heat generation rate (LHGR), and minimum critical power ratio (MCPR). The analysis should include a sample uncertainty evaluation for a typical plant application.

If bounding analyses rather than uncertainty analyses are to be performed, bounding values for input parameters similar to those described in the SRP sections or RGs that are used for plant operating conditions, such as accident initial conditions, setpoint values, and boundary conditions, can be substituted. The LTR provides a demonstration case that uses this approach.

SETs should also be used to determine the uncertainty bounds of individual physical models. IETs should be performed to demonstrate that the interactions between different physical phenomena and reactor coolant system (RCS) components and subsystems are identified and predicted correctly.

Quality Assurance Plan

The SRP recommends that the EM be maintained under a quality assurance program that meets the requirements of 10 CFR 50 Appendix B. The acceptable outcome of this evaluation was addressed in an audit conducted by the staff (Ref. 6) and is thus not a topic for this document.

2. REGULATORY EVALUATION

Title 10 of the *Code of Federal Regulations* (10 CFR) 50.34, "Contents of Applications; Technical Information," requires that the licensee/applicant (or vendor) provide a safety analysis report (SAR) to the NRC detailing the performance of systems, structures, and components provided for the prevention or mitigation of potential accidents. General Design Criterion (GDC) 10 (Ref. 7) requires that the reactor core and associated coolant, control, and protection systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during any condition of normal operation, including the effects of AOOs.

The acceptance criteria for AOO events are defined in SRP Section 15.0 and meet the GDC applicable to AOOs. The relevant portions of the acceptance criteria are as follows:

- *Pressure in the reactor coolant and main steam systems should be maintained below 110 percent of the design values in accordance with the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code.*

- *Fuel cladding integrity shall be maintained by ensuring that the critical power ratio (CPR) remains above the minimum critical power ratio (MCPR) safety limit for BWRs.*

- *An AOO should not generate a postulated accident without other faults occurring independently or result in a consequential loss of function of the RCS or reactor containment barriers.*

The provisions for mitigating the consequences of potential ATWS events is discussed in 10 CFR 50.62 (Ref. 8). The NRC staff uses Section 15.8, "Anticipated Transients Without Scram," of the SRP (Ref. 5) as guidance in the review of analyses to demonstrate compliance with 10 CFR 50.62.

The design requirements for ATWS events for evolutionary plants are defined in SRP Section 15.8, Subsection 15.8.II in Paragraph 3.C of "Specific Acceptance Criteria" and restated as follows:

- *Coolable geometry for the reactor core. If fuel and clad damage were to occur following a failure to scram, GDC 35 requires that this condition should not interfere with continued effective core cooling. 10 CFR 50.46 defines three specific core-coolability criteria: (1) Peak clad temperature shall not exceed 1221°C (2200°F), (2) Maximum cladding oxidation shall not to* [sic] *exceed 17% the* [sic] *total cladding thickness before oxidation, and (3) Maximum hydrogen generation shall not exceed 1% of the maximum hypothetical amount if all the fuel clad had reacted to produce hydrogen.*

- *Maintain reactor coolant pressure boundary integrity. Appendix A to WASH-1270 states that in evaluating the reactor coolant system boundary for ATWS events,* *"the calculated reactor coolant system transient pressure should be limited such that the maximum primary stress anywhere in the system boundary is less than that of the 'emergency conditions' as defined in the ASME Nuclear Power Plant Components Code, Section III." The acceptance criteria for reactor coolant pressure, based upon the ASME Service Level C limits, are approximately 10.3 MPa (1500 psig) for BWRs and approximately 22MPa (3200 psig) for PWRs* [pressurized water reactors].

- *Maintain containment integrity. Following a failure to scram, the containment pressure and temperature must be maintained at acceptably low levels based on GDC 16 and 38. The containment pressure and temperature limits are design dependent; but to satisfy GDC 50, those limits must ensure that containment design leakage rates are not exceeded when subjected to the calculated pressure and temperature conditions resulting from any ATWS event.*

3. SUMMARY OF TECHNICAL INFORMATION

3.1 Introduction

The LTR proposes methods for the analysis of fast transients including ATWS events, maintaining applicability to BWR/2-6 reload analysis while extending their applicability to first core analysis and to the ABWR design. The LTR includes the following sections:

- Transient Grouping and Plant Specification
- Acceptance Criteria
- Phenomenological Description
- Phenomena Identification and Ranking
- Analysis Methodology
- Uncertainty Analysis
- Demonstration Analysis

The following Sections 3.2 through 3.8 summarize and briefly discuss each of these LTR sections.

3.2 Transient Grouping and Plant Specification

Section 2 of the LTR provides information regarding the classification scheme for transients within the scope of the LTR. This classification scheme applies to the ABWR, and its purpose is to facilitate the identification and ranking of phenomena that influence the FOM for each category of transients. The categorization presented in LTR Section 2 regroups the transients listed in Section 15.0 of the SRP into four groups based on the dominant phenomenological effect in the RCS:

1. Pressure increase/decrease (PI/PD)
2. Reactor coolant flow increase/decrease (RI/RD)

3. Feedwater flow increase/decrease (FI/FD)
4. Reactor coolant temperature increase/decrease (TI/TD)

This categorization scheme allows one transient group to include more than one SRP Section 15.0 event type. Section 2 of the LTR lists the events included in each group, along with a cross reference to the SRP section that describes the event. Section 2 of the LTR also presents the following categories for sub-categorization of ATWS scenarios, based on the means of mitigation:

1. Reactor shutdown by alternate rod insertion
2. Reactor shutdown by fine motion control rod drive run-in (a feature unique to the ABWR design)
3. Reactor shutdown by activation of standby liquid control system (SLCS)

3.3 Acceptance Criteria

LTR Section 3.1 provides the acceptance criteria for both AOO and ATWS events.

LTR Section 3.2 provides the FOM derived from the AOO and ATWS acceptance criteria. These FOM are used in Section 5 of the LTR as input to the ranking of phenomena identified in the PIRT. The FOM identified in the LTR for the AOOs are:

- Minimum critical power ratio (MCPR)
- Reactor vessel pressure (RVP)
- Linear heat generation rate (LHGR)

The FOM identified for the ATWS events are:

- Cladding temperature
- RVP
- Mass and energy release to containment

3.4 Phenomenological Description

Section 4 of the LTR provides phenomenological descriptions of the nature and typical progression of the previously defined PI/PD, RI/RD, FI/FD, and TI/TD transient categories. Since the details of these transients are plant-specific, the LTR provides only general descriptions. The LTR states that plant-specific phenomenological descriptions will be provided in other licensing documents such as the SAR, design control document (DCD), or license amendments.

3.5 Phenomena Identification and Ranking

Section 5 of the LTR presents a PIRT for the AOOs and ATWS stated to be applicable to ABWR and BWR/2-6. The LTR indicates that the phenomena identified in the PIRT are based on the following previously developed PIRTs with some additions based on the opinions of an expert panel:

- "Phenomenon Identification and Ranking Tables (PIRTs) for Loss-of-Coolant Accidents in Pressurized and Boiling Water Reactors Containing High Burn up Fuel," NUREG/CR-6744 (Ref. 9)
- "Phenomenon Identification and Ranking Tables (PIRTs) for Rod Ejection Accidents in Pressurized Water Reactors Containing High Burnup Fuel," NUREG/CR-6742 (Ref. 10)
- "Phenomenon Identification and Ranking Tables (PIRTs) for Power Oscillations Without Scram in Boiling Water Reactors Containing High Burnup Fuel," NUREG/CR-6743 (Ref. 11)

LTR Appendix A defines the phenomena identified in the PIRT, which are grouped into eight categories:

1. Initial conditions
2. Transient power distribution
3. Steady-state and transient cladding to coolant heat transfer and core spray heat transfer
4. Transient coolant conditions as a function of elevation and time
5. Fuel rod response
6. Multiple rod mechanical effects
7. Multiple rod thermal effects
8. Plant component/system data

Table 5-2 of the LTR assigns a separate importance ranking to each phenomenon for the four AOO groups (PI/PD, RI/RD, FI/FD, and TI/TD) and ATWS and provides the rationale for the rankings.

3.6 Analysis Methodology

LTR Section 6 documents the generic, top-level analysis methodology used for each transient group classified in LTR Section 2. This material is supplemented by the uncertainty evaluation methods provided in LTR Appendix B. The proposed methodology uses a combination of uncertainties, conservative values, and nominal values having no uncertainty components; the details are discussed further in the subsequent SER sections. The objective of the analysis is to ensure that appropriate plant conditions are used to obtain the fuel and core operating limits and to verify the adequacy of the protective systems.

The methodology described in the LTR enables the evaluation of each potentially limiting transient and ATWS event to determine the limiting plant condition(s) throughout the entire ABWR operating domain. If an event is found to conservatively bound all other possible events, the bounding event may be used to establish operating limits for first cores and/or reload cores.

The LTR describes the methodology for calculating the operating limit minimum critical power ratio (OLMCPR) and incorporating uncertainties therein, as well as the methodology for calculating the LHGR. Since the OLMCPR already accounts for the uncertainty, uncertainties for LHGR calculations are not incorporated. The LTR also describes the RVP overpressure protection analysis methodology, which incorporates some specific assumptions to eliminate the need to consider other failures.

The LTR states that NRC-approved one-dimensional (1D) or three-dimensional (3D) computer codes will be used for the analysis of events. The LTR also discusses the process for using 1D and 3D computer codes for simulating fuel and core performance data. The generic analysis methodology for each of the transient groupings discussed in Section 2 of the LTR discusses some of the basic code requirements needed to analyze the group of transients and some of the conservative assumptions that will be incorporated.

The LTR also lists systems used to shut down the reactor during ATWS events and the generic methodology for performing the ATWS analyses.

3.7 Uncertainty Analysis

LTR Section 7 and Appendix B describe the proposed uncertainty analysis methodology. The stated purposes of the uncertainty evaluation are to provide context for the prediction of a suitably conservative FOM and to ensure that operating limits and safety margins meet the acceptance criteria when uncertainties and biases of the input and modeling parameters are taken into account. The section proposes what it describes as a "new method using 95% probability with a 95% confidence level" for calculating these resulting "conservative values." This nomenclature means that calculated FOM will have a 95 percent probability of bounding 95 percent of the FOM range using the methodology described.

3.7.1 Selection of Input Parameters to Uncertainty Analysis

The input parameters to the DUA are chosen using guidance from the PIRT table and the analysis methodology. The PIRT ranks the phenomena or plant components (e.g., recirculation pumps, steam lines) according to their importance to the FOM under consideration. The LTR supplies a limited DUA for the demonstration case with the statement:

> *The following sections contain the description of CCA and DUA on an overall process level. Neither CCA nor DUA is performed for any particular code in this topical report.*

3.7.2 Code Capability Assessment

The CCA evaluates the ability of a computer code under consideration. The CCA uses the applicable PIRT and a database of experimental evidence concerning the capability of the code to determine whether code performance addresses with sufficient accuracy the phenomena of importance to the events under consideration. The LTR supplies a limited CCA for the demonstration case.

3.7.3 Data Uncertainty Assessment

The DUA establishes links between code-dependent input and model candidate parameters for pertinent phenomena for use in further uncertainty and sensitivity analyses. The process identifies "candidate parameters," establishes those that have large enough uncertainties to be considered "relevant parameters," and then establishes applicable probability distributions and bounding values. The phenomena or plant components subject to a statistical uncertainty analysis use probability distributions and standard deviations.

The LTR states that such distributions are derived as follows:

- [ ]a,c
- [ ]a,c
- [ ]a,c

3.7.4 Uncertainty Analysis Methodology

LTR Section 7.4 describes the methodology for determining the combined bias and uncertainty when evaluating operating limits or safety margins relative to the applicable acceptance criteria. The evaluation methodology includes the following steps:

- The desired tolerance limits are defined, and for AOOs and ATWS events, the LTR presents the uncertainty results for each operating or safety limit as compared to the relevant acceptance criteria in terms of 95/95 values.
- [ ]a,c
- [ ]a,c
- A determination of the uncertainty intervals for parameters of interest is performed following the guidelines defined in NUREG/CR-5249 (Ref. 12). Probability distributions for the input parameters are defined as discussed in Section 3.7.3 of this SER.
- [ ]a,c
- The plant response to a transient is computed for each of the *n* cases by using each of the run matrix values as input to the computer code that calculates the desired FOM.
- The results are tested for normality using methods such as the Anderson-Darling normality test. If the data pass the normality test, the 95/95 value is calculated using the statistical properties of the normal distribution method as shown in LTR Appendix B, Equation 28. If the computed results do not pass the normality test, the order statistics method (a non-parametric statistics method) is used instead to determine the 95/95 value. In this method, the results are ranked from highest to lowest, and the 95/95 value

corresponds to the largest (in case of an upper limit) or the smallest (in case of a lower limit) of the obtained *n* results. [

]^{a,c}

The combination of PIRT rankings and CCA dictates which phenomena/plant components are subject to uncertainty analysis, as shown in LTR Table 7-1. The phenomenon/plant component may undergo the statistical treatment described in the LTR, be assigned a conservative value, or be evaluated at its nominal value with no uncertainty analysis performed.

3.8 Demonstration Analysis

Section 8 of the LTR provides an example calculation for demonstration purposes, not as a contribution to a licensing application, for a single transient. The transient selected is a generator load rejection without bypass (LRNBP). This transient assumes fast closure of the turbine control valves (TCVs), resulting in a sudden reduction of steam flow and a rapid increase in the RCS pressure. This transient therefore belongs to the PI transient class.

The analysis presents the evaluation of only one FOM, OLMCPR. Table 8-1 of the LTR identifies phenomena that significantly influence OLMCPR.

Since the computer code BISON (Refs. 13 and 14), a one-dimensional code, is selected as the underlying transient analysis code for demonstration purposes, the phenomena identified are evaluated in the CCA to determine the applicability of BISON to perform the analysis of the transient. The DUA then aims to link the "high" ranked phenomena to the selected code inputs and define the distribution functions and bounding values for each parameter required.

The LTR states that conservative values are employed for certain parameters described in LTR Section 8.6.1, including the decision to perform the analysis [

]^{a,c} The logic and means are similar in concept to using values of parameters based on technical specification limits (e.g., operating points and valve operating times), conservative and approved methods (e.g., CPR), and values determined from design documents (e.g., scram tables).

The LTR presents the transient calculation for the nominal case and the case considering the uncertainties. In both cases, the analysis uses a combination of conservative assumptions and statistically treated parameters as directed by the DUA. The analysis for the nominal case does not consider the uncertainty in different plant parameters and results in [

]^{a,c} Considering the uncertainty in the cited parameters and applying the uncertainty analysis technique discussed in the LTR results in [ ]^{a,c}

4. TECHNICAL EVALUATION

4.1 Introduction

The staff's evaluation considers the original LTR (Ref. 1), the revised LTR (Ref. 2), and all NRO RAI responses (Refs. 17, 18, 24, 25, 27, 31, and 35). In addition, the NRO staff considered all NRR RAIs and responses for their applicability to ABWR.

The LTR states that the current documentation is only a portion of what will eventually become the complete documentation package for the EM. NRO-RAI 1 (Ref. 15) requested information on the extent of documentation pertaining to this LTR and how it relates to the total package, and follow-up NRO-RAI 1b S01 (Ref. 16) inquired about validation for the EM.

The responses to NRO-RAI 1 (Ref. 17) and NRO-RAI 1b S01 (Ref. 18) clarified how this LTR fits into the analysis system. The responses identified elements of the EM with a description of the corresponding sections in the LTR and described the applicability of the methodology utilizing the current BISON and POLCA codes. The response to NRO-RAI 1 further stated that the LTR intends to provide guidelines for the process that should be applied to the development of the code-specific topical reports that will implement this methodology. The staff finds the issue resolved because the response identified the role of the LTR in terms of an overall EM.

4.2 Transient Grouping and Plant Specification

The previous methodology report (Ref. 3) was applicable only to reload analysis for BWR/2-6 and contained a more comprehensive list of transients than that in Table 2-1 of the LTR. The staff questioned the methodology applicability in NRO-RAI 3 (Ref. 15). This RAI raised two issues. The first is whether the LTR's list of fast transients is comprehensive. The second is that some items listed in LTR Table 2-1 are accidents, not transients.

The response to NRO-RAI 3 (Ref. 17) confirmed that the list in LTR Table 2-1 is a comprehensive list of events to be analyzed using the LTR methodology. In addition, the response stated that the use of the term "transient" in this and other such reports is generally applicable to discussions of AOOs, ATWS events, and accidents. The response explained that this usage is consistent with that in previous topical reports and that it is desirable to be consistent with the overall framework of approved methods. The response committed to update the original LTR Section 1.3 to be consistent with this terminology. The staff finds this terminology and update acceptable since it is consistent with previously approved topical reports. Therefore, the staff concludes that NRO-RAI 3 is resolved.

The NRR staff also raised these issues in NRR-RAIs 4 and 6 (Ref. 19). The responses to these RAIs (Refs. 20 and 21, respectively) do not alter the evaluation of the response to NRO-RAI 3. The response to NRR-RAI 4 provided a useful table showing the methodology mapping between the events considered in the LTR and those in the original reload methodology (Ref. 3). This table, with that provided in the response to NRO-RAI 1 discussed in Section 4.1 of this SER, provides a roadmap of the approach to analyzing the events in SRP Chapter 15.

In NRR-RAI 14 (Ref. 19), the NRC staff pointed out that the event category "Feedwater flow increase/decrease" in Table 2-1 should only consider FD transients because the FI event is included among the PI transients. The response (Ref. 22) clarified that an FI is treated in the "Feedwater flow increase/decrease" category **[**

]^{a,c} In addition, a footnote was added to Table 2-1 in the LTR clarifying the event categorization questioned in the RAI. The NRO staff finds the response and footnote acceptable with regard to ABWR. NRR will evaluate this response with regard to BWR/2-6 separately.

NRO-RAI 2 (Ref. 15) and its supplement (Ref. 16) discussed the use of the term "infrequent event," which is not expected to be applicable to the ABWR. The responses to NRO-RAI 2

(Ref. 17) and NRO-RAI 2 S01 (Ref. 18) stated that the LTR is applicable to the ABWR as well as BWR/2-6. Due to differences in plant designs and licensing commitments, the frequency of an initiating event may vary from one plant design to another. Since the EM will be applied on a plant-specific basis, the response stated that the correct category of event will be analyzed appropriately during plant-specific licensing activities. The use of the term "infrequent event" in the LTR is therefore acceptable, and NRO-RAI 2 and NRO-RAI 2 S01 are resolved. NRR-RAI 1 (Ref. 19) also raised this issue. The corresponding response (Ref. 23) is consistent with, and does not alter the evaluation of, the responses to NRO-RAI 2 and its supplement.

According to SRP Section 15.8 regarding ATWS mitigation in BWRs, "[e]quipment shall be provided to initiate an automatic reactor coolant recirculation pump trip under conditions indicative of an ATWS" (Ref. 5). The ATWS mitigation methods listed in Section 2.2 of the LTR do not include such a statement, although Section 6.5 of the LTR does indicate such intent. As a result, NRO-RAI 4 (Ref. 15) asked for clarification of the methods that will be used for ATWS mitigation.

The response to NRO-RAI 4 (Ref. 17) described the equipment and procedures available for ATWS mitigation; in addition, it stated that the methods and procedures used are plant-specific and can be manually or automatically initiated. According to the response, the automatic reactor coolant recirculation pump trip (RPT) and other mitigation methods (e.g., feedwater runback) are accounted for in the ATWS analyses to determine the ability to shut down the reactor independent of a reactor scram. This response provides assurance that RPT and other operations, such as feedwater runback, are available and active in the analysis if appropriate conditions are encountered. Therefore, the response is acceptable, and NRO-RAI 4 is resolved.

In conclusion, the staff finds the transient grouping and plant specification information presented in the LTR acceptable.

4.3 Acceptance Criteria

As NRO-RAI 5 pointed out (Ref. 15), for AOOs, the pressure acceptance criteria reference was erroneously given as SRP 4.2 instead of SRP 5.2.2 in LTR Section 3.1. NRO-RAI 5 also asked the applicant to confirm the applicability of the 120 percent design pressure limit for ATWS events based on the SRP 15.8 ATWS limit of ASME Service Level C since the LTR cites a 110 percent upset limit.

The response to NRO-RAI 5 (Ref. 17) committed to correct the SRP reference in LTR Section 3.1. The response also clarified that a value of 120 percent design pressure will be used when evaluating reactor pressure vessel integrity during ATWS events. The staff finds the response and change in LTR Revision 0-2 acceptable because they confirmed appropriate referencing and use of acceptance criteria, and the RAI is resolved.

Because the LTR did not include separate acceptance criteria and FOM for some events typically considered accidents in operating plants' licensing bases, NRR-RAI 2 (Ref. 19) requested the applicant to clarify whether the AOO criteria and FOM are to be applied for accidents and infrequent events within the scope of the LTR. The response to NRR-RAI 2 (Ref. 20) committed to add new text to LTR Section 3.1 explaining the AOO acceptance criteria and revised references to the GDC in LTR Section 3.1.1, "ATWS acceptance criteria," points 2 and 3. This response does not alter the evaluations of the response to NRO-RAI 5, and the NRO staff finds the response and addition acceptable with regard to ABWR since they provided clarification and correction. However, NRR will evaluate this response with regard to BWR/2-6 separately.

Section 3.2 of the LTR provides the FOM determined to be important for AOO and ATWS events. These FOM are quantitative values used to determine whether the reactor system performance satisfies the acceptance criteria. For AOOs, FOM include MCPR, LHGR, and RVP; for ATWS, FOM include cladding temperature, RVP, and mass and energy released to containment.

Revision 0 of the LTR stated:

> *[f]or phenomena identification purposes there is no need for evaluation against fuel enthalpy because, for the transients of interest, the fuel enthalpy limit is met if the MCPR safety limit is met. Thus, a fuel enthalpy analysis will not introduce any new phenomena that are not already covered by the MCPR FOM.*

Even though there is no need to evaluate the fuel enthalpy for phenomena identification purposes, the basis for assuming that the fuel enthalpy limit is met if the MCPR meets the safety limit is not clear from the LTR. NRO-RAI 6 (Ref. 15) requested the applicant to clarify the basis for this assumption.

The response to NRO-RAI 6 (Ref. 24) noted that the fuel enthalpy limit exists to provide protection from rapid energy deposition events and therefore is not used for the fast transient and ATWS events listed in LTR Table 2-1. The response also committed to revise the above statement in LTR Section 3.2 to explain that fuel enthalpy is not used as a FOM since it does not introduce phenomena not already covered by the MCPR, RVP, and LHGR. The staff finds the response and revision in LTR Revision 0-2 acceptable because it corrected the misstatement. Therefore, the RAI is resolved.

In conclusion, the staff finds the acceptance criteria information presented in the LTR acceptable.

4.4 Phenomenological Description

The LTR provides a general description of each of the transient groups (PI/PD, RI/RD, FI/FD, and TI/TD). The events pertaining to each category are discussed briefly.

The LTR states that the performance of the ABWR in response to the transients described will be provided in other licensing documents, such as the SAR, DCD, or license amendments, with the understanding that the methodology outlined in the LTR is general and that the actual EM will be completely described and be self-sufficient in subsequent plant licensing submittals. This is acceptable to the staff.

The LTR considers the reactor coolant pump rotor seizure/shaft break events as members of the RD transient group. In NRO-RAI 7 (Ref. 15), the staff questioned the inclusion of this accident category event in the transients. The response (Ref. 24) clarified that the LTR uses the term "transient" for all fast transients regardless of event classification. As discussed in Section 4.2 of this SER in reference to NRO-RAI 3, the staff finds this reasoning acceptable, and the RAI is resolved.

NRR-RAI 17 (Ref. 19) questioned the applicability of the description of the PI event initiation to the FI transient that is included in the PI/PD category. Similarly, NRR-RAI 18 (Ref. 19) requested clarification on a PI phenomenon description. The applicant's responses (Ref. 23) clarified the transient descriptions and re-emphasized that an FI transient evolves into the PI transient group due to pressure increase following TSV closure. The responses also agreed to modify the text in Section 4.1.1 of the LTR accordingly. The staff finds the responses and changes in Revision 0-2 of the LTR acceptable with regard to ABWR because they provide clarification on the transient evolution. NRR will evaluate these responses with regard to BWR/2-6 separately.

In conclusion, the staff finds the phenomenological description information presented in the LTR acceptable.

4.5 Phenomena Identification and Ranking

As stated in Subsection 1.1.4 of RG 1.203, the EM development and assessment should be based on a credible and scrutable PIRT. The development of this PIRT is an important step in the EM development and assessment process. The PIRT is used to determine the requirements for the physical model development, scalability, validation, and sensitivity studies.
The importance rankings used are "high," "medium," and "low," and all such rankings are quoted to indicate that they are rankings in the main body of this text.

The staff notes that the phenomena identified under [$]^{a,c}$

The set of components/systems identified under Category H in the LTR PIRT does not include [$]^{a,c}$ The modeling of [$]^{a,c}$ is essential for many AOOs considered in the LTR. RG 1.203, Subsection 1.1.4 recommends PIRT development down to the component function or component performance parameter level. In such cases, [$]^{a,c}$, as are feedwater lines from feedwater pumps. The staff notes that greater granularity in PIRTs is generally desirable. Therefore, NRO-RAI 8 (Ref. 15) requested the applicant to provide the basis for not including the [$]^{a,c}$ and the associated phenomena in the PIRT.

The response to NRO-RAI 8 (Ref. 17) clarified that [$]^{a,c}$ The staff accepted the clarification and the commitment to update LTR Table 5-2 and A-1. However, the later response to NRR-RAI 11 S1 (Ref. 29) committed to separate the PIRT component H8 into two distinct phenomena: H8, [$]^{a,c}$ and H19, [$]^{a,c}$ The response also did the same for H1, [$]^{a,c}$ and the new component H18, [$]^{a,c}$ however, LTR Revision 0-2 states that [$]^{a,c}$ The resulting changes, which the staff confirmed in Revision 0-2 of the LTR, provide increased granularity and are acceptable to the NRO staff with regard to ABWR.

Therefore, NRO-RAI 8 is resolved. NRR will evaluate the responses to NRR-RAI 11 and NRR-RAI 11 S1 with regard to BWR/2-6 separately.

4.5.1 PIRT Importance Ranking

The PIRT presented in the LTR provides the rationale for importance ranking of each phenomenon. However, the LTR did not adequately describe the rationale for some phenomena, and the staff issued RAIs as follows:

A1, [ ][a,c] In the LTR, the [ ][a,c] is assigned a "high" ranking for the PI/PD and ATWS transients and "medium" and "low" rankings for other transients. The reason for these transient-specific ranking differences was not clear from the rationale provided in Table 5-2 of the LTR, as was pointed out in NRR-RAI 8a (Ref. 19).

The response to NRR-RAI 8a (Ref. 21) noted that [

][a,c] The staff finds the response acceptable with regard to ABWR because of the [ ][a,c] and confirmed the changes in LTR Revision 0-2. Therefore, the issue in NRR-RAI 8a is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

Furthermore, the response to NRR-RAI 13 (Ref. 22), which requested a basis for [ ][a,c] not being ranked "high" when [ ][a,c] is ranked "high" (Ref. 19), committed to revise the definition of the [ ][a,c] (A1) phenomenon in Table A-1 to clarify that it is a function of [ ][a,c] The NRO staff concludes the response is acceptable with regard to ABWR because [ ][a,c] The staff confirmed the change in LTR Revision 0-2. Therefore, NRR-RAI 13 is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

A2 [ ][a,c] and A3, [ ][a,c] In the BWR LOCA PIRT, the [ ][a,c] were assigned a "high" and "medium" ranking, respectively. However, the LTR PIRT ranks these properties "low." The reason for this lower ranking was not clear from the rationale provided in Table 5-2 of the LTR, as was pointed out in NRO-RAI 9b (Ref. 16).

The response to NRO-RAI 9b (Ref. 17) clarified that the "high" ranking of [ ][a,c] in the LOCA PIRT is due to concern regarding [

][a,c] The staff concludes this ranking is acceptable because the core remains covered for AOOs and ATWS events. Therefore, this issue in NRO-RAI 9b is resolved.

NRO-RAI 9b S01 (Ref. 16) and NRO-RAI 9b S02 (Ref. 26) sought clarification for the ranking of [ ][a,c] The LOCA PIRT ranked this phenomenon "high" due to its [ ][a,c] The applicant's responses (Refs. 25 and 27, respectively) provided detailed analyses of [ ][a,c] The information presented supports the "low" ranking assigned to [ ][a,c] therefore, the response is acceptable, and NRO-RAI 9b and its supplements are resolved.

A4. [ ]a,c The initial rationale of Phenomenon A4 aimed to clarify that the [ ]a,c should not be double-counted in A4. A4 considers [

]a,c Therefore, NRR-RAIs 8b and 13 (Ref. 15) inquired about the rationale for A4. The response to NRR-RAI 8b (Ref. 21) provided revised rationale for A4. The staff confirmed the changes in Revision 0-2 of the LTR and finds them acceptable with regard to ABWR because the revised rationale emphasizes that the phenomenon does not concern the [ ]a,c Therefore, the issue in NRR-RAI 8b is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

A7. [ ]a,c The phenomenon descriptions for A7 and A18, [ ]a,c were not clear, as was identified in NRO-RAI 9e (Ref. 15). The applicant provided a clarification in response (Ref. 17). NRO staff then issued NRO-RAI 9e S01 (Ref. 16) requesting the applicant to confirm that the revised Phenomenon A7 refers to the [ ]a,c while Phenomenon A18 refers to [ ]a,c The response (Ref. 18) confirmed this information and agreed to update Table A-1 of the LTR accordingly. Therefore, NRO-RAI 9e and its supplement are resolved.

NRO-RAI 10g S01 (Ref. 16) pointed out that the description of Phenomenon A7 did not contain sufficient detail on the fundamental processes represented therein. The applicant's response (Ref. 18) provided detail for Phenomena A7 and D5, [ ]a,c to explain more clearly the phenomena and [ ]a,c and committed to update LTR Table A-1 accordingly.

The staff finds these responses acceptable because they provided the staff understanding of the phenomena. In addition, the staff confirmed the changes in Revision 0-2 of the LTR; therefore, the issues in NRO-RAI 10g S01 are resolved.

A8. [ ]a,c This initial condition was ranked "medium" because it can affect [ ]a,c This appeared to be inconsistent with the "low" ranking assigned for the [ ]a,c (Phenomenon A2), an issue raised by NRO-RAI 9c (Ref. 15). The response (Ref. 17) indicated that the influence ranking for Phenomenon A8, [ ]a,c would be updated in the LTR to correspond to the influence ranking for Phenomenon A2. NRO-RAI 9c S01 (Ref. 16) also asked the applicant to provide the basis for the ranking. The response (Ref. 25) demonstrated the appropriateness of the rankings through sensitivity calculations; therefore, these responses are acceptable. The staff confirmed the indicated update in LTR Revision 0-2, so the issues in NRO-RAIs 9c and 9c S01 are resolved.

The previously discussed NRR-RAI 8a also requested a basis for Phenomenon A8. The response (Ref. 21) committed to update the rationale for Phenomenon A8 to "low" to clarify that it has [ ]a,c The NRO staff concludes that [ ]a,c and therefore finds the response acceptable with regard to ABWR. The staff confirmed the changes in LTR Revision 0-2. Therefore, the issue in NRR-RAI 8a is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

A11. [ ]a,c and A14. [ ]a,c This initial condition was ranked "medium" for the PI/PD transient category and for ATWS events. [ ]a,c during a transient.

A "medium" ranking was consistent with the ranking assigned for the [ ]^{a,c} (Phenomenon A14) for PI/PD transients and ATWS. However, for RI/RD transients, the [ ]^{a,c} is assigned a "low" ranking, and the [ ]^{a,c} is assigned a "medium" ranking. NRO-RAI 9d (Ref. 15) pointed out this inconsistency.

The response (Ref. 17) committed to revise the LTR to make the ranking of [ ]^{a,c} consistent with the ranking of the [ ]^{a,c} for the RI/RD transients as "medium." NRO-RAI 9d S01 (Ref. 16) asked the applicant to justify this ranking. The response (Ref. 25) reported results from sensitivity calculations that show phenomena A11 and A14 should actually be ranked "low" for the RI/RD transients and committed to rank them as such in the LTR. This is acceptable to the staff, and the staff confirmed that Phenomenon A11 was updated accordingly in LTR Revision 0-2.

The staff notes that Phenomenon A14 was not updated in Revision 0-2 of the LTR. However, the ranking of Phenomenon A14 as "medium" instead of "low" for the RI/RD transient category is conservative. Medium-ranked phenomena have a moderate effect on FOM, whereas low-ranked phenomena have little or no effect. Therefore, modeling accuracy is more important for medium-ranked phenomena. In addition, the [ ]^{a,c} Though the staff agrees based on the RAI response that Phenomenon A14 could be ranked as "low" for the RI/RD transients, its ranking as "medium" is also acceptable due to the discussed conservatism. Therefore, the issue in NRO-RAIs 9d and NRO-RAI 9d S01 is resolved.

NRR-RAI 9b (Ref. 19) raised similar issues, and the response (Ref. 21) provided additional sensitivity calculations for all transient classes (PI/PD, RI/RD, FI/FD, and TI/TD) including ATWS to assess the rankings of Phenomenon A11. The response showed that [ ]^{a,c} (A11) is unimportant to AOO events but may be important to the [ ]^{a,c} for ATWS events. Consequently, the response proposed a "low" ranking for all AOO transients and "high" ranking for ATWS events for Phenomenon A11 and committed to update Table 5-2 of the LTR, including the rationale. The NRO staff concludes the response is acceptable with regard to ABWR because the sensitivity calculations adequately support the rationale. The staff confirmed the change in LTR Revision 0-2. Therefore, the issue in NRR-RAI 9b is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

<u>A17, [ ]^{a,c} C4, [ ]^{a,c} and C6, [ ]^{a,c}</u>
NRR-RAI 2 S1 (Ref. 28) asked for clarification on whether updates would be made to these phenomena for plants that use [ ]^{a,c} The response (Ref. 29) committed to revise the rationale for these phenomena in the LTR. The NRO staff finds this response and the revised rationale in LTR Revision 0-2 acceptable with regard to ABWR because they specify a conservative ranking for these phenomena if [ ]^{a,c} Therefore, the issue in NRR-RAI 2 S1 is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

<u>A18, [ ]^{a,c}</u> As discussed for Phenomenon A7, [ ]^{a,c} the response to NRO-RAI 9e S01 (Ref. 18) acceptably clarified how this initial condition is different from the initial conditions considered in Phenomenon A7, and the LTR was updated

accordingly. This is acceptable to the staff, and the issue in NRO-RAI 9e S01 is resolved.

B2. [ ]a,c The [ ]a,c affects the transient through [ ]a,c While it is important that this be correctly modeled, it is not clear why the LTR ranks it "high" for ATWS events; NRO-RAI 9f (Ref. 15) raised this issue. The response (Ref. 17) explained that the [ ]a,c is ranked "high" for ATWS transients because it is [ ]a,c This response is acceptable because it justified the ranking. Therefore, the issue in NRO-RAI 9f is resolved.

NRR-RAI 8b (Ref. 19) requested similar clarification. The response (Ref. 21) proposed changes to the rationale for the Phenomenon B2 in Table 5-2 of the LTR to clarify its "high" ranking for ATWS and "low" ranking for AOO transients. The NRO staff concludes the response and resulting change to LTR Revision 0-2 are acceptable with regard to ABWR because they provided additional clarification. Therefore, the issue in NRR-RAI 8b is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

C1. [ ]a,c Since the rationale given for this phenomenon was not specific, the staff requested clarifications in NRR-RAI 8 (Ref. 19). The response (Ref. 21) clarified that this phenomenon has insignificant impact on the system response or the outcome of the transient and committed to revise the rationale in the LTR accordingly. The NRO staff finds the response and change to LTR Revision 0-2 acceptable with regard to ABWR because they provide additional clarification. Therefore, the issue in NRR-RAI 8 is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

C2. [ ]a,c These phenomena are ranked "low" in the LTR. However, in BWRs, these phenomena typically dominate [ ]a,c The correlations used to predict these phenomena could substantially influence the FOM for AOOs and ATWS. Because the LTR does not describe the basis for the "low" ranking, NRO-RAI 9g (Ref. 15) sought clarification.

The response to NRO-RAI 9g (Ref. 17) explained that [ ]a,c is ranked "low" because the [ ]a,c is sufficiently large to make the [ ]a,c (Phenomenon E2) the key phenomenon dictating the coupling between the [ ]a,c for transient system response. Therefore, the staff determines the "low" ranking of Phenomenon C2 is justified. The issue in NRO-RAI 9g is resolved.

D4. [ ]a,c NRR-RAI 10 S1 (Ref. 28) requested the applicant to update the definition of this item. The response (Ref. 29) committed to revise the definition in LTR Table A-1 to clarify that it indicates [ ]a,c The NRO staff concludes that the response and change in LTR Revision 0-2 are acceptable with regard to ABWR because they provide additional clarification. Therefore, the issue in NRR-RAI 10 S1 is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

D5. [ ]a,c As discussed for Phenomenon A7 [ ]a,c the definitions of Phenomena A7 and D5 were revised, and LTR Table A-1 was updated accordingly in response to NRO-RAI 10g S01. This is acceptable to the staff, and the issue in NRO-RAI 10g S01 is resolved.

D6. [ ]^{a,c} NRO-RAI 9h (Ref. 15) asked the applicant to provide the basis for the "low" ranking of this phenomenon. The response (Ref. 17) stated that, due to the negligible amount of [ ]^{a,c} the difference between the [ ]^{a,c} becomes insignificant; thus, Phenomenon D6 is ranked "low." The staff determined that this explanation justified the "low" ranking, and the issue in NRO-RAI 9h is resolved.

E1. [ ]^{a,c} This phenomenon is ranked "low" for the AOO and ATWS events in the PIRT. However, [ ]^{a,c} is possible in AOO and ATWS events; therefore, the basis for the ranking assigned is unclear, as was pointed out in NRO-RAI 9i (Ref. 15). The response (Ref. 17) noted that the [ ]^{a,c} are not expected in AOOs or ATWS. As a result, Phenomenon E1 is assigned a "low" ranking. The staff concludes that the "low" ranking is acceptable because the core remains covered for AOOs and ATWS events, and the issue in NRO-RAI 9i is resolved.

E4. [ ]^{a,c} This phenomenon is ranked "low" for the AOO and ATWS events. However, as NRO-RAI 9j S01 (Ref. 16) noted, it is not clear whether the [ ]^{a,c} is insignificant for the calculation of [ ]^{a,c} The response (Ref. 18) provided a scaling analysis to estimate the [ ]^{a,c} The response stated that for the [ ]^{a,c} case, the contribution from the [ ]^{a,c} which is small compared to the estimated [ ]^{a,c} The staff concludes that the [ ]^{a,c} is small enough to rank the phenomenon "low," and the issue in NRO-RAI 9j is resolved.

E6. [ ]^{a,c} This PIRT ranks this phenomenon as "low" for ATWS events. Since this is a FOM for ATWS events, the staff expected it to be of greater importance, and NRO-RAI 9k S01 (Ref. 16) requested the applicant to explain the rationale for this ranking. The response (Ref. 18) clarified that this phenomenon refers to the influence of [ ]^{a,c} The response committed to update the description of Phenomenon E6 in LTR Tables 5-2 and A-1 to reflect this clarification. The staff concludes the clarification is acceptable and confirmed the change in LTR Revision 0-2, so the issue in NRO-RAI 9k is resolved.

G1. [ ]^{a,c} and G2. [ ]^{a,c} These phenomena are assigned a "low" ranking for AOOs and ATWS. However, [ ]^{a,c} begins to have some significance. The staff expected that for ATWS events, these phenomena could have greater importance under conditions of [ ]^{a,c} Therefore, NRO-RAI 9l (Ref. 15) sought a basis for the ranking. The response (Ref. 17) stated that in AOOs and ATWS, the [ ]^{a,c} The staff concludes that, due to the core being covered, these phenomena are of low importance; therefore, the issue in NRO-RAI 9l is resolved.

H5. [ ]^{a,c} NRR-RAI 9c S1 (Ref. 28) questioned the statement that [ ]^{a,c} The response (Ref. 30) committed to update the rationale for this phenomenon to clarify that its purpose is to deal with the [ ]^{a,c}

[ ]a,c The response also noted that the [ ]a,c is explicitly covered by Phenomenon D8, [ ]a,c that was added to LTR Table A-1. The staff finds the response and change in LTR Revision 0-2 acceptable with regard to ABWR since they add clarification. Therefore, the issue in NRR-RAI 9c S1 is resolved for this review. NRR will evaluate this response with regard to BWR/2-6 separately.

In summary, the responses to the NRO-RAIs and their supplements in the above list are acceptable, and the stated concerns are resolved. The PIRT in Table 5-2 of the LTR and the phenomena definitions in Table A-1 were revised in accordance with the RAI responses provided.

4.5.2 PIRT Phenomena

The staff found that the LTR PIRT did not identify several phenomena that could play an important role under the conditions of the AOO and ATWS events. The staff issued RAIs requesting the applicant to provide an explanation for the lack of inclusion of the following phenomena in the PIRT:

[ ]a,c is typically important for the transients identified in the LTR. As NRO-RAI 10a (Ref. 15) pointed out, the [ ]a,c The response to NRO-RAI 10a (Ref. 17) explained that [ ]a,c is covered in the PIRT under Phenomenon H9, [ ]a,c Because the phenomenon is accounted for, the staff finds the response acceptable. The issue in NRO-RAI 10a is resolved.

[ ]a,c This issue was raised in NRO-RAI 10b (Ref. 15). The response to NRO-RAI 10b (Ref. 17) stated that the phenomena were covered by phenomena already in the PIRT, but the staff disagreed and issued NRO-RAI 10b S01 (Ref. 16). NRR-RAI 10a (Ref. 19) posed a similar question. The responses to NRO-RAI 10b S01 (Ref. 18) and NRR-RAI 10a (Ref. 23) proposed to update the PIRT to include Phenomenon D7, [ ]a,c as a separate phenomenon and to update LTR Tables 5-2 and A-1 accordingly. The responses also provided a detailed description of this phenomenon and its rankings for AOOs and ATWS. The staff concludes the responses adequately described the definition, rankings, and rationale, and the addition to the PIRT in LTR Revision 0-2 is acceptable. Therefore, the issues in NRO-RAI 10b, NRO-RAI 10b S01, and NRR-RAI 10a are resolved for this review. NRR will evaluate the response to NRR- RAI 10a with regard to BWR/2-6 separately.

[ ]a,c This phenomenon is modeled as [ ]a,c of the original BISON LTR, RPA 90-90-P-A (Ref. 43). As noted in NRO- RAI 10c (Ref. 15), [ ]a,c The response (Ref. 17) clarified that [ ]a,c is evaluated as part of Component H2, [ ]a,c in the PIRT. The description of phenomenon H2 provided in Table A-1 of the LTR indicates this as well. The response is acceptable because it shows that [ ]a,c is accounted for, so the issue in NRO- RAI 10c is resolved.

[ ]a,c As noted in NRO-RAI 10d (Ref. 15), the phenomenological description of fast transients and ATWS events in Section 4 of the LTR indicates there is a substantial interaction between the [ ]a,c The response (Ref. 17) clarified that [ ]a,c are included in Phenomena B1, [ ]a,c B3, [ ]a,c and B9, [ ]a,c in the PIRT. The response is acceptable because it clarified how the phenomena [ ]a,c so the issue in NRO-RAI 10d is resolved.

[ ]a,c NRO-RAI 10e S01 (Ref. 16) noted that prediction of [ ]a,c can affect the progression of AOOs and ATWS. The response (Ref. 18) committed to include Phenomenon H17, [ ]a,c as a separate phenomenon in the PIRT and to update LTR Tables 5-2 and A-1. The response also provided a description of the phenomenon and its ranking for the AOOs and ATWS. This response is acceptable because it adds consideration of the [ ]a,c and the staff confirmed the revision in LTR Revision 0-2. Therefore, this RAI is resolved.

[ ]a,c is typically important for [ ]a,c as NRO-RAI 10f S01 (Ref. 16) and NRR-RAI 10b (Ref. 15) noted. The responses (Refs. 18 and 23, respectively) proposed to update LTR Tables 5-2 and A-1 to include D8, [ ]a,c as a separate phenomenon. The responses also provided a description of this phenomenon and its ranking for AOOs and ATWS. The responses to NRO-RAI 10f S01 and NRR-RAI 10b are acceptable because they added the relevant phenomenon, and staff confirmed the change in LTR Revision 0-2. Therefore, NRO-RAI 10f S01 and NRR-RAI 10b are resolved for this review. NRR will evaluate the response to NRR-RAI 10b with regard to BWR/2-6 separately.

[ ]a,c is typically important for the simulation of [ ]a,c As discussed in Subsection 4.5.1 of this SER, the response to NRO-RAI 10g S01 (Ref. 18) provided updated descriptions of Phenomena A7, [ ]a,c and D5, [ ]a,c and committed to update LTR Table A-1 accordingly. The response is acceptable because it added the [ ]a,c phenomenon, and the staff confirmed the changes in LTR Revision 0-2. Therefore, the issue is resolved.

[ ]a,c The staff noted that [ ]a,c is ranked "high" and that it would be determined from input, including the [ ]a,c Therefore, the staff issued NRO-RAI 10h (Ref. 15) requesting an explanation for not including the [ ]a,c in the PIRT. The response (Ref. 17) clarified that the [ ]a,c is evaluated from the core simulation at initial conditions and is part of Phenomenon A5, [ ]a,c in the PIRT. The response is acceptable because it clarified that the [ ]a,c is already part of a phenomenon, so the RAI is resolved.

[ ]a,c As discussed in NRO-RAI 10i S01 (Ref. 16) and NRR- RAI 10b (Ref. 19), [ ]a,c

[

][a,c] Therefore, the RAIs requested justification for [
][a,c] as a PIRT phenomenon. The responses to these RAIs (Refs. 18 and 23, respectively) proposed four new phenomena: D8, [ ][a,c] D9, [
][a,c] D10, [ ][a,c] and D11, [
][a,c] to account for the importance of [
][a,c] The responses committed to update LTR Tables 5-2 and A-1 accordingly. The responses also provided descriptions of these phenomena and their rankings for the AOOs and ATWS. The responses are acceptable because they provided new phenomena that capture the [ ][a,c] and the staff confirmed the changes in LTR Revision 0-2. Therefore, the issues in NRO-RAI 10i S01 and NRR-RAI 10b are resolved. NRR will evaluate the response to NRR-RAI 10b with regard to BWR/2-6 separately.

In conclusion, the responses to the above NRO-RAIs and their supplements are acceptable, and the staff confirmed the above changes in LTR Revision 0-2. Therefore, the stated concerns and corresponding RAIs are resolved.

LTR Rev. 0, Section 1.1 states, "[t]he methodology described in this topical report is code independent and is applicable to both 1-D and 3-D transient analysis codes." However, the PIRT presented in Section 5 of LTR Rev. 0 did not identify any 3D phenomena. NRO-RAI 11 (Ref. 15) was issued to obtain additional information.

The response to NRO-RAI 11 offered a few examples of PIRT phenomena that may have 3D effects on the plant (Ref. 17). However, the staff felt this list was not comprehensive and issued NRO-RAI 11 S01 (Ref. 16) requesting additional details. The response (Ref. 18) provided a table listing those phenomena/plant components for which 3D effects are important enough to be considered in the model evaluation and development process. This information was also included in Table 5-3 of LTR Revision 0-2. The staff concludes that this table identifies phenomena/plant components for which 3D effects may be significant. Therefore, the issue in NRO-RAIs 11 and 11 S01 is resolved.

4.5.3 PIRT Development

Subsection 1.1.4 of RG 1.203 states that PIRT development is typically based upon expert opinion and can be a subjective process. However, it also states the importance of experimentation and analysis to validate the PIRT. The LTR does not document such experimentation and analysis. The staff issued NRO-RAI 13 (Ref. 15) requesting further information. The response to NRO-RAI 13 (Ref. 31) described the PIRT development process as follows:

- Formed an evaluation panel of internal company experts
- Started from NUREG-6744, which provides a LOCA PIRT
- Revised the LOCA PIRT to address non-LOCA events
- Identified AOO/ATWS items
- Evaluated the preliminary PIRT items
- Performed sensitivity studies

- Reviewed relevant literature
- Performed cross-code comparisons
- Reviewed and updated the preliminary PIRT and reevaluated it

The staff concludes that this is a reasonable PIRT development process. Therefore, NRO-RAI 13 is resolved.

In conclusion, the staff finds the phenomena identification and ranking information presented in the LTR and the associated RAI responses acceptable.

4.6 Analysis Methodology

LTR Section 6 presents the analysis methodology for each transient category defined in LTR Section 2. The evaluation process for each transient group consists of the following steps:

- Definition of the limiting condition(s) that most significantly affect(s) the analysis
- Evaluation of core and fuel operating limits
- Parameter selection process
- Specification of input parameters used in the uncertainty analysis

4.6.1 Limiting Plant States and Events

Section 6.1 of the LTR states, "[e]ach potentially limiting transient and ATWS event is evaluated for the limiting plant condition(s) throughout the plant operating domain."

NRO-RAI 14 (Ref. 15) requested clarification on this statement regarding whether the limiting event for each class of transient will be determined generically (e.g., for all ABWRs as a class) or on a plant-specific basis. The response (Ref. 31) stated that the limiting events are determined on a plant-specific basis. This is consistent with other supplied RAI responses that emphasize the need to maintain a plant-specific licensing basis that will include plant-specific transient grouping, parameter input, and analysis code(s). Therefore, the staff considers the response acceptable, and the RAI is resolved.

NRR-RAI 23 (Ref. 19) requested the applicant to expand on the discussion in LTR Section 6.1 to ensure conservatism of the methodology. The response (Ref. 21) agreed that the wording in this section was not ideal and proposed a revision. The revision includes discussion regarding the treatment of conservative parameters as discussed in the SRP and illustrates the relationship of the analytical limit to the safety limit for mitigating system setpoints. In addition, the response proposed updates for the text, introducing LTR Tables 6-1, 6-3, 6-4, 6-5, and 6-7. The NRO staff concludes the response and the proposed changes are acceptable with regard to ABWR because they provide clarification on the methodology. The staff also confirmed the changes have been incorporated in LTR Revision 0-2. Therefore, NRR-RAI 23 is resolved for this review. However, the proposed revisions, although acceptable to the issues identified in this RAI, affected the balance of conservatism associated with the methodology. The staff issued NRR-RAI 43 requesting additional information on other phenomena, and the discussion and resolution of that RAI is in Subsection 4.6.4 of this SER. NRR will evaluate the response to NRR-RAI 23 with regard to BWR/2-6 separately.

4.6.2 Fuel and Core Operating Limits

In the evaluation of LTR Section 6.2, the staff noted four issues. In NRO-RAI 15 (Ref. 15), the staff pointed out inconsistencies in the development of Equation 4 in the LTR. The response (Ref. 17) acknowledged the inconsistencies and committed to revise the noted issues in LTR Section 6.2.1. NRO-RAI 15 S01 (Ref. 16) pointed out the need for an update to Equation 2, and the response (Ref. 18) revised the equation to provide clarification. Similarly, the responses to NRO-RAI 16 (Ref. 17) and NRR-RAI 22 (Ref. 23) and 22 S1 (Ref. 29) resulted in the correction of a typographical error and changing of a subscript in Equation 5. The staff confirmed these changes in LTR Revision 0-2. NRO-RAI 15, its supplement, and NRO-RAI 16 are resolved because the equation errors were corrected; for the same reason, the staff concludes the NRR-RAI responses are acceptable with regard to ABWR. Therefore, NRO-RAIs 15, 15 S01, and 16 and NRR-RAI 22 and its supplement are resolved for this review. NRR will evaluate the response to NRR-RAI 22 and its supplement with regard to BWR/2-6 separately.

Section 6.2.1 of the LTR describes [

]^{a,c} NRO-RAI 16 (Ref. 15) requested the applicant to provide details on how these factors in the formula are determined. The response (Ref. 17) provided a correction to the formula and with details on how the two factors will be derived based on [ ]^{a,c} This response is acceptable because it clarified the unclear information on the [ ]^{a,c} The staff confirmed the correction in LTR Revision 0-2, and the RAI is resolved.

In NRO-RAI 17 (Ref. 15), the staff focused on the statement in LTR Section 6.2.1 that [ ]^{a,c} The applicant's response (Ref. 24) provided some clarification, explaining that [

]^{a,c} NRO-RAI 17 S01 (Ref. 32) requested a description of the methodology.

The response to the supplemental RAI (Ref. 25) further clarified that the process for first cores involves comprehensively evaluating AOOs throughout the allowable operating domain using a process that depends to a certain extent on the plant licensing basis and the generation of several lower-tiered documents controlled by a licensing applicant's procedures. The process results in determination of the K_p and K_f multipliers that are supplied via the core operating limits report. Potentially limiting AOOs are evaluated for the limiting plant conditions throughout the allowable operating domain using a detailed thermal-hydraulic computer code. The staff concludes that such treatment is acceptable because it utilizes the most complete combination of information available at the time; therefore, the issue is resolved. This issue was also discussed in NRR-RAI 16 (Ref. 19) using the FI transient as an example. The response to that RAI (Ref. 23) is consistent with the response to NRO-RAI 17 and its supplement and does not alter the evaluation of the NRO-RAIs.

Section 6.2.3.2 of the LTR describes the methodology used to analyze overpressurization protection. This methodology includes [

]^{a,c} However, the SRP states that the rapid closure of the TCVs associated with the loss of external load (SRP Section

15.2.1(1)) is usually more limiting than MSIV closure (SRP Section 15.2.1(4)) for overpressurization events. Furthermore, a turbine trip (SRP Section 15.2.1(2)), which involves rapid closure of the TSVs, is usually more limiting than a loss of external load. NRO-RAI 28 (Ref. 15) asked the applicant to provide the rationale for choosing [ ]^{a,c} rather than TCV/TSV closure as the dominant overpressurization event.

The response to NRO-RAI 28 (Ref. 31) explained that, based on the sequence of events during an overpressurization transient, [

]^{a,c}

The staff sought further clarification and issued NRO-RAI 28 S01 (Ref. 16) requesting information on the process and methodology used to determine other pressurization events that may be more severe than [ ]^{a,c} and the steps taken to ensure the most severe pressurization event is identified and analyzed. The response (Ref. 25) indicated that PI events are analyzed [

]^{a,c} the staff concludes that the response is acceptable. Therefore, the issue in NRO-RAI 28 and its supplement is resolved.

LTR Section 6.2.3.2 further states, "[b]ecause of the conservatism in this approach, and conservatism assumed in the event conditions, no other failures are assumed." In addition, the section discusses [

]^{a,c} However, use of the 110 percent limit is called for in the SRP, and one of the SRP acceptance criteria in SRP Sections 15.2.1-15.2.5 states "[t]he most limiting plant system single failure, as defined in "Definitions and Explanations," 10 CFR Part 50, Appendix A, must be assumed in the analysis according to the guidance of RG 1.53 and GDC 17."

NRO-RAI 30 (Ref. 15) requested clarification on this topic by asking the applicant to:

a) provide justification that the analysis does not require the assumption of the most limiting single failure in addition to the initiating event
b) confirm that the correct overpressurization limit for AOOs is 110 percent
c) identify the correct overpressurization limit to be used for ATWS
d) confirm that this also applies to initial cores

The response to NRO-RAI 30 (Ref. 24), item (a), stated that the method used for pressurization transients does consider the most limiting single failure in addition to the initiating event, as recommended by the SRP. The response to item (b) confirmed that the overpressurization limit for AOOs is 110 percent and stated that this value is used for the special event overpressure protection analysis. The response to item (c) stated that the ASME code emergency limit of 120 percent of design pressure will be used for the ATWS analyses. The response to item (d) confirmed that the overpressure protection analysis is performed on a cycle-specific basis, including first cores. The response also proposed to correct LTR Reference 6 to Reference 7 (referring to the ASME code) in Sections 6.2.3.1 and 6.2.3.2. The staff concludes that the response is acceptable because it addressed the concerns regarding overpressurization events, and the staff confirmed the change in LTR Revision 0-2. Therefore, the issues in NRO-RAI 30 are resolved.

NRR-RAI 41 (Ref. 19) raised issues regarding the method for determining the limiting overpressure event. The response (Ref. 34) explained that the method for determining the limiting overpressure event is the same as the method for determining limiting events, as discussed in NRO-RAI 28, NRO-RAI 17, and their supplements. For overpressurization analysis, [ ]a,c NRR-RAI 41 S1 (Ref. 29) requested this clarification be included in the LTR. The response (Ref. 29) provided a markup of LTR Section 6.2.3.2. The staff concludes that the NRR-RAI responses and the proposed changes are acceptable with regard to ABWR because they demonstrate that the most limiting overpressure event is evaluated. The staff also confirmed that the proposed changes have been incorporated in LTR Revision 0-2. Therefore, the issues in NRR-RAI 41 and its supplement are resolved. NRR will evaluate this response with regard to BWR/2-6 separately.

4.6.3 Analysis Codes

LTR Section 6.3 states that the methods under discussion are applicable to NRC-approved 1D and 3D dynamic codes. Since previously approved fast transient EMs have used BISON, a 1D code, significant discussion is provided in the LTR supporting the use and applicability of BISON. This discussion includes how BISON is supplied with state point information (e.g., control rod position) and cross-section information from 3D codes. Furthermore, it describes how fuel performance information and thermal-hydraulic feedback are integrated. In many respects, BISON performance is tied to the acceptable performance of higher-order spatial codes.

The material in this section required no RAIs and satisfies the review requirements for this topic.

4.6.4 Analysis Methodology

LTR Section 6.4 discusses the analysis methodology for AOOs and separates the discussion into subsections according to the categorization of the AOOs in Section 4 of the LTR: PI/PD, RI/RD, FI/FD, and TI/TD. For each AOO category, there is a discussion of the analysis code requirements and the modeling techniques required to address the transient category. LTR Section 6.4 also presents a list of parameter assumptions the stated to be conservative in the analysis of each AOO. For example, according to LTR Table 6-1, analysis of PI transients shall use [ ]a,c

The analysis code requirements discussed in LTR Section 6.4 are unique to this submittal. The code considerations are generic in that they make no presumption as to the spatial capability of the code (i.e., 1D or 3D). Furthermore, the LTR provides significant information regarding combinations or orders of events to preserve conservatism in the analysis. A series of tables (Tables 6-1 to 6-8) document the conservative assumptions intended by the methodology.

LTR Section 6.4.1.1 states:

To ensure that the condition captured in the PIRT is valid, confirmatory analysis will be performed to ensure that:

1. The limiting case that utilizes the PIRT captures unique and significant plant specific design features.

2. The analysis of transient events include combinations of the transient categories defined herein if these conditions are more limiting than the conditions analyzed in the PIRT.

NRO-RAI 29 (Ref. 15) sought additional information clarifying how combinations of transients are determined to be more or less limiting than conditions analyzed in the PIRT. The response to NRO-RAI 29 (Ref. 24) stated that the process used for fast transient analysis includes checking to determine if an event has transitioned to another transient grouping. If group changes occur, the bounding values are re-checked, and confirmatory calculations ensure that conservatism is maintained. NRO-RAI 29 S01 (Ref. 32) requested documentation of this clarification in the LTR, and the response committed to update LTR Section 6.4 accordingly in its response (Ref. 25). This response is acceptable because it clarified that the analysis is adjusted to ensure conservatism during event category transitions, and the staff confirmed the update in LTR Revision 0-2. Therefore, the issue in NRO-RAI 29 and its supplement is resolved.

NRR-RAI 26 (Ref. 19) sought clarification for limiting PI and PD transients, including transitions from one category to the other. The response to NRR-RAI 26 (Ref. 21) presented a sensitivity analysis for a PD transient (opening of all turbine and bypass valves) evolving into a PI transient to demonstrate the application of the information summarized in the response to NRO-RAI 29 S01. NRR-RAI 26 S1 (Ref. 28) requested confirmation that the LTR would be updated to reflect the changes required for LTR Subsection 6.4.1.3.1. The response (Ref. 29) included a set of changes to Table 6-3 and Subsection 6.4.1.3.1. The staff concludes that the response to NRR-RAI 26 and its supplement and the related changes to LTR Revision 0-2 are acceptable with regard to ABWR since they provide additional insights into the issue previously raised by NRO-RAI 29 S01 and do not alter the conclusions of that NRO-RAI response. NRR will evaluate the response to NRR-RAI 26 and its supplement with regard to BWR/2-6 separately.

NRO-RAI 31 (Ref. 15) noted that the only FOM evaluated for the demonstration case in Section 8.2 of the LTR was OLMCPR, whereas LTR Subsection 6.4.1.2.1 identifies other related parameters, such as **[** **]**^{a,c} The response (Ref. 31) clarified that Section 8 of the LTR is for demonstration purposes only and committed to modify the text in LTR Subsections 6.4.1.2.1, 6.4.1.3.1, 6.4.2.2.2, 6.4.2.3.2, 6.4.3.2.1, 6.4.3.3.2, and 6.4.4.2.2 to clarify the approach for modeling techniques. This response is acceptable because it clarified the intent of LTR Section 8.2 to provide general understanding of the process. In addition, the staff concludes the changes in LTR Revision 0-2 provide better clarification of the methodology. Therefore, the issue identified in NRO-RAI 31 is resolved. In addition, the response to NRR-RAI-16S1 (Ref. 33) proposed to add two additional analysis assumptions to the list in Section 6.4.3.2.1 of the LTR. The staff concludes these changes in LTR Revision 0-2 provide additional detail and are therefore acceptable with regard to ABWR. NRR will evaluate the response to NRR-RAI-16S1 with regard to BWR/2-6 separately.

NRR-RAI 24 S1 (Ref. 28) noted several instances of confusing usage of terms such as "moderator density coefficient" and "void coefficient." The response (Ref. 29) agreed and committed to modify the text in LTR Subsections 6.4.1.2.1, 6.4.1.3.1, 6.4.2.2.2, 6.4.2.3.2, 6.4.3.2.1, 6.4.3.3.2, and 6.4.4.2.2, as well as Tables 6-1, 6-3, 6-4, 6-5, 6-6, 6-7, and 6-8. The NRO staff concludes that these changes in LTR Revision 0-2 are acceptable with regard to ABWR since they clarify terminology. NRR will evaluate this response with regard to BWR/2-6 separately.

NRR-RAI 25 (Ref. 19) and 25 S1 (Ref. 28) raised issues regarding consistency within the LTR, particularly among several subsections of Sections 1, 6, 7 and 9. The responses (Refs. 22 and 33) included a set of LTR changes that affected Tables 6-1 and 6-3; Subsections 6.4.2.1, 6.4.3.1, 6.4.3.3, 6.4.4.2.1, 7.4.1; Appendix A; references on pages 1-2 and 5-1; and page 1-1. The NRO staff concludes that the changes to LTR Revision 0-2 are acceptable with regard to ABWR because they improve the consistency of the LTR; however, NRR will evaluate this response with regard to BWR/2-6 separately.

As a follow-up to NRR-RAI 23, which the staff considers resolved (see Subsection 4.6.1 of this SER), the staff issued NRR-RAI 43 (Ref. 28) requesting additional information on the discussion of methodology conservatism. The response to NRR-RAI 43 (Ref. 30) provided further details on the use of the hot rod and average channel approach to determine the number of failed fuel rods. [

]a,c The response to NRR-RAI 43 also clarified the intention of validating the assumed biases in Section 6.4 of the LTR for the hot and average fuel rods by performing code-specific confirmatory calculations on first application. The NRO staff concludes this approach is acceptable with regard to ABWR because it is consistent with other staff-approved methodologies; in addition, the commitment is applicable to ABWR. The staff therefore imposes the related Condition 1 in Section 5.0 of this SER. With this imposed condition, the issue in NRR-RAI 43 is resolved. NRR will evaluate this response with regard to BWR/2-6 separately.

In summary, the responses to the NRO-RAIs and their supplements related to LTR Section 6.4 are acceptable, and these RAIs (NRR-RAIs 24, 25, 26, and 43, and NRO RAI 29 and 31, supported by NRR-RAI 16S1) and their associated supplements, if any, are resolved. The staff imposes Condition 1 for validating the biases assumed for the hot and average fuel rods, as discussed above.

4.6.5 Anticipated Transients Without Scram

LTR Section 6.5 addresses the analysis methodology for ATWS. The ATWS methodology is developed to comply with the requirements of 10 CFR 50.62, which requires for new plants the availability of equipment to automatically shut down the reactor in the event of a reactor trip system failure. The same basic analysis methodology used for the AOOs is used in the ATWS analysis, except that, according to Rev. 0 of the LTR:

According to the PIRT, CCA, and DUA, [

]a,c

In this instance, it was unclear [ ]^{a,c} so NRO-RAI 18 (Ref. 15) sought additional information. The response to NRO-RAI 18 (Ref. 24) stated that for ATWS analyses, [ ]^{a,c} Clarifying changes were made in Revision 0-2 of LTR Sections 6.5.1.1 and 6.5.1.2. The staff finds the response and changes acceptable because the use of [ ]^{a,c} provides reasonable assurance of appropriate analysis results, and the issue is resolved and closed. The response to NRO-RAI 33 (Ref. 24), whose resolution is discussed in Section 4.7.1 of this SER, provided additional clarification of the meaning and intent of [ ]^{a,c}

As previously stated, the analysis methodology for ATWS events is developed to comply with the requirements of 10 CFR 50.62, which requires the availability of certain equipment to automatically shut down the reactor. As discussed in Section 4.2 of this SER, the acceptable response to NRO-RAI 4 (Ref. 17) stated that the ATWS analyses account for such equipment as well as plant responses such as automatic recirculation pump trip.

According to the LTR, the methodology for SLCS as a means of mitigating ATWS effects may credit operator action or assume automated actuation. [ ]^{a,c} In NRO-RAI 12 (Ref. 15) and NRO-RAI 12 S01 (Ref. 16), the staff sought further information about [ ]^{a,c}

The response to NRO-RAI 12 (Ref. 17) stated that [ ]^{a,c} is code-specific and beyond the scope of the current LTR but that the code would be NRC- reviewed and approved in this respect (e.g., BISON or POLCA-T). NRO-RAI 12 S01 asked for details of how model conservatism with respect to this phenomenon would be demonstrated. The response (Ref. 18) stated that the relevant FOM would be [ ]^{a,c} Procedures for establishing a particular [ ]^{a,c} as conservative with respect to this FOM, including for specific scenarios, are code-specific and discussed in other topical reports. The response is acceptable because [ ]^{a,c} is an adequate FOM, and [ ]^{a,c} are code-dependent. Therefore, the issue in NRO- RAI 12 is resolved.

NRR-RAI 20 (Ref. 19) and its supplement, NRR-RAI 20 S1 (Ref. 28), asked how control systems are modeled under this methodology, including assumptions made. The responses (Refs. 34 and 33, respectively) explained that the control systems are treated consistently with Table 7-1 of the LTR; the control system may be treated [ ]^{a,c} depending on PIRT ranking, CCA ranking, and the DUA. The responses also described the process for ensuring that [ ]^{a,c} in the PIRT. The NRO staff concludes these responses are acceptable with regard to ABWR because they demonstrate that the uncertainty treatment for control systems is consistent with the treatment for other phenomena, and the control system mode assumption is conservative.

NRR-RAI 31 (Ref. 19) and 31 S1 (Ref. 28) raised issues regarding boron settlement. The responses (Refs. 23 and Ref. 29, respectively) addressed these concerns by revising a bullet in LTR Section 6.5.1.2 to state that boron settlement will be modeled based on an NRC-approved. The NRO staff concludes the response and changes in LTR Revision 0-2 are acceptable with regard to ABWR because the modeling method is code-dependent. NRR will evaluate this response with regard to BWR/2-6 separately.

In conclusion, the responses to NRO-RAIs 20 and 31 and their supplements are acceptable, and the RAIs are resolved.

4.6.6 Conclusions Regarding the Analysis Methodology

The LTR provides guidance for fast transient and ATWS analysis methodology, including code requirements, analysis requirements, and assumptions used to preserve the conservative nature of the results generated. The staff's review is limited to a general assessment of the applicability of the methodology to fast transient and ATWS analyses. Although the analysis methodology provides detailed guidance for code assessment, LTR Section 8.4 does not demonstrate the full use of the LTR guidance for the demonstration case.

The staff notes that the analysis methodology described in the LTR is [

]^{a,c}

The LTR explains that the analyses will be performed using 1D and/or 3D NRC-approved dynamic analysis codes. When 1D analysis codes are used, the process for obtaining a 1D model from a 3D model is required. This process is not described in detail in this LTR, but it is the subject of Supplement 4 to the BISON code (Ref. 14). This LTR also describes some of the general code calculation capabilities needed for analyses and demonstrates the use of the PIRT and the CCA to justify the code selection. The staff concludes that these descriptions are acceptable.

The LTR explains that an ATWS analysis is performed to verify the adequacy of the mitigating equipment required by 10 CFR 50.62. The ATWS methodology analyzes AOOs using [

]^{a,c} The LTR describes additional specific analysis assumptions for the SLCS ATWS analyses. The staff concludes that the assumptions related to ATWS are acceptable.

The demonstration case provides a limited but valuable insight into the use of the methods outlined in this LTR. The LRNBP event, a PI transient, was chosen to demonstrate the analysis methodology. The logical progression of the methodology described in the LTR is demonstrated in a sequence of events leading to the determination of the FOM for the transient, [ ]^{a,c}

As noted in the LTR and the responses to various RAIs discussed in Sections 4.6.1 through 4.6.6 of this SER, the methodology that will be employed during licensing will be plant-specific. Consequently, the review and approval of this LTR is necessarily limited to a determination regarding the soundness of the approach described. The analysis methodology is generally acceptable. In addition, the staff confirmed that the updates committed to in RAI responses were incorporated into the LTR.

4.7 Uncertainty Analysis

The staff noted that CENPD-300-P-A (Ref. 3), the previously approved methodology for fast transient and ATWS methodology for BWRs, proposed several approaches for uncertainty analysis and that the NRC only accepted Approach A [ ]^{a,c} to evaluate fast and slow transients for BWR reload fuel.

NRO-RAI 19 (Ref. 15) requested details regarding what precedent exists for use of best-estimate methods to evaluate fast transients and ATWS and requested information on why such an approach is acceptable now. The response (Ref. 31) provided examples of when the NRC has previously accepted best-estimate methods for fast transients. The response also noted that Section 4.4 of the SRP directs treatment of uncertainties in the values of process parameters, core design parameters, and modeling parameters with at least a 95 percent probability at the 95 percent confidence level when evaluating thermal margins during AOOs. In addition, the response stated that the best-estimate method (95/95 calculations) would be used with respect to the CPR remaining above the MCPR, consistent with the guidance of SRP Chapter 15 and SRP Section 4.4. The response stated that a deterministic approach would be used for the evaluation of other AOO acceptance criteria.

Regarding the fact that NRC did not approve best-estimate methods when it first reviewed CENPD-300-P, the response to NRO-RAI 19 noted that Method B in the original CENPD-300-P submittal, which most closely resembles the proposed uncertainty analysis in this LTR, is based on the assumption of normally distributed input parameters. The response stated that Method B would not be applied to determine thermal margins and noted that the new method of treating uncertainties in this LTR imposes no requirement on the distribution function's shape for the parameters evaluated.

However, the staff had further questions on a portion of the response regarding statistical significance of the parameters in the database. Therefore, the staff issued follow-up RAIs NRO-RAI 19 S01 (Ref. 16), and NRO-RAI 19 S02 (Ref. 26). The responses (Refs. 25 and 27, respectively) explained that a dataset is considered statistically significant [ ]^{a,c} If the data pass the normality test, they are treated according to the "statistical properties of the normal distribution" method discussed in Section 4.7.4 of this SER. If the data do not pass the normality test, [ ]^{a,c}

The responses to NRO-RAI 19 and its supplements are acceptable because they establish the bases for the best-estimate methods and discuss statistical treatment similar to other treatments the staff has approved for other applications. Therefore, the issue in NRO-RAI 19 and its supplement is resolved.

The uncertainty analysis methodology discussed in Section 7 and Appendix B of the LTR provides for a best-estimate value and a 95/95 value to be determined. However, the LTR does not appear to provide some other information that would typically be available for an uncertainty analysis, such as standard deviation or variance, the shape of the underlying probability density or distribution function, and correlation of input parameter uncertainties to uncertainty in the code output. In NRO-RAI 26 (Ref. 15), the staff asked the applicant to clarify how uncertainties will be reported for transient analysis that uses the methodology outlined in the LTR.

The response (Ref. 31) stated that the analysis of variance method (which has been corrected to the statistical properties of the normal distribution method in subsequent RAI responses and the LTR, as discussed in Section 4.7.4 of this SER) will be used to obtain the 95/95 value when the result passes the normality test. However, when the normality test fails, the 95/95 value is obtained by the order statistics method, a non-parametric statistics method. This response is consistent with the statistical treatment described in other staff-approved methodologies and is therefore acceptable, and the issue in NRO-RAI 26 is resolved.

4.7.1 Selection of Input Parameters

Table 7-1 of the LTR provides guidance as to how uncertainty methods are assigned in accordance with PIRT and CCA ranking. Based on this guidance, [

][a,c] In addition, LTR Section 7.1 states that when the code capability ranking is "high" for a phenomenon, [

][a,c] This raises an issue regarding how uncertainties and biases are, or should be, addressed for phenomena that are ranked "medium" in the PIRT. SRP Section 15.0.2 states regarding the review of uncertainty analysis that the review should ensure that all important sources of code uncertainty have been addressed, including the mathematical models in the code as well as aspects of user modeling, such as nodalization. NRO-RAI 20 (Ref. 15) requested additional information on how biases are included in the proposed uncertainty methodology.

The response (Ref. 31) acceptably explained that biases and uncertainties for parameters with a "high" PIRT ranking are addressed mostly based on comparison against SETs. However, discussion of "medium" rankings did not consider combinations of uncertainties and biases, so follow-up RAIs NRO-RAI 20 S01 (Ref. 16) and 20 S02 (Ref. 26) sought additional information. The responses (Refs. 25 and 27, respectively) provided adequate justification, [

][a,c]

Therefore, the issue in NRO-RAI 20 and its supplements is resolved.

The LTR stated in several places that "nominal" values will be used for various input variables, including references to the input to the analysis treatment in Table 7-1, the data that is part of the DUA example in Table 7-3, and the DUA in Section 8.6. However, the term "nominal" is not defined in the LTR. Therefore, the staff sought explanation of this term in NRO-RAI 33 (Ref. 15).

The response (Ref. 24) provided a detailed explanation of the term "nominal" and its variations (e.g., "nominal with uncertainty analysis," "nominal without uncertainty analysis") for each location cited in NRO-RAI 33. Essentially, "nominal" refers to a rated value or a value without bias or uncertainty. The response acceptably clarifies the data input and uncertainty analysis approach, and the issue in NRO-RAI 33 is resolved.

In addition, as discussed in Section 4.8.6 of this SER, it was not clear that SRP Section 15.0.2 recommendations to treat parameters conservatively would be applied in actual analyses after staff reviewed the demonstration case. The response to NRR-RAI 36 (Ref. 21) clarified the treatment of parameters and the intent to conform to SRP Chapter 15. The staff concludes this response is acceptable with regard to ABWR because it provided additional explanation of conservative treatment of parameters, including a detailed clarification of the treatment for the demonstration case. NRR will evaluate the response to NRR-RAI 36 with regard to BWR/2-6 separately.

4.7.2 Code Capability Assessment

Section 7.2.3 of the LTR states that results from verification of model accuracy will be provided in a model assessment table. NRO-RAI 21 (Ref. 15) requested additional information about the process and criteria used to assess model accuracy. The response (Ref. 31) stated that model accuracy is judged by subject matter experts who compare model capabilities and computer run results with SET data and/or IET data. The response also provided an example of how model accuracy would be judged. The comparisons against SET and/or IET data provide an acceptable means of assessing model accuracy, so NRO-RAI 21 is resolved.

Section 7.2.4 of the LTR provides an example of a CCA matrix that rates the capability of the BISON computer code to emulate the parameter or component of interest. NRO-RAI 22 (Ref. 15) requested the applicant describe the criteria against which the qualification data will be judged in determining the sufficiency and relevancy of data to the phenomenon of interest. In addition, the RAI asked the applicant to provide additional information describing how scaling considerations are incorporated in the bias and uncertainty evaluation.

The response (Ref. 31) indicated that the relevancy of a particular test record is based on the level of applicability of the test data to a particular phenomenon or model. For example, SETs are typically highly relevant, whereas comparison to other codes is typically of medium relevancy. The response also stated that sufficiency of an experimental database is based on the completeness of the qualification data. This response provides sufficient information to understand the "relevancy" and "sufficiency" terminology but does not provide specific acceptance criteria. This issue was resolved during an audit (Ref. 6) performed by the NRC staff and contractors who reviewed the LTR, where WEC provided clarification that the judgment regarding sufficiency and relevancy is ultimately engineering judgment made by subject matter experts. This explanation satisfactorily clarified the information docketed in the RAI response, so the issue in NRO-RAI 22 is resolved.

The CCA presented is limited in scope and does not serve as a full examination of any particular code, including BISON. However, the staff concludes that the process presented is acceptable for the demonstration in the LTR.

4.7.3 Data Uncertainty Assessment

SRP Section 15.0.2 states that SETs should be used to determine the uncertainty bounds of individual physical models. NRO-RAI 25 (Ref. 15) asked the applicant to clarify how this topic is addressed in the methodology and how the uncertainty analysis in the LTR takes into account the uncertainties in the mathematical models, closure relationships in the underlying codes, and user modeling (e.g., nodalization and solution techniques). The RAI also asked the applicant to discuss how uncertainties in the experimental database are factored into the uncertainty analysis.

The response to NRO-RAI 25 (Ref. 31) explained that the DUA described in Section 7.3 of the LTR provides the process by which uncertainties in the mathematical models and closure relationships are evaluated. The response provided an example parameter (void correlation) and discussed the closure relationships in the underlying codes, user modeling, and the uncertainty analysis.

The response also explained that the uncertainties in experimental databases are addressed in two ways: (1) uncertainties in the experimental database for thermo-physical data are evaluated [ ]^{a,c} and (2) uncertainties in experimental databases arising from the experiments themselves [ ]^{a,c} (an implicit uncertainty).

NRO-RAI 25 S01 (Ref. 16) requested additional clarification on the uncertainty methodology for experimental databases. The response (Ref. 25) explained that the number of leading parameters identified for each important phenomenon (where importance of the phenomenon is determined by the PIRT) is based on the number of output parameters associated with this phenomenon that have a relevant effect on the FOM, where "relevant" is numerically defined for each FOM in the response to NRO-RAI 23 S01 (Ref. 25). The response further explains how experimental and modeling uncertainties are mathematically combined, depending on whether the uncertainties or errors are relative or absolute in nature. The staff concludes that this process is mathematically correct. The response also explained that [ ]^{a,c}

In NRO-RAI 25 S02 (Ref. 26), staff asked how leading parameters are chosen and requested clarification on the relationship among candidate parameters, relevant parameters, and leading parameters. The response (Ref. 35) explained the parameter types in detail. Candidate parameters are those that are considered for a statistical evaluation instead of using a conservative value. Relevant parameters are candidate parameters with uncertainties that could have a significant influence on FOM. Leading parameters are relevant parameters for which the uncertainty from the experimental database is combined with model uncertainty. NRO-RAI 25 and its supplements are resolved because the RAI responses adequately addressed treatment of uncertainty for experimental databases and explained the relationship among candidate, relevant, and leading parameters.

Sections 7.3 and 7.3.2 of the LTR state that candidate parameters judged to have very small uncertainties or an insignificant effect on the FOM will be removed from further analysis. NRO-RAI 23 (Ref. 15) requested the applicant to describe how it will judge whether a candidate parameter has a small uncertainty or has minimal effect on a FOM.

The response (Ref. 24) provided the criteria by which it judges whether uncertainties are so small that they can be neglected. The response provided a table that lists the limiting values by which a FOM can change when candidate parameters are evaluated at the endpoints of their expected ranges. In addition, the response shows an example of candidate parameters for a particular phenomenon and examines the change in a FOM at the endpoints of the ranges. This response is acceptable because the criteria are reasonably conservative; therefore, NRO-RAI 23 is resolved.

NRR-RAI 32 (Ref. 19) and its supplement, NRR-RAI 32 S1 (Ref. 28), discussed how discarding candidate parameters near the cut-off limit for exclusion from further analysis could collectively lead to excessive truncation errors in the FOM. The response to NRR-RAI 32 S1 (Ref. 30) stated that excluding several candidate parameters near the exclusion limits could lead to non-conservatism in the FOM results. In addition, the response included a commitment to perform

[

]^{a,c} The NRO staff finds the response acceptable with regard to ABWR because it provides a method to evaluate whether non-conservatisms exist due to truncation. The staff imposes Condition 2 in Section 5.0 of this SER for plant-specific sensitivity analyses. With this imposed condition, the issue in NRR-RAIs 32 and 32 S01 is resolved. NRR will evaluate this response with regard to BWR/2-6 separately.

The DUA presented is limited in scope and does not serve as a full examination of any particular code, including BISON. However, the staff finds the process presented acceptable for the purposes stated in the LTR subject to Condition 2 discussed above.

4.7.4 Uncertainty Analysis Methodology

The stated purpose of the uncertainty analysis in the LTR is to predict a best-estimate value of a FOM by accounting for uncertainties and biases of the input and modeling parameters to ensure that operating limits and safety margins meet the acceptance criteria. The LTR describes the process for defining applicable input and model parameters as well as the uncertainty evaluation. The LTR introduced a method that uses non-parametric statistics for including uncertainties and biases in the determination of operating limits and safety margins.

The parameters used as inputs to EMs are ranked as "high," "medium," or "low" in the PIRT. These rankings are influenced by how well the computer EM actually models the parameter of interest. In the LTR, [

]^{a,c}

When performing the uncertainty evaluation of "high" ranked parameters, the guidance in the LTR states that tolerance limits are chosen— 95/95 is used for all operating limits or safety margin to acceptance criteria—and the number of output parameters of interest is determined. These values influence the number of computer runs (*n*) that must be made to achieve the desired tolerance limits. The probability distribution of each of the "high" ranked parameters is then determined. A Monte Carlo sampling of the distributions is performed to extract parameter input values for each run (i.e., each parameter is sampled *n* times). Each of the *n* runs is performed. If the resulting FOM are determined to be normally distributed, the 95/95 level is determined by the statistical properties of the normal distribution method described in Appendix B of the LTR. If it is not normally distributed, the order statistics method is used. In this case, the largest value of the FOM among the runs represents the 95/95 value. [

]^{a,c}

If a "high" ranked parameter is not evaluated statistically, the staff finds it acceptable for it to be evaluated using conservative value(s). The practice of combining the use of conservatively treated parameters and statistically treated parameters is an acceptable interpretation of the hybrid methodology discussed in RG 1.203.

The uncertainty analysis methodology discussed in Section 6.2.1.1, Section 7.4, and Appendix B of the LTR alludes to the choice and use of an estimator grade, which influences the number of calculations that must be performed. NRO-RAI 27 (Ref. 15) asked the applicant to clarify the method for determining the estimator grade for a specific type of analysis and to provide a discussion of, or reference to, the decision-making process for the selection of the estimator grade as a function of the tradeoff between the number of calculations and the risk of over-conservatism. The response (Ref. 24) provided a reference (Ref. 36) that discusses the use of non-parametric statistics in estimating uncertainties in PCT, local maximum cladding oxidation, and core-wide oxidation for large break LOCAs. This paper includes a discussion of the estimator grade used in performing an uncertainty analysis. The staff notes that the process for evaluating uncertainties for LOCAs is useful for estimating AOO uncertainties as well.

The response also discussed the tradeoff between the number of calculations made and the risk of over-conservatism. The response described the estimator grade and associated number of code runs, as calculated using Equation 11 in LTR Appendix B, within a table that indicated the probability level correspondence to the confidence interval. The table showed that to obtain 95/95 results, [ ]^{a,c} The response is consistent with statistical practices and guidance the staff finds acceptable, so NRO-RAI 27 is resolved.

NRR-RAI 44 (Ref. 28) built upon NRO-RAI 27. The response (Ref. 29) agreed to update the discussion in LTR Section 7.4 to clarify that the first estimator grade (i.e., [ ]^{a,c} is the most conservative choice, and higher estimator grades would be chosen only when conservatisms are present in the input and modeling parameters. The NRO staff concludes that the first estimator grade is indeed the most conservative and therefore finds the response and changes in LTR Revision 0-2 acceptable with regard to ABWR. Therefore, the issue in NRR-RAI 44 as it applies to ABWR is resolved. NRR will evaluate this response with regard to BWR/2-6 separately.

NRR-RAI 40 (Ref. 19) raised a quality assurance concern that the uncertainty analysis methodology allows increasing the estimator grade and corresponding number of code runs; however, without any measures stating otherwise, the methodology allows reverting to a lower estimator grade if a higher estimator grade produced a more restrictive outcome. The response (Ref. 34) agreed to make changes to LTR Section 7.4 to ensure that such practices are prohibited. The NRO staff concludes this response and the related changes in LTR Revision 0-2 are acceptable with regard to ABWR because they help ensure conservatism in the number of code runs. Therefore, the issue in NRR-RAI 40 as it applies to ABWR is resolved. NRR will evaluate this response with regard to BWR/2-6 separately.

NRR-RAI 23 (Ref. 19), 23 S1 (Ref. 32), and 23 S02 (Ref. 37) raised several issues regarding the degree of conservatism recommended by the SRP. The detailed responses (Refs. 24, 29, and 38, respectively) included a discussion of how biases are determined. The responses also committed to update LTR Section 7.4.1 to more accurately describe how biases are considered by revising the discussion on tolerance limits in the LTR and replacing the term "analysis of variance" with the term "statistical properties of the normal distribution" in all six places it is used. The NRO staff finds these responses and changes in LTR Revision 0-2 acceptable with regard to ABWR because they provide additional background on the consideration of biases. Therefore, the issue in NRR-RAI 23 and its supplements as it applies to ABWR is resolved. NRR will evaluate this response with regard to BWR/2-6 separately.

NRR-RAI 42 (Ref. 28) requested clarification regarding the approach to combining model and experimental uncertainties. The response (Ref. 30) describes the process as being consistent with the methods used in the code scaling, applicability, and uncertainty methodology. Model uncertainties are used in the statistical evaluation of uncertainties in FOM and are applied in a [ ]^{a,c}

[

]^{a,c} The NRO staff concludes this response is acceptable with regard to ABWR because it demonstrates staff- accepted practices for combination of uncertainty. Therefore, the issue in NRR-RAI 42 as it applies to ABWR is resolved. NRR will evaluate this response with regard to BWR/2-6 separately.

The staff considered several guidance documents while evaluating the uncertainty methodology in the LTR. RG 1.203 (Ref. 4) provides broad guidance regarding uncertainties and references 10 CFR 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors" (Ref. 39). In 10 CFR 50.46, the NRC's regulatory position allows the use of statistical methods to determine a FOM such that when it is compared to limits or criteria, "there is a high level of probability that the criteria would not be exceeded."

This has been further interpreted in RG 1.157 (Ref. 40), which explains the acceptance of the 95 percent probability level as follows:

> *The basis for selecting the 95% probability level is primarily for consistency with standard engineering practice in regulatory matters involving thermal hydraulics. Many parameters, most notably the departure from nucleate boiling ratio (DNBR), have been found acceptable by the NRC staff in the past at the 95% probability level.*
>
> *... techniques that account for the uncertainty in a more detailed manner may be used. These techniques may require the use of confidence levels.*

The staff concludes that the methods outlined in the LTR can correctly result in the determination of FOM that have a 95 percent probability with a 95 percent confidence interval if the uncertainty process is properly applied. However, the staff noted that the process leading up to the statistical manipulation of the parameters of interest involves several areas where engineering judgment, rather than statistical evaluation or engineering calculations, is used to determine such areas as the ultimate rankings and binning of parameters. If the engineering judgment is faulty, it has potential to affect code outputs used for setting operating limits and safety margins. The staff also noted that there are many areas where engineering judgment is applied appropriately and successfully in evaluating nuclear reactors, including areas that are deterministic in nature.

The staff finds the uncertainty analysis as described in the LTR is mathematically correct and acceptable. It can provide statistically correct 95/95 values for FOM and can be used to establish operating limits and safety margins. The LTR and responses to RAIs address sources of code uncertainty, including the mathematical models in the code and the user-selected inputs. In addition, the staff imposes Condition 3 in Section 5.0 of this SER regarding plant-specific sensitivity analyses as part of CCA and DUA to consider the effect of discarded parameters upon FOM.

4.8 Demonstration Analysis

The demonstration case and results presented in Section 8 of the LTR rely upon the logical framework established in earlier sections. The LTR used LRNBP, a PI transient, as a demonstration of the analysis methodology. The demonstration illustrates the application of the following activities:

4.8.1 Transient Group and Power Plant Type Specification

The LTR presents a demonstration of the described capability using the generator LRNBP event. In this event, there is a complete loss of electrical load to the turbine generator coupled with the assumed failure of the turbine bypass system. The TCVs close rapidly to prevent overspeed of the turbine generator rotor. The rapid closure of the TCVs causes a sudden reduction of steam flow, which results in an RCS pressure increase. The generator LRNBP event is therefore in the PI transient class.

NRO-RAI 31, part (a) (Ref. 15) requested additional information regarding the rationale for selecting of this event. The response (Ref. 31) stated that LRNBP is typically the limiting AOO used to establish the OLMCPR. The staff notes that LRNBP is indeed typically limiting for OLMCPR, so the response is acceptable. Full resolution of NRO-RAI 31 is discussed in the next section of this report.

4.8.2 Operating Limits and Safety Margins to Acceptance Criteria

The LRNBP transient is evaluated as an AOO in the plant design basis and therefore is evaluated to determine the plant operating limits. The FOM employed is the OLMCPR. NRO-RAI 31, part (b) (Ref. 15) asked for the reasoning used to conclude that OLMCPR alone is the appropriate FOM for an overpressure transient. The response (Ref. 31) conceded that OLMCPR alone is inadequate to fully characterize the transient and explained that the intent of the presentation in the LTR is not to characterize a transient with one parameter, but rather to demonstrate the overall methodology in the LTR. For the purpose of a simple demonstration whose results cannot be used for licensing, the staff finds this acceptable. In addition, the response recognized the need for improving the description in the LTR and proposed modifications to the text in several parts of LTR Section 6.4. As discussed in Section 4.6.4 of this SER, the modifications in the LTR Revision 0-2 are acceptable. Therefore, the issue in NRO-RAI 31 is resolved.

4.8.3 Phenomena Identification and Ranking

LTR Table 8-1 lists the phenomena that significantly influence the OLMCPR FOM. The staff examined the phenomena and confirmed that they are the "high" ranked phenomena of importance to this transient. This list also helps to resolve one of the issues from NRO-RAI 31 by illustrating the method by which other parameters of importance to the transient influence the determination of the final OLMCPR. The categories of phenomena include the initial conditions, power distribution, and RCS flow and pressure conditions of greatest interest to the staff.

4.8.4 Selection of Computational Tools

LTR Section 6.4.1.1 defines the analysis code requirements for the PI transient. The LTR documents the use of the BISON code to analyze the selected transient. Based upon a review of the BISON Supplement 4 topical report (Ref. 14) and the broad history of using BISON for such analysis, the staff concludes that BISON is an appropriate computational tool for this purpose.

However, the staff notes that the demonstration case does not constitute a complete EM submittal, so although BISON may be an appropriate tool, the staff is not evaluating its acceptability in conjunction with the methodology in the LTR in this SER.

4.8.5 Code Capability Assessment

The CCA is presented in LTR Table 8-2. LTR Section 8.5 states, "Table 8-2 is presented only for demonstrational purposes. It is given without reference to the rationale for the code ranking and will not be used in licensing calculations."

For each phenomenon having a "high" rank, the CCA provides an assessment of the qualification data and BISON capability. For the qualification data, two assessments are provided: sufficiency and relevancy. The meaning of these assessments and the resolution of the related NRO-RAI 22 are discussed in Section 4.7.2 of this SER.

The staff noted that [

]a,c

BISON capability is judged to be [

]a,c

It was unclear why the LTR referred to recirculation pumps when the ABWR has RIPs, so NRO-RAI 32 (Ref. 15) sought additional information. The response (Ref. 31) explained that although reference is made to recirculation pumps, which the ABWR design does not have, the analysis actually performed modeling RIPs. The staff finds this portion of the response acceptable because the analysis is applicable to ABWR when RIPs are modeled. The remainder of the RAI and its response are discussed in Section 4.8.7 of this SER.

The process by which the limiting plant conditions and the plant operating domain are determined is not defined in this LTR and is not provided via reference to another report. This is the subject of NRO-RAI 24 (Ref. 15), which inquired about uncertainties and biases arising from the POLCA7 code that then affect the BISON model and how they propagate through the analysis and into plant operating limits.

The responses to NRO-RAI 24 (Ref. 24) and its follow-up, NRO-RAI 24 S01 (Ref. 25) explained that any bias and deviation in power distribution resulting from the comparison of POLCA7 to traversing in-core probe measurements is accounted for [

]a,c The response provided a demonstration of how the methodology accounts for biases. The response is acceptable because it adequately addressed the topic of bias from the POLCA7 code. Therefore, the issue in NRO-RAI 24 and its supplement is resolved.

4.8.6 Data Uncertainty Assessment

The LTR states that Table 8-2 is presented only for demonstration purposes. The staff considers the statement in the LTR that the DUA may not be used in licensing applications to be acceptable.

The DUA process links the "high" ranked phenomena from the PIRT with the corresponding modeling parameters and defines their probabilistic distribution functions. Parameters ranked "medium" and "low" are evaluated with either nominal values or conservative values. These then become the uncertainty analysis input parameters. This approach is what RG 1.203 refers to as a "hybrid uncertainty analysis."

LTR Table 8-3 lists the input and model parameters and their distributions, nominal values [ ]^{a,c} or conservative values that are applicable to the analysis of the event. The staff noted that several phenomena are treated conservatively. The rationale for the conservatism in these phenomena is based on the analysis methodology described in LTR Section 6.4.1.2. Moreover, the definition of the term "nominal" value and its variants with respect to the DUA for the demonstration case was provided in the response to NRO-RAI 33 (Ref. 24) discussed in Subsection 4.7.1 of this report.

SRP Chapter 15 recommends certain parameters to be used in a conservative manner in the EM. Briefly, they are:

1. The initial power shall include an allowance of 2 percent to account for power measurement uncertainties.
2. Conservative scram characteristics shall be used.
3. The core burnup used shall yield the most limiting conditions.
4. Mitigating systems should be assumed to be actuated at setpoints that allow for instrument inaccuracy.

Several conservatisms are reflected in the demonstration case. [ ]^{a,c}

NRR-RAI 36 (Ref. 19) expanded significantly on the subject of conservatism. The response (Ref. 21) explained how the method chooses which analysis parameters are set to conservative values, which are not treated statistically in the methodology, and which are treated statistically. Specifically:

1. [ ]^{a,c}
2. [ ]^{a,c}
3. [ ]^{a,c}

The response also provided additional clarification regarding parameters treated conservatively and committed to modify the text in Subsection 8.6.1 of the LTR accordingly. The response clarified the topic considerably; therefore, the NRO staff finds the response and related changes to LTR Revision 0-2 acceptable with regard to ABWR. The issues described in NRO-RAI 33 and NRR-RAI 36 are resolved. NRR will evaluate the response to NRR-RAI 36 with regard to BWR/2-6 separately.

In summary, the staff finds the data uncertainties in LTR Table 8-3 acceptable for the purpose of this demonstration case, as are the conservatisms selected.

4.8.7 Analysis of Nominal Case

This analysis examines an ABWR equilibrium reactor core after five cycles of operation with [$]^{a,c}$ fuel assemblies; basic operating parameters are indicated in LTR Table 8-4. The analysis of the nominal case provides a baseline so calculated MCPR can be compared to the final OLMCPR value that includes uncertainty. For the nominal case, all input and modeling parameters are set to their nominal values with the following exceptions:

- [$]^{a,c}$
- [$]^{a,c}$
- [$]^{a,c}$
- [$]^{a,c}$
- [$]^{a,c}$

LTR Table 8-5 shows the predicted sequence for the generator LRNBP transient, and Table 8-6 shows the analysis results. The determined OLMCPR is [$]^{a,c}$

NRO-RAI 32 (Ref. 15) sought to understand some aspects of the demonstration case better. The response (Ref. 31) clarified that Table 8-5 is not the predicted or expected sequence, but rather the sequence calculated by BISON, and committed to update the LTR text accordingly. In addition, the response clarified the participation of ABWR safety systems in the transient – namely, the steam bypass and pressure control system, the recirculation flow control system, and the SRVs. This response acceptably clarifies the sequence of events presented in this section. The staff confirmed the changes in LTR Revision 0-2, and the issue in NRO-RAI 32 is resolved.

4.8.8 Analysis Including the Uncertainty Evaluation

Uncertainties and biases in the input and modeling parameters are accounted for to develop the 95/95 value of OLMCPR for the LRNBP event. The distributions of individual uncertainty contributors, as defined in Table 8-3, are sampled using a Monte Carlo sampling method. The initial steady-state CPR and minimum transient CPR values are extracted [$]^{a,c}$ and MCPR is calculated according to Equation 4 in the LTR. Then, the final OLMCPR is taken [$]^{a,c}$

The results are then tested for normality. The LTR uses the Anderson-Darling test. In Revision 0 of the LTR, the Anderson-Darling statistic was incorrectly stated and resulted in rejecting the hypothesis of normality at the 5 percent significance level. The LTR thus used the order statistics method to calculate the OLMCPR.

However, NRR-RAI 38 S1 (Ref. 28) questioned the results supplied in LTR Section 8.8.2. The response (Ref. 29) reported that the quoted results were incorrect; the Anderson-Darling statistic was incorrectly stated, and the hypothesis of normality should not have been rejected. As a result, the statistical properties of the normal distribution method should have been used to calculate the OLMCPR, and the reported OLMCPR value of [ ]^{a,c} should have been [ ]^{a,c} The response committed to revise the affected LTR section. The NRO staff finds the response and change in LTR Revision 0-2 acceptable with regard to ABWR since it corrected an error in the original submittal. NRR will evaluate this response with regard to BWR/2-6 separately.

The staff finds the analysis with the uncertainty evaluation, as corrected, acceptable for the demonstration case.

4.8.9 Conclusions Regarding the Demonstration Case

The staff concludes that the demonstration case for generator LRNBP is representative of limiting ABWR transients. The LTR used an appropriate FOM, OLMCPR, to establish acceptability of the results. The LTR identified appropriate phenomena and ranked them properly.

The CCA described in the LTR prior to the demonstration analysis justifies the use of BISON for this demonstration. This CCA includes expert judgment.

The DUA identifies appropriate uncertainty components detailed in LTR Table 8-3. These include those with normal distributions [ ]^{a,c} and uniform distributions [ ]^{a,c} Appropriate conservative factors are also employed [ ]^{a,c} The staff concludes that the DUA is appropriate for the demonstration.

The staff concludes the sequence of events is appropriate and as expected. The determination of the FOM includes an appropriate uncertainty analysis, and the resulting uncertainty is applied correctly to the nominal value for establishing an operating limit. Comparison of the nominal value [ ]^{a,c} and the value with uncertainty [ ]^{a,c} shows that consideration of uncertainties provides a more conservative result.

5. CONDITIONS

The staff approves the revised LTR for use in ABWR licensing applications subject to the following conditions.

1. The assumed biases in Section 6.4 of the LTR for the hot and average fuel rods must be validated by performing code-specific confirmatory calculations on first application.
2. The CCA and DUA process must be used to determine the final list of uncertainty parameters (both code and input) on a plant-specific basis.

6. CONCLUSION

The LTR presents a methodology for evaluating fast transients and ATWS for first and reload cores. The overall methodology is defined in a code-independent manner that can be used to support the use of either 1D or 3D codes. The PIRT identifies phenomena that must be addressed in the evaluation. A Monte Carlo-based method for performing uncertainty evaluations that supplements the method currently approved for BWR reload analysis (conservative analysis) is also presented.

The review finds that, subject to the stated conditions, this methodology is acceptable to support ABWR analyses.

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