

U.S. NUCLEAR REGULATORY COMMISSION

SAFETY EVALUATION

BY THE OFFICE OF NUCLEAR REACTOR REGULATION

FOR EPRI TOPICAL REPORT 3002028674 AND 3002028675, REVISION 0

“LOCA ANALYSIS OF FUEL FRAGMENTATION, RELOCATION, AND DISPERSAL FOR

WESTINGHOUSE 2-LOOP, 3-LOOP, AND 4-LOOP PLANTS”

ELECTRIC POWER RESEARCH INSTITUTE, INC.

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1.0 INTRODUCTION

By letter dated April 26, 2024 (Ref. 1) (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML24121A203), Electric Power Research Institute (EPRI) submitted: (1) EPRI Report 3002028673, “Loss-of-Coolant-Accident (LOCA)-Induced Fuel Fragmentation, Relocation and Dispersal (FFRD) with Leak-Before-Break (LBB) Credit - Alternative Licensing Strategy (ALS)” (Ref. 2); (2) EPRI Report 3002028675 (NP)/3002028674 (P), “LOCA Analysis of Fuel Fragmentation, Relocation, and Dispersal for Westinghouse 2-Loop, 3-Loop and 4-Loop Plants – Proprietary, Evaluation of Cladding Rupture in High Burnup Fuel Rods Susceptible to Fine Fragmentation” (Ref. 3); and (3) EPRI Report 3002023895, “Materials Reliability Program: xLPR Estimation of PWR [Pressurized Water Reactor] Loss-of-Coolant Accident Frequencies (MRP-480)” (Ref. 4) (collectively called ALS for LOCA Analysis of FFRD), to the U.S. Nuclear Regulatory Commission (NRC) for review and approval. EPRI Report 3002028674/5 proposes to demonstrate acceptable performance for LOCA-induced FFRD phenomena in high burnup PWR fuel.

This safety evaluation (SE) describes the NRC’s technical review of EPRI topical report (TR) 3002028674/5 which describes the ALS approach for dispositioning small break (SB, Region I) and intermediate break (IB, Region IB) size LOCAs regarding FFRD. Specifically, EPRI TR 3002028674/5 presents a set of bounding composite plant models for 2-, 3-, and 4-loop Westinghouse Electric Company (Westinghouse) plants to demonstrate that fuel dispersal from high burnup fuel rods is precluded using the methodology described in WCAP-18850-P/NP-A, Revision 0, “Adaptation of the FULL SPECTRUM LOCA (FSLOCA) Evaluation Methodology to Perform Analysis of Cladding Rupture for High Burnup Fuel” (Ref. 5). WCAP-18850-P/NP-A, Revision 0, presents a methodology to demonstrate applicability of the FSLOCA Evaluation Methodology (EM) for cladding rupture analysis at higher burnup and high enrichment.

By letters dated May 14 and October 28, 2025 (Refs. 6 and 7), EPRI provided a response to NRC requests for additional information (RAIs). The response letter dated October 28 2025, provided discussion and corrections to the implementation of the WCAP-18850-P/NP-A, Revision 0, methodology in EPRI Report 3002028674/5. WCAP-18850-P/NP-A, Revision 0, was

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reviewed concurrently with EPRI Report 3002028674/5 and WCAP-18850-P/NP-A, Revision 0, was modified during the review. Therefore, modifications to EPRI Report 3002028674/5 were necessary to ensure the implementation of WCAP-18850-P/NP-A, Revision 0, was consistent with the approved methodology.

2.0 REGULATORY EVALUATION

The key applicable regulatory requirements are listed below.

- General Design Criterion (GDC) 10, in Appendix A to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, 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 anticipated operational occurrences.
- NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR [Light Water Reactor] Edition, (SRP) Section 4.2, ‘Fuel System Design’” (Ref. 8) provides review guidance to the NRC staff concerning the establishment of specified acceptable fuel design limits to assure:
 - The fuel system is not damaged as a result of normal operation and anticipated operational occurrences.
 - Fuel system damage is never so severe as to prevent control rod insertion when it is required.
 - The number of fuel rod failures is not underestimated for postulated accidents.
 - Core coolability is maintained.
- 10 CFR 50.46 specifies requirements pertaining to the performance of emergency core cooling systems (ECCS) during a postulated LOCA. As noted in Section 7.3 of WCAP-18850-A, Revision 0, this methodology is not intended to demonstrate compliance with the ECCS acceptance criteria of 10 CFR 50.46. This methodology only assures, with a high degree of confidence, that cladding rupture will not occur. GDC 27 states that reactivity control systems shall be designed to have a combined capability, in conjunction with poison addition by the ECCS, of reliably controlling reactivity changes to assure that under postulated accident conditions, and with appropriate margin for stuck rods, the capability to cool the core is maintained.
- GDC 35 establishes minimum requirements for water-cooled nuclear power plants with respect to emergency core cooling. In particular, GDC 35 requires abundant core cooling capable of transferring heat from the reactor core following any loss of reactor coolant, such that fuel and cladding damage that could interfere with continued effective core cooling is prevented and cladding metal-water reaction is limited to negligible amounts. GDC 35 further incorporates design requirements for ECCS, addressing redundancy, leak detection and isolation, and functionality both with and without offsite power.
- GDC 50 which requires the reactor containment structure, including access openings, penetrations, and the containment heat removal system shall be designed so that the containment structure and its internal compartments can accommodate, without exceeding the design leakage rate and with sufficient margin, the calculated pressure and temperature conditions resulting from any LOCA.

- SRP Section 15.0.2, “Review of Transient and Accident Analysis Methods” (Ref. 9) provides guidance to support the NRC staff’s review of analytical evaluation models used to perform safety analyses for nuclear reactors.
- SRP Section 15.6.5, “Loss-of-Coolant Accidents Resulting from Spectrum of Postulated Piping Breaks within the Reactor Coolant Pressure Boundary” (Ref. 10) provides guidance to support the NRC staff’s review of LOCA analyses.
- Regulatory Guide (RG) 1.203, “Transient and Accident Analysis Methods” (Ref. 11) provides regulatory guidance to applicants concerning the development and assessment of evaluation models used to perform safety analyses for nuclear reactors.
- Research Information Letter (RIL) 2021-13 (Ref. 12) summarizes the NRC staff’s interpretation of research related to FFRD and presents a conservative, empirical threshold for when significant fuel fragmentation begins as 55 GWd/MTU pellet average burnup.
- NUREG-1829, “Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process” (Ref. 15) provides probabilistic estimates of LOCA frequencies across a range of break sizes to support risk-informed regulatory decision-making.

3.0 **TECHNICAL EVALUATION**

3.1 **Background**

LOCA analyses are regulated under 10 CFR 50.46 and Appendix K which establishes a set of ECCS acceptance criteria which LOCA analyses must meet to be considered acceptable. Both 10 CFR 50.46 and Appendix K do not specifically describe acceptance criteria associated with FFRD, although one could draw connections to the core coolability acceptance criteria. There is increased consideration and concern associated with FFRD as industry seeks to increase fuel enrichment and maximum fuel burnup for more economical core designs. As noted in RIL 2021-13, fuel fragmentation is expected to occur for pellet exposures beyond 55 GWd/MTU where the fuel becomes increasingly fragmented at higher burnups. According to Westinghouse correlations, this corresponds to a [[REDACTED]], as discussed in WCAP-18850-P/NP-A, Revision 0.

There are numerous factors to consider in the modeling of fuel dispersal which lead to significant uncertainties in the consequences of FFRD. As such, industry has sought to develop methods and evaluation models which demonstrate the capability to preclude fuel dispersal. Adequately demonstrating that fuel cladding does not rupture under LOCA conditions may eliminate the need to perform detailed and complex analyses of fuel dispersal.

The ALS methodology proposes a new methodology to address FFRD in LOCA evaluations and may be divided into two parts depending on the LOCA break size. The first part, which is largely discussed in EPRI Report 3002028673, focuses on large break LOCAs (LBLOCAs). EPRI Report 30020287673 demonstrates that a LBLOCA will not occur using a LBB justification. In short, there would be adequate time for reactor operators to detect a leak or pipe defect that could develop into a LBLOCA and shut down the reactor and take necessary actions to prevent a LBLOCA to preclude fuel dispersal. The second part, which is discussed here and in EPRI Report 3002028674/5 focuses on SBLOCAs and IBLOCAs. This methodology intends to demonstrate acceptable plant performance during a postulated limiting SBLOCA or IBLOCA such that the cladding will not rupture, thus fuel dispersal is precluded.

3.2 Methodology for Cladding Rupture Calculations

This methodology intends to demonstrate acceptable performance with regard to FFRD during SBLOCAs and IBLOCAs for Westinghouse 2-, 3-, and 4-loop designs. Acceptable performance is defined by the preclusion of fuel dispersal, which is determined by [REDACTED]

[REDACTED]. The efficiency gained by licensees utilizing this TR is that licensees will not have to perform detailed LOCA analyses for the analyzed break sizes that include consideration of fuel dispersal because this TR generates composite plant designs intended to bound the fleet of Westinghouse 2-, 3-, and 4-loop designs. The cladding rupture analysis of the bounding composite plant designs should result in the maximum fuel cladding temperatures, [REDACTED]. Licensees will only need to demonstrate that their plant-specific geometric parameters and operating conditions are within the bounding design envelope established by the composite plant designs. Licensees will still need to perform a [REDACTED] LOCA analysis to demonstrate compliance with the ECCS acceptance criteria in 10 CFR 50.46 but would not need to explicitly address fuel dispersal as part of this analysis.

This methodology is an implementation of WCAP-18850-P/NP-A, Revision 0, Westinghouse's methodology for using the FSLOCA EM for high burnup and high enrichment cladding rupture calculations. This methodology proposed the [REDACTED] and is applicable up to a rod length-average and fuel assembly average burnup of [REDACTED], enrichments up to [REDACTED], for Westinghouse 2-, 3-, and 4-loop and Combustion Engineering (CE) designs. The NRC staff notes that the FSLOCA EM is not currently approved for 2-loop designs and this EPRI Report is not applicable to CE designs. As such, WCAP-18850-P/NP-A, Revision 0, and this TR are subject to similar limitations as described by limitation & condition (L&C) 1 of this SE. This TR does not make any deviations from the methodology proposed in WCAP-18850-P/NP-A, Revision 0, and addresses all L&Cs in WCAP-18850-P/NP-A, Revision 0, in Section 5 of the TR.

Table 1-1 of the TR describes the maximum break sizes considered in the cladding rupture analyses for each PWR class. These break sizes are consistent with the definition of transition break size in NUREG-1829. Further, the break sizes considered in this analysis are similar to those considered in WCAP-18850-P/NP-A, Revision 0, when defining SB and IB break sizes. The NRC staff decided to include L&C 4 to require licensees to confirm that the maximum break sizes considered in Table 1-1 of the TR bound the maximum break size of reactor coolant system (RCS) piping excluding the main coolant loop. This ensures that the analyzed break sizes considered in the LOCA evaluations in EPRI Report 3002028674/5 adequately bound plant-specific potential break sizes.

The TR discussed the differences between hot-leg and cold-leg breaks and noted that the maximum break size for the hot leg is larger for Westinghouse 3- and 4-loop PWRs. To determine the bounding break, hot or cold leg, a break spectrum analysis was performed confirming that the maximum cold leg break is limiting despite being a SB size. According to the analysis, cold-leg breaks produce higher peak cladding temperatures (PCTs) than hot-leg breaks by [REDACTED]. EPRI has elected to only analyze cold leg breaks due to this difference. The NRC staff found that limiting the LOCA evaluations to cold leg breaks is acceptable because hot leg breaks will result in a considerably [REDACTED], thus the evaluation of cold leg breaks will produce the [REDACTED].

The EPRI LOCA analyses for each plant class include two separate uncertainty analyses for each break size region, Regions I and IB. Region II breaks are not within the scope of this evaluation. The NRC staff found that performing separate uncertainty analyses for Region I and

IB break sizes is acceptable because the different break sizes result in different responses and behavior. This treatment is consistent with the methodology described in WCAP-18850-P/NP-A, Revision 0.

This methodology uses the PAD5 (Ref. 16) fuel performance code, consistent with the methodology described in WCAP-18850-P/NP-A, Revision 0. PAD5 is not currently approved up to the maximum burnup limit proposed in this TR. Therefore, the NRC staff is unable to make a final determination on the acceptability of the fuel performance input until an NRC-approved Westinghouse fuel performance code is used to demonstrate that the fuel performance input data used in this methodology is bounding. This is consistent with proposed L&C 4 of WCAP-18850-P/NP-A, Revision 0, and implementation requirement 2 in this TR. The NRC staff has further highlighted this requirement in L&C 2 of this SE. The NRC staff has determined that the use of an unapproved fuel performance code for use in this application is acceptable because the input data must be reevaluated and shown to be bounding later by an approved fuel performance code. If it is later shown that the input data for this evaluation is not bounding, the impact to the results must be considered and a reanalysis may be necessary.

The NRC staff notes that the FSLOCA EM is not yet approved for use with 2-loop Westinghouse plant designs. This is also noted in L&C 2 of WCAP-16996-P/NP-A, Revision 1 (Ref. 13), L&C 1 of WCAP-18850-P/NP-A, Revision 0, and L&C 2 of this SE. EPRI has included a LOCA evaluation for 2-loop plants assuming no deviation from the current approved version of the FSLOCA EM and the as submitted version of WCAP-18850-P/NP-A, Revision 0. The NRC staff reviewed the 2-loop composite design analysis under the same assumption. However, as noted in the above L&Cs, any changes to the FSLOCA EM, or WCAP-18850-P/NP-A, Revision 0, related to 2-loop plant analyses must be evaluated and incorporated into the analyses contained herein once the FSLOCA EM has received approval for 2-loop analyses. Until the FSLOCA EM applicability is extended, this TR may not be referenced in licensing applications for 2-loop plant designs. Thus, the NRC staff's conclusions related to the acceptability of the 2-loop composite plant design are contingent upon addressing L&C 3 of this SE.

3.3 Bounding PWR Model Development

Section 3 of the TR discusses EPRI's approach in creating bounding composite plant models to be evaluated in the LOCA evaluations described in Section 4 of the TR. EPRI intends for these plant models and LOCA analyses to be referenced by licensees to preclude the need to perform detailed plant-specific LOCA analyses for Region I and IB breaks that include consideration of fuel dispersal. The justification for precluding the need for detailed LOCA analyses is because the composite plant models contain bounding geometric, operating, and boundary conditions such that the calculated $[[\text{ }]]$ compared to what would be calculated in a detailed plant-specific analysis. The resulting bounding composite plant designs form a design envelope described by Table 3.4-1 of the TR. Licensees with plants that fall within every bound of this envelope may be eligible to incorporate the results of this TR into their safety analyses and preclude the need to perform detailed fuel dispersal calculations for Region I and IB LOCA analyses. Licensees with unbounded plant designs may still adopt this TR if they are able to demonstrate acceptable performance given the unbounded parameter as described in L&C 1 of this SE.

EPRI analyzed plant-specific inputs identified in the FSLOCA EM to create a set of composite plant designs. The inputs in consideration were found in Table 2-1, "Phenomena Identification and Ranking Table (PIRT) for Full Spectrum LOCA for Westinghouse and Combustion Engineering (CE) Plants," of WCAP-16696-P-A, Revision 1. Only high-ranked parameters with a

clear direction of conservatism were considered in the development of the composite design envelope. The NRC staff inquired about what impact medium-ranked parameters might have on the results if they were also to be included in the development of the design envelope. It was noted that conservatively biasing medium-ranked parameters would result in an even more bounding model, however this may be considered overly conservative. In response to RAI 4A, EPRI references the benchmark analysis in Section 3.5 of the TR. The analysis demonstrates that only conservatively biasing high-ranked parameters sufficiently bounds plant-specific designs. The benchmarking analysis is discussed in more detail in Section 3.3.5 of this SE. The result of EPRI's PIRT evaluation is found in Table 3.4-2 of the TR and the NRC staff's evaluation of each parameter is documented in Table 1 of this SE.

The NRC staff found that this is a reasonable approach to develop a composite plant design because important parameters are modeled conservatively and are expected to bound actual plant-specific designs. The resulting composite plant design LOCA evaluations should therefore result in the calculation of a conservative, [[REDACTED]].

3.3.1 Bounding Model Parameter Overview

The NRC staff have reviewed the selected parameters described in Sections 3.1 through 3.3 of the TR. The selected values in Table 3.4-1 of the TR are based on a survey of existing plant designs (i.e., minimum and maximum values of relevant parameters for all plants of that class) for geometric and operating parameters related to high-ranked phenomena. Geometric and operating parameters related to medium or low-ranked phenomena were not changed from the selected plant-specific base model, as described in response to RAI 4B and 4C. This conservative biasing treatment was discussed and found acceptable in Section 3.2 of this SE.

Table 1: PIRT Parameter Bounding Treatment Evaluations

Parameter	NRC Evaluation
[[REDACTED]]	[[REDACTED]]
[[REDACTED]]	The TR proposes to use bounding fuel performance data and core power in the composite models to [[REDACTED]]. The NRC staff found the proposed treatment of using bounding fuel performance data to be acceptable because bounding fuel performance data will result in a [[REDACTED]]. Fuel performance data must be generated using an NRC-approved fuel performance code as required by L&C 2 of this SE.

Parameter	NRC Evaluation
[[[REDACTED]]]	<p>The TR does not propose a bounding treatment related to [[[REDACTED]]] in the composite models.</p> <p>The NRC staff found the proposed treatment to be acceptable because the [[[REDACTED]]] is not influenced by geometric or operating parameters. Further, WCAP-16696-P/NP, Revision 1, discusses [[[REDACTED]]]. Tables 3.5-1, 3.5-2, and 3.5-3 indicate that [[[REDACTED]]] could be considered a less than high-ranking parameter, as discussed in Section 2.3.2.1 of WCAP-16696-P/NP, Revision 1.</p>
[[[REDACTED]]]	<p>The TR proposes to use a [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment of using bounding operating power and peaking factors to be acceptable because operating power and peaking factors, dispositioned later in this table, are selected in a conservative manner, [[[REDACTED]]]. This will result in higher cladding and fuel temperatures during the postulated LOCA.</p>
[[[REDACTED]]]	
[[[REDACTED]]]	<p>This TR does not propose a bounding treatment related to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to not require a bounding design parameter to be acceptable because [[[REDACTED]]] are influenced by assembly design and certain conditions which are dispositioned elsewhere in the design envelope.</p>
[[[REDACTED]]]	<p>This TR does not propose a bounding treatment related to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to not require a bounding design parameter to be acceptable because these parameters are not directly influenced via any geometrical or plant operating condition.</p>
[[[REDACTED]]]	<p>This TR proposes to use bounding core power and peaking factors in the composite models to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to use bounding operating power and peaking factors to be acceptable because these bounding parameters will ensure conservative results. It is noted that the [[[REDACTED]]] is not influenced by any plant geometric or operating parameters and thus does not require a specific parameter to be included in the design envelope. [[[REDACTED]]].</p>

Parameter	NRC Evaluation
[[[REDACTED]]]	<p>This TR does not propose a bounding treatment related to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to not require a bounding design parameter to be acceptable because [[[REDACTED]] and not geometric or plant operating conditions. Some relevant parameters, such as [[[REDACTED]]], are addressed separately.</p>
[[[REDACTED]]]	
[[[REDACTED]]]	<p>This TR proposes to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because the [[[REDACTED]]]. This causes the [[[REDACTED]] and higher cladding temperatures.</p>
[[[REDACTED]]]	
[[[REDACTED]]]	<p>The TR proposes to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because the [[[REDACTED]]].</p> <p>The NRC staff further notes that this parameter is ranked, at most, as [[[REDACTED]]], which would normally be omitted from this evaluation. Inclusion of this parameter enhances the conservatism of the model.</p>
[[[REDACTED]]]	<p>This TR proposes to [[[REDACTED]]] in the composite models.</p> <p>The NRC staff found the proposed treatment to be acceptable because this TR utilizes the existing FSLOCA EM approach for modeling the [[[REDACTED]]] of WCAP-16996-P/NP-A, Revision 1, which will yield conservative results.</p>
[[[REDACTED]]]	
[[[REDACTED]]]	<p>The disposition of [[[REDACTED]]] is discussed in the following three parameters.</p>

Parameter	NRC Evaluation
[[[REDACTED]]]	<p>This TR proposes to use a [[[REDACTED]]] in the composite models.</p> <p>The NRC staff found the proposed treatment to be acceptable because EPRI describes the primary factors that impact [[[REDACTED]]] which that staff notes is treated conservatively. This will ensure that there is a [[[REDACTED]]], exacerbating the consequences of the LOCA. The NRC staff inquired about the importance of the [[[REDACTED]]] during an audit. The NRC staff found that the defining characteristics for this analysis were appropriately included in the design envelope.</p> <p>The NRC staff further notes that this parameter is ranked, at most, [[[REDACTED]]], which would normally be omitted from this evaluation. Inclusion of this parameter enhances the conservatism of the model.</p>
[[[REDACTED]]]	<p>This TR proposes to use the methodology described in WCAP-16696-P-A, Revision 1, with respect to [[[REDACTED]]] in the composite models.</p> <p>The NRC staff found the proposed treatment to be acceptable because this TR utilizes the existing FSLOCA EM approach for modeling the [[[REDACTED]]]. The approach is conservative.</p>
[[[REDACTED]]]	<p>This TR proposes to use a [[[REDACTED]]] in the composite models. Specifically, the [[[REDACTED]]]. The design envelope is applicable between the proposed minimum and maximum [[[REDACTED]]] levels.</p> <p>The NRC staff found the proposed treatment to be acceptable because EPRI describes the primary factors that impact [[[REDACTED]]]. The NRC staff inquired about the importance of the [[[REDACTED]]] during an audit. The NRC staff found that the defining characteristics for this analysis were appropriately included in the design envelope. Therefore, the parameter is biased in a conservative direction. The effect of [[[REDACTED]]] is discussed later in this table.</p>

Parameter	NRC Evaluation
[[[REDACTED]]]	
[[[REDACTED]]]	<p>The TR does not propose a bounding treatment related to [[[REDACTED]]] in the composite models.</p> <p>The NRC staff found the proposed treatment to be acceptable because EPRI identifies that there are no geometric or operating parameters that impact these parameters as they relate to steam venting efficiency. The TR does note that [[[REDACTED]]]. The NRC staff inquired if other geometric parameters of the piping may be of significance. The NRC staff found the [[[REDACTED]]] to be the most important parameter with little variation in piping diameter within each respective Westinghouse plant class, thus not requiring an additional bounding parameter to be included in the design envelope.</p>
[[[REDACTED]]]	
[[[REDACTED]]]	<p>The TR proposes to model the [[[REDACTED]]].</p> <p>This specific parameter is associated with the [[[REDACTED]]] during a postulated LOCA and is not accounted for in Table 3.4-2 as a geometric or operating parameter that must be accounted for conservatively. The NRC staff further notes that parameters associated with the [[[REDACTED]]], and therefore may be omitted from the list of conservatively treated parameters. The NRC staff found the proposed treatment to be acceptable because the [[[REDACTED]]] is treated in accordance with the FSLOCA EM and WCAP-18850-P/NP, Revision 0, and further conservative treatment does not need to be considered for medium and low-ranked parameters.</p>
[[[REDACTED]]]	
[[[REDACTED]]]	<p>The TR does not propose a bounding treatment related to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because [[[REDACTED]]] is related to the thermal hydraulic performance during the transient and not any plant geometric or operating condition parameters.</p>

Parameter	NRC Evaluation
[[[REDACTED]]]	<p>The TR does not propose a bounding treatment related to [[[REDACTED]]].</p> <p>This parameter is not addressed in this TR despite being ranked [[[REDACTED]]] by the FSLOCA PIRT. The NRC staff issued RAI 4D to clarify why this parameter does not require some conservative treatment. [[[REDACTED]]].</p> <p>[[[REDACTED]]].</p>
[[[REDACTED]]]	<p>The TR does not propose a bounding treatment related to the [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because the [[[REDACTED]]] is dependent on the flow characteristics during the transient and not any plant geometric or operating condition parameters.</p>
[[[REDACTED]]]	<p>The TR proposes to use a [[[REDACTED]]] in the composite models to prolong cladding heatup.</p> <p>The NRC staff found the proposed treatment to be acceptable because the design envelope includes a [[[REDACTED]]], allowing the cladding to heat up longer. Thus, the parameter is biased in a conservative direction.</p>

Parameter	NRC Evaluation
[[[REDACTED]]]	
[[[REDACTED]]]	<p>The TR proposes to model a [[[REDACTED]]]</p> <p>in the composite models.</p> <p>The NRC staff found the proposed treatment to be acceptable because the [[[REDACTED]]] is representatively modeled with respect to each plant class. EPRI credits conservatisms in other parameters in the bounding models to make up for any potential [[[REDACTED]]] that may be possible in existing plant designs. Namely that [[[REDACTED]]]. The NRC staff determined that the conservative nature of the bounding composite plant designs is maintained despite this exception.</p>
[[[REDACTED]]]	
[[[REDACTED]]]	<p>The TR does not propose a bounding treatment related to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because [[[REDACTED]]] is not directly impacted by any geometric parameters. EPRI notes that steam generation will increase with increasing core power, but conservative core power parameters are already considered.</p>
[[[REDACTED]]]	
[[[REDACTED]]]	<p>The TR does not propose a bounding treatment related to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because [[[REDACTED]]] is not directly influenced by any plant geometric or operating condition parameters. The [[[REDACTED]]]. Various conservatisms in the design envelope will influence the [[[REDACTED]]] characteristics, resulting in the calculation of a conservative PCT.</p>
[[[REDACTED]]]	<p>The TR does not propose a bounding treatment related to [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because this parameter is only influenced by the [[[REDACTED]]] in the piping and not any plant geometric or operating conditions.</p>

Parameter	NRC Evaluation
PWR Geometry	
[[[REDACTED]]]	<p>The TR proposes to use a [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because a [[[REDACTED]]]. This allows for more core uncover and cladding heatup. Therefore, the parameter is biased in a conservative direction.</p>
[[[REDACTED]]]	<p>The TR proposes to use a [[[REDACTED]]] in the composite model to minimize steam venting.</p> <p>The NRC staff found the proposed treatment to be acceptable because the [[[REDACTED]]], and allowing for longer cladding heatup. [[[REDACTED]]] is addressed as a separate parameter. Therefore, the parameter is biased in a conservative direction.</p>
[[[REDACTED]]]	<p>The TR proposes to use a [[[REDACTED]]] in the composite models to minimize the flow rate of fluid into the core.</p> <p>The NRC staff found the proposed treatment to be acceptable because the [[[REDACTED]]]. Therefore, the parameter is biased in a conservative direction.</p>
[[[REDACTED]]]	<p>The TR proposes to use a maximum [[[REDACTED]]] in the composite model to reduce steam venting.</p> <p>The NRC staff found the proposed treatment to be acceptable because the [[[REDACTED]]]. This limits steam venting capability, delaying SI actuation. Therefore, the parameter is biased in a conservative direction.</p>

Parameter	NRC Evaluation
[[[REDACTED]]]	<p>The TR proposes to model [[[REDACTED]]] geometry in the composite model. The 2-loop composite model uses a 14x14 fuel design and the 3- and 4-loop composite models use a 17x17 fuel design.</p> <p>The NRC staff found the proposed treatment to be acceptable because only the applicable fuel assembly designs are evaluated for each plant class. EPRI notes that [[[REDACTED]]]</p> <p>[[[REDACTED]]] described in this TR. Fuel rod performance data must be shown to be conservative per L&C 2 of this SE.</p>
Initial and Boundary Conditions	
[[[REDACTED]]]	<p>The TR proposes to [[[REDACTED]]]</p> <p>[[[REDACTED]]] in the composite models. The [[[REDACTED]]] defining the design envelope are in Tables 3.4-3 through 3.4-5. The [[[REDACTED]]] considered include [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because [[[REDACTED]]] will result in increased cladding heatup and increased stored energy which will result in a higher PCT and increased likelihood of rupture. Therefore, the parameter is biased in a conservative direction.</p>
[[[REDACTED]]]	<p>The TR proposes to [[[REDACTED]]]</p> <p>in the composite models. The described treatment was clarified in response to RAI 2. It was confirmed that the treatment described in Section 29.4.1.1 of WCAP-16996-P/NP-A, Revision 1, is used. This treatment [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because [[[REDACTED]]] will result in increased likelihood of rod burst. [[[REDACTED]]]. Therefore, the parameter is biased in a conservative direction.</p>

Parameter	NRC Evaluation
[[[REDACTED]]]	<p>The TR proposes to [[[REDACTED]]] in the composite models. The proposed value is consistent for all plant classes and is [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because typical [[[REDACTED]]] and results in increased reactivity and rod power. Therefore, the parameter is biased in a conservative direction.</p>
[[[REDACTED]]]	<p>The TR proposes to treat [[[REDACTED]]] as described in WCAP-18850-P/NP, Revision 0, which is to [[[REDACTED]]] in the composite models. The range of [[[REDACTED]]] allowed by the design envelope is [[[REDACTED]]].</p> <p>The NRC staff found the proposed treatment to be acceptable because the proposed [[[REDACTED]]] was found to be acceptable in WCAP-18850-P/NP, Revision 0. The range [[[REDACTED]]]. Further, the [[[REDACTED]]]. The NRC staff confirmed during the review of WCAP-18850-P/NP, Revision 0, that [[[REDACTED]]].</p>
[[[REDACTED]]]	<p>The TR proposes to [[[REDACTED]]] in the composite models.</p> <p>The NRC staff found the proposed treatment to be acceptable because [[[REDACTED]]] on PCT for Region IB transients were analyzed in Section 6.1.5 of WCAP-18850-P/NP, Revision 0, where Westinghouse [[[REDACTED]]] sensitivity studies were submitted for information only. The NRC staff confirmed during the review that [[[REDACTED]]]. A similar discussion for Region I breaks is found in Section 21.18 of WCAP-16996-P/NP-A, Revision 1. Therefore, the parameter is biased in a conservative direction.</p>

Parameter	NRC Evaluation
[[[REDACTED]]]	<p>The TR proposes to [[[REDACTED]] and SI analysis limit in the composite models.</p> <p>The NRC staff found the proposed treatment to be acceptable because a [[[REDACTED]]].</p> <p>Therefore, the parameter is biased in a conservative direction.</p>
[[[REDACTED]]]	<p>The TR proposes to [[[REDACTED]]] in the composite models.</p> <p>The NRC staff found the proposed treatment acceptable because [[[REDACTED]]]. Therefore, the parameter is biased in a conservative direction.</p>
[[[REDACTED]]]	<p>The TR proposes to [[[REDACTED]]] in the composite models. [[[REDACTED]]], as shown in Tables 3.4-6 through 3.4-8 of the TR.</p> <p>The NRC staff found the proposed treatment acceptable because [[[REDACTED]]]. Therefore, the parameter is biased in a conservative direction.</p>
[[[REDACTED]]]	<p>The TR proposes to [[[REDACTED]]] in the composite models.</p> <p>The NRC staff found the proposed treatment acceptable because [[[REDACTED]]].</p> <p>[[[REDACTED]]] were submitted for information only. The NRC staff confirmed during the review that [[[REDACTED]]]. A similar discussion for Region I breaks is found in Section 31.3 of WCAP-16996-P/NP-A, Revision 1. Therefore, the parameter is biased in a conservative direction.</p>

Parameter	NRC Evaluation
[[[REDACTED]]]	The TR proposes to [[[REDACTED]]] in the composite models. The NRC staff found the proposed treatment acceptable because [[[REDACTED]]]. Therefore, the parameter is biased in a conservative direction.

3.3.2 Fuel-Related Parameters

Section 3 of the TR and Table 1 of this SE do not explicitly discuss certain fuel design parameters which are included in the design envelope described in Table 3.4-1 of the TR. To ensure a composite plant model was bounding for all important aspects of a LOCA analysis, the NRC staff issued RAI 3. The parameters of interest were fuel material, burnable absorbers, and initial enrichment. Table 3.4-1 allows for either Advanced Doped Pellet Technology (ADOPT) or UO₂ fuel, integral fuel burnable absorber (IFBA) or Gadolinium burnable absorbers and un-poisoned fuel, and fuel enrichments up to [[[REDACTED]]]. Various combinations of these fuel-related parameters could result in more limiting configurations. RAI 3 asks EPRI to ensure a limiting treatment is used for each of these parameters.

3.3.2.1 Fuel Material

RAI 3A is related to the use of UO₂ versus ADOPT fuel pellets. The response to RAI 3A notes that in the review of WCAP-18482-P-A that [[[REDACTED]]], which is an important parameter for LOCA analyses. [[[REDACTED]]] is addressed in WCAP-18850-P/NP-A, Revision 0. The composite models utilize fuel performance data that bounds the use of ADOPT and UO₂ pellets. This data is generated by an unapproved version of the PAD5 code, and is the subject of L&C 2 of this SE.

The NRC staff found the proposed fuel material treatment in the TR acceptable because the inputs used are assumed to be bounding. The bounding nature of these inputs are yet to be confirmed in an NRC review. L&C 2 of this SE requires that for a utility to implement this TR, it must be demonstrated that the plant-specific fuel performance data is bounded by the fuel performance data used in the composite model calculations in this TR.

3.3.2.2 Burnable Absorbers

RAI 3B is related to the use of burnable absorbers in the fuel. Burnable absorbers can have a significant impact on the power response during a transient. The design envelope includes IFBA, Gadolinium, and un-poisoned fuel. The composite model uses bounding inputs from various fuel cycle designs. WCAP-18850-P/NP-A, Revision 0, and subsequently this TR, focuses primarily on high burnup fuel, beyond a [[[REDACTED]]], at which point the burnable absorbers are likely entirely depleted. However, the presence of burnable absorbers early in the lifetime of the fuel can significantly alter the performance of that fuel later in life. Of particular concern are the rod internal pressure and [[[REDACTED]]].

The response to RAI 3B references L&Cs 1 and 2 of this SE, noting that these parameters will be confirmed to be bounding on a plant-specific basis.

The NRC staff found the proposed treatment of burnable absorbers in the composite models acceptable because L&Cs 1 and 2 of this SE will confirm the bounding nature of the proposed treatment on a plant-specific basis. L&C 1 of this SE is related to the applicability of the design envelope to the plant-specific applicant. Demonstrating compliance with L&C 1 of this SE will ensure that the [[REDACTED]] remain within the bounding range established by the design envelope. Compliance with L&C 2 of this SE requires the fuel performance data used in the composite designs to be bounded by an NRC--approved fuel performance code. This ensures parameters like rod internal pressure are bounded.

3.3.2.3 Fuel Enrichment

RAI 3C is related to the modeling of initial fuel enrichment. Higher initial fuel enrichment can result in [[REDACTED]] and changes to decay heat during a transient. The response to RAI 3C indicates that an initial fuel rod enrichment of [[REDACTED]] was used in the composite models. [[REDACTED]], therefore this treatment is conservative. The composite models already assume [[REDACTED]], as described in Table 1 of this SE.

The NRC staff found the proposed treatment of modeling the initial fuel enrichment as [[REDACTED]] in the composite models acceptable because this will result in a conservative decay heat. The impact to [[REDACTED]] is bounded by the treatment described in Table 1 of this SE.

3.3.3 Upper Plenum Injection

While Westinghouse 2-loop PWRs include upper plenum injection (UPI), for which evaluation is not yet approved in WCAP-16996-P/NP-A, Revision 1, there is discussion in WCAP-16996-P/NP-A, Revision 1, Supplement 1 (Ref. 14), [[REDACTED]]. The high-pressure SI systems in Westinghouse 2-loop PWRs are similar to those in Westinghouse 3- and 4-loop PWRs in that they are all injected through the cold leg. This includes accumulator injection which is shown to be responsible for reflooding the core and cooling the rods from their PCT in the LOCA analyses submitted in this TR. Unlike 3- and 4-loop PWRs, Westinghouse-designed 2-loop PWRs with UPI inject above the core as opposed to cold leg. Westinghouse asserts in WCAP-16996-P/NP-A, Revision 1, Supplement 1, that the SI from UPI is not required to terminate the transient.

The NRC staff used this information to make a safety determination related to the absence of parameters related to UPI in the design envelope described in Table 1 of this SE. Table 2.2-5 of WCAP-16996-P/NP-A, Revision 1, Supplement 1, indicates that [[REDACTED]]. The Westinghouse 2-loop LOCA analyses show that [[REDACTED]] before the core refloods and the cladding cools. There was [[REDACTED]]. These results indicate that UPI does not play any role in the termination of the transient and are not required to preclude cladding rupture of high burnup fuel rods in these composite plant designs. Therefore, the NRC staff find the omission of design envelope parameters related to UPI in Westinghouse-designed 2-loop PWRs acceptable as it has been shown that [[REDACTED]].

█]] in the LOCA analyses for the 2-loop composite design.

3.3.4 2-, 3-, and 4-Loop Composite Design Envelope

Tables 3.4-1 through 3.4-8 of the TR define the design envelope which the composite models bound along with the direction of conservatism which defines the treatment used to build the composite models. The justification for the treatment of each parameter is dispositioned in Section 3 of the TR and Table 1 of this SE. The NRC staff found the proposed treatment of all parameters to be acceptable. Therefore, the design envelope established by these parameters is also acceptable.

The TR notes that fuel performance data is absent from Table 3.4-1 through 3.4-8. L&C 2 of this SE requires licensees to demonstrate, on a plant-specific basis, that the fuel performance data used in the cladding rupture calculations bounds the plant-specific fuel performance data. Further, the plant-specific fuel performance data must be generated using an NRC-approved code with an appropriate range of applicability for maximum burnup and initial fuel enrichment. The key fuel performance data that licensees must demonstrate are bounded are [█]]. The NRC staff found this approach to ensuring fuel performance data remains bounding on a plant-specific basis acceptable because L&C 2 of this SE requires an NRC-approved fuel performance code be used to confirm the bounding nature of the cladding rupture calculations.

The TR also outlines two approaches that licensees may take if they are unable to demonstrate that their plant-specific design is constrained by the design envelope described in Tables 3.4-1 through 3.4-8 of the TR. The first approach described is to perform a plant-specific analysis and compare against the composite model to demonstrate the composite model is bounding. This approach is convenient if one or a few parameters are unconstrained by the design envelope, but other parameters are more conservatively constrained. The TR describes one specific scenario where an unconstrained parameter results in a loss-of-margin, but conservatisms in another parameter can make up for that loss-of-margin. The second approach is to perform a plant-specific cladding rupture analysis according to the methodology described in WCAP-18850-P/NP-A, Revision 0. The NRC staff found that both approaches can adequately demonstrate acceptable performance with respect to FFRD. Therefore, both approaches are documented as potential resolutions if a licensee is unable to confirm its plant-specific design is constrained by the design envelope in L&C 1 of this SE.

3.3.5 Benchmarking of Composite Bounding PWR Models

Section 3.5 of the TR contains a benchmarking analysis comparing the composite models to plant-specific designs for each plant class. The benchmarking analysis consists of a [█]]

█]]. The results of this benchmarking analysis are documented in Tables 3.5-1 through 3.5-3 for 2-, 3-, and 4-loop plants, respectively and are summarized in Table 2 of this SE.

The NRC staff notes the limited number of 2-loop plants to compare against the composite model. The TR states that 2-loop Plant A represents a plant with more limiting design features than other 2-loop plants. Other 2-loop plants of differing designs are expected to be bounded by both 2-loop Plant A and the composite model.

The benchmarking analysis included a comparison to 3-loop Plant D, which uses a 15x15 fuel array, which is not permitted under the proposed design envelope. Thus, it has been excluded

from the Table 2 summary. The NRC staff noted that Plant D represents a far more limiting design and remains bounding with respect to the PCT of the composite model, providing additional confidence that the proposed composite models are sufficiently bounding.

The 4-loop benchmarking analysis did not contain any unique considerations, and all plants are bounded by the composite model in terms of PCT.

Table 2: Composite Model PCT Benchmark Results

	2-Loop	3-Loop	4-Loop
PCT Margin (°F)*	7	134**	76

*PCT Margin = Composite Model PCT - Maximum Plant PCT

**Does not include Plant D because it is not within the design envelope.

The NRC staff found that the benchmarking analysis adequately demonstrates the bounding nature of the composite models. The positive PCT margin in Table 2 of this SE provides reasonable assurance that the approach to conservatively bias only the parameters associated with high-ranking phenomena is sufficient to produce a bounding composite model.

3.4 Cladding Rupture Analysis Results

The cladding rupture analysis results are presented in response to RAI 1 of Reference 8. These analyses supersede the analyses documented in Section 4 of EPRI Report 3002028674/5 in their entirety. The new analyses were performed to accommodate differences between the original and approved versions of the WCAP-18850-P/NP-A, Revision 0, methodology, incorporating changes to the analysis method and L&Cs.

Analyses are performed for Westinghouse 2-, 3-, and 4-loop PWRs for both Regions I and IB. The analyses assume the limiting offsite power configurations, consistent with the methodology described in Section 5.2.4 of WCAP-18850-P/NP-A, Revision 0. The Westinghouse 3-loop PWR analysis considers [[REDACTED]]. The analyzed break sizes are consistent with the method for determining the limiting break sizes described in WCAP-18850-P/NP-A, Revision 0. The NRC staff determined that the initial conditions and geometric configurations for the bounding LOCA analyses for the composite Westinghouse 2-, 3-, and 4-loop PWRs are acceptable because bounding configurations are used.

The results of the cladding rupture analyses, in terms of [[REDACTED]], are provided Table 3 of this SE. The uncertainty analyses were performed with [[REDACTED]], consistent with Table 30-1 of WCAP-16996-P/NP-A, Revision 1. For all cases the [[REDACTED]], indicating, with 95 percent probability at 95 percent confidence, that cladding rupture of high burnup fuel rods, and thus fuel dispersal, does not occur during the postulated LOCA for these composite plant designs.

The NRC staff notes the [[REDACTED]], indicates with high probability that cladding rupture will not occur for high burnup fuel rods, the NRC staff gave additional attention to these analyses. The NRC staff compared the results from Table 3 to the benchmarked results in Table 2 of this SE. There it is found that

Westinghouse 3- and 4-loop plants are most conservatively bounded by the composite model. This indicates that the 3- and 4-loop composite designs are much more conservative compared to the 2-loop composite design and that [[REDACTED]

[[REDACTED]]].

The NRC staff finds the uncertainty analyses for the Westinghouse-designed 2-, 3-, and 4-loop composite plant designs to be acceptable in that they demonstrate, at 95 percent probability with 95 percent confidence, that cladding rupture will not occur for fuel rods susceptible to fine fragmentation. The composite plant designs have been shown to be conservative, and a [[REDACTED]] is calculated for all designs. Realistic plant designs would therefore have additional margin than what is shown in Table 3 if their plant design is bounded by the design envelope. Therefore, it has been shown that plant designs bounded by the design envelope would not experience cladding rupture of high burnup fuel rods during the postulated LOCA transients.

Table 3: Cladding Rupture Analysis 95/95 Results

	2-Loop		3-Loop			4-Loop	
	Region I	Region IB	[[REDACTED]]	[[REDACTED]]	Region IB	Region I	Region IB
[[REDACTED]]	[[REDACTED]]	[[REDACTED]]	[[REDACTED]]	[[REDACTED]]	[[REDACTED]]	[[REDACTED]]	[[REDACTED]]

*[[REDACTED]], respectively.

3.5 Implementation

To implement this methodology, licensees must address the L&Cs described in Section 4.0 of this SE. This TR is an implementation of the WCAP-18850-P/NP-A, Revision 0, methodology, which includes 11 L&Cs. EPRI has dispositioned each of the L&Cs below to demonstrate that their application of WCAP-18850-P/NP-A, Revision 0, is consistent with the approved methodology, and is therefore acceptable. Some of the proposed L&Cs in WCAP-18850-P/NP, Revision 0, were modified in the NRC’s final SE for WCAP-18850-P/NP-A, Revision 0. Any impacts to EPRI’s disposition of those L&Cs are addressed in response to RAI 1b of Reference 7.

3.5.1 Disposition of WCAP-18850-P/NP-A, Revision 0, Limitations and Conditions

Limitation 1

The TR WCAP-18850-P/NP-A, Revision 0, is applicable to Westinghouse-designed 2-loop PWRs equipped with UPI, 3-loop PWRs with cold-side injection, and 4-loop PWRs with cold-side injection as well as CE-designed PWRs. The methodology for the LOCA cladding rupture calculations can only be applied to the Westinghouse 2-loop PWR and CE PWR designs once the FSLOCA EM is approved for these designs, and any plant design-specific sensitivity studies have been acceptably completed. Any applicable

differences in the approved methodology for these plant designs must be addressed in the cladding rupture calculations. Furthermore, any deviations from the method described in this TR should be described and justified.

EPRI acknowledges that the FSLOCA EM has not been approved for 2-loop PWRs and references implementation requirement #3 in Section 5.2 of the TR. This implementation requirements states that the FSLOCA EM must be approved to be applied to 2-loop plants and any differences in the approved methodology for 2-loop PWRs versus 3- and 4-loop PWRs must be addressed.

The NRC staff has determined that L&C 1 of WCAP-18850-P/NP-A, Revision 0, can be satisfied by addressing implementation requirement 3, which has been included as L&C 1 of this SE. This will ensure that when Westinghouse extends the applicability of the FSLOCA EM to 2-loop plants that any methodological differences are captured and evaluated in the proposed EPRI 2-loop composite design. EPRI Report 3002028674/5 is not applicable to any Westinghouse-designed plants that are not addressed herein.

Limitation 2

The following conditions apply with regard to decay heat modeling and sampling in the cladding rupture calculations for all regions: 1) the decay heat uncertainty will be [[[REDACTED]]], and 2) the cladding rupture calculations cannot be performed for transient timers longer than 10,000 seconds following shutdown unless the decay heat model is shown to be acceptable for the analyzed core conditions. The latter limitation is [[[REDACTED]]].

EPRI states that the decay heat multiplier was sampled as specified in the L&C; therefore, the NRC staff has determined that L&C 2 has been satisfied.

Limitation 3

The maximum fuel rod length-average burnup and fuel assembly average burnup permitted with this TR is [[[REDACTED]]]. Details behind the various burnup-related limitations associated with this TR are provided in Section 7.2.1.

EPRI states that the maximum fuel rod length-average burnup and fuel assembly average burnup supported by the methodology, as described in Tables 3.4-3 through 3.4-5, is [[[REDACTED]]]; therefore, the NRC staff has determined that L&C 3 has been satisfied.

Limitation 4

The fuel performance data utilized to initialize the fuel rods for the cladding rupture calculations should be from a fuel performance code which includes the effect of thermal conductivity degradation and is NRC-approved through the fuel rod-average burnups and initial fuel enrichments that are analyzed. The [[[REDACTED]]], and the generation of all the fuel performance data should adhere to the NRC-approved methodology.

EPRI used the PAD5 methodology to generate fuel performance data. This methodology is not yet approved for high burnup applications. This limitation can only be met if a Westinghouse fuel performance code is used that has been NRC-approved throughout the entire analyzed burnup

range. This is described in implementation requirement 2 of Section 5.2 of the TR. The NRC staff found that this evaluation and implementation requirement are acceptable for meeting limitation 4. This implementation requirement is also described in Section 4.0 of this SE as L&C 2.

Limitation 5

The [[[REDACTED]]].

The EPRI analysis adheres to the above limitations for the cladding rupture calculations. Therefore, the NRC staff found that limitation #5 is satisfied.

Limitation 6

For each cladding rupture analysis performed:

- a. The [[[REDACTED]]], analysis seed(s), and the analysis inputs will be declared and documented prior to performing the cladding rupture calculations. The [[[REDACTED]]], and the analysis seed(s) will not be changed once they have been declared and documented.
- b. Should a plant-specific application of the cladding rupture methodology deviate from the originally declared analysis inputs for the intended purpose of demonstrating that cladding rupture does not occur with high probability, all modifications shall be discussed in the analysis submittal to the NRC. The calculated preliminary analysis result for each case shall be summarized for information only in the analysis submittal to the NRC. Because these preliminary analyses and results are not intended to demonstrate that no cladding rupture occurs during the evaluated limiting LOCA, formal 10 CFR Part 50, Appendix B, verification and archival documentation of these preliminary analyses are not required. All final calculations used to demonstrate the final evaluation are subject to formal 10 CFR Part 50, Appendix B, verification and archival documentation rules.
- c. Plant operating ranges which are sampled for the cladding rupture calculations will be provided in the analysis submittal associated with the cladding rupture calculations.

The EPRI analysis adheres to the documentation and reporting requirements of item (a) and the plant operating ranges in item (c) are described in Section 3 of the TR. The analysis results did not exceed the cladding rupture criterion; therefore item (b) does not apply. Therefore, the NRC staff found that limitation #6 is satisfied.

Limitation 7

Plant-specific applications of the cladding rupture methodology for Region II should include two complete sets of sampled statistical evaluations: 1) a complete set with OPA, and 2) a second complete set with a loss-of-offsite power. For each set, the calculated statistical results at the 95/95 probability, confidence level should result in margin to cladding rupture. The [[[REDACTED]]] to provide the required 95/95 probability, confidence statement that addresses the MTR.

The EPRI cladding rupture analysis is not performed for Region II breaks. The only applicable

portion of this limitation is the [[[REDACTED]]]. Therefore, the NRC staff found that limitation #7 is satisfied.

Limitation 8

L&Cs number 3, 12, and 13 from WCAP-16996-P-A, Revision 1 must be satisfied for the application of this cladding rupture methodology.

L&C 3 of WCAP-16996-P/NP-A, Revision 1, is associated with Region II breaks, which were not considered in this analysis. Therefore, L&C 3 is not applicable. L&C 12 is associated with the dynamic pressure loss from the SG secondary side to the MSSV. [[[REDACTED]]]. Plant-specific applications adopting this TR must demonstrate that the geometry and operating conditions contained in Table 3.4-1 bound the plant-specific design. Therefore, this parameter is accounted for in the analysis and L&C 12 of WCAP-16696-P-A, Revision 1, is met. Lastly, L&C 13 is associated with the [[[REDACTED]]]. The first part of this L&C is met for similar reasons that L&C 12 is met. The EPRI cladding rupture analysis does not [[[REDACTED]]]; therefore, L&C 13 of WCAP-16696-P-A, Revision 1, is met. The NRC staff has found that limitation #8 is satisfied because L&Cs 3, 12, and 13 of WCAP-16696-P/NP-A, Revision 1, have been appropriately dispositioned.

Limitation 9

This TR is applicable to standard UO₂ or ADOPT fuel with AXIOM cladding. However, prior to applying the methodology to new fuel designs approved subsequent to the issuance of this SE, Westinghouse shall confirm the applicability of the methodology to the new fuel design or propose any modifications necessary to acceptably model the new fuel design.

Table 3.4-1 requires the fuel material to be UO₂ or ADOPT with AXIOM cladding. Therefore, the NRC staff found that limitation #9 is satisfied.

Limitation 10

This TR is applicable to un-poisoned fuel, fuel with IFBA, and fuel with Gadolinia. This limitation does not preclude the use of wet annular burnable absorbers or other discrete burnable absorbers during the lifetime of an assembly.

The burnable absorbers described in Table 3.4-1 include un-poisoned fuel rods, IFBA, and Gadolinia. Therefore, the NRC staff found that limitation #10 is satisfied.

Limitation 11

A maximum of [[[REDACTED]]] is permitted with this TR. This limitation results from the maximum enrichment that is supported by the WCOBRA/TRAC/-TF2 kinetics and decay heat module.

The maximum fuel enrichment described in Table 3.4-1 is [[[REDACTED]]]. Therefore, the NRC staff found that limitation #11 is satisfied.

4.0 LIMITATIONS AND CONDITIONS

1. A licensee implementing this methodology must demonstrate that the plant geometry and operating conditions are consistent with or bounded by the values presented in

Tables 3.4-1 through 3.4-8 (where there are two different configurations to consider for 3-loop Westinghouse PWRs). If any geometry or operating conditions are unbounded by the design envelope, then justification must be provided to demonstrate that adequate margin remains despite the unbounded parameter. Justification should include sensitivity studies quantifying the relative effect on **[[REDACTED]]** when perturbing the unbounded parameter, consistent with the discussion in Section 3.4 of the TR. Alternatively, a cladding rupture analysis may be performed for the plant-specific design, according to the methodology described in WCAP-18850-P/NP-A, Revision 0.

2. A licensee implementing this methodology must demonstrate that the plant-specific fuel performance data, from a version of a Westinghouse fuel performance code that is NRC-approved through the analyzed fuel rod-average burnups and initial fuel rod enrichments, is bounded by the fuel performance data that was utilized in the cladding rupture calculations presented in this report. This condition satisfies L&C 4 from WCAP--18850-P/NP-A, Revision 0. Note that higher fuel temperatures and rod internal pressures are considered bounding for the cladding rupture calculations. This is because a higher fuel temperature will result in increased cladding heatup from initial stored energy if the core is uncovered, which increases the likelihood of rupture. The increased fuel rod internal pressure will increase the hoop stress across the cladding, which also increases the likelihood of rupture.
3. If the plant is a Westinghouse-built 2-loop PWR, then the FSLOCA EM must be approved for 2-loop PWRs and any differences in the approved methodology for 2-loop PWRs versus 3-loop and 4-loop PWRs must be addressed. This condition satisfies L&C 1 from WCAP-18850-P/NP-A, Revision 0.
4. A licensee implementing this methodology must demonstrate that the maximum break sizes in Table 1-1 of EPRI Report 3002028674/5 bound the plant-specific maximum break sizes of the reactor coolant pressure boundary piping excluding the main coolant loop.

5.0 CONCLUSION

The NRC staff reviewed EPRI Report 3002028674/5 which describes the proposed methodology for addressing FFRD in Westinghouse-designed 2-, 3-, and 4-loop plants for SB and IB LOCAs are part of the ALS methodology. The proposed method provides a means for applicants to compare plant-specific designs to the composite design envelope to confirm whether cladding rupture of high burnup fuel rods susceptible to fine fragmentation is credible during postulated SB and IB LOCAs. Applicants adequately demonstrating that their place is bounded by the design envelope per L&C 1 of this SE will not need to perform a detailed analysis to address FFRD for SB and IB LOCAs.

The NRC staff concluded that the proposed method in EPRI Report 3002028674/5 is acceptable for use in plant-specific applications and licensing. EPRI and Westinghouse have adequately demonstrated through the use of the WCAP-18850-P-A, Revision 0, methodology that cladding rupture of high burnup fuel rods susceptible to fine fragmentation does not occur in the bounding composite designs. Therefore, there is reasonable assurance that plants bounded by the composite design envelope will not experience fuel dispersal during a postulated SB and IB LOCA provided that the L&Cs in Section 4.0 of this SE are fully met.

6.0 REFERENCES

1. Electric Power Research Institute, “Request for NRC Review of EPRI’s Alternative Licensing Strategy (ALS), described herein, which addresses PWR LOCA-Induced Fuel Fragmentation, Relocation, and Dispersal” (ADAMS Accession No. ML24121A204), April 2024.
2. Electric Power Research Institute, “EPRI Report 3002028673, ‘Loss-of-Coolant-Induced Fuel Fragmentation, Relocation and Dispersal with Leak-Before-Break Credit’” (ADAMS Accession No. ML24121A207), April 2024.
3. Electric Power Research Institute, “EPRI Report 3002028674/5, ‘LOCA Analysis of Fuel Fragmentation, Relocation, and Dispersal for Westinghouse 2-Loop, 3-Loop, and 4-Loop Plants – Evaluation of Cladding Rupture in High Burnup Fuel Rods Susceptible to Fine Fragmentation’” (ADAMS Accession Nos. ML24121A208 (non-proprietary) / ML24121A210 (proprietary)), April 2024.
4. Electric Power Research Institute, “EPRI Report 3002028676, ‘Materials Reliability Program: xLPR Estimation of PWR Loss-of-Coolant Accident Frequencies (MRP-480)’” (ADAMS Accession No. ML24123A223), February 2024.
5. Westinghouse, “WCAP-18850-P/NP-A, Revision 0, ‘Adaptation of the FULL SPECTRUM LOCA (FSLOCA) Evaluation Methodology to Performed Analysis of Cladding Rupture for High Burnup Fuel’” (ADAMS Accession Nos. ML25363A155 (non-proprietary) / ML24060A162 (ML25363A154)), December 2025.
6. Electric Power Research Institute, “Responses to RAIs on EPRI Report 3002028674/5 on LOCA Analysis of FFRD for Westinghouse Plants” (ADAMS Package Accession No. ML25140A054), May 2025.
7. Electric Power Research Institute, “Responses to RAIs on EPRI Report 3002028674/5 on LOCA Analysis of FFRD for Westinghouse Plants” (ADAMS Accession Nos. ML25301A506 (non-proprietary) / (proprietary)), October 2025.
8. U.S. Nuclear Regulatory Commission, “NUREG-0800, Standard Review Plan Section 4.2, ‘Fuel System Design’” (ADAMS Accession No. ML070740002), March 2007.
9. U.S. Nuclear Regulatory Commission, “NUREG-0800, Standard Review Plan Section 15.0.2, ‘Review of Transient and Accident Analysis Methods’” (ADAMS Accession No. ML070820123), March 2007.
10. U.S. Nuclear Regulatory Commission, “NUREG-0800, Standard Review Plan Section 15.6.5, ‘Loss-of-Coolant Accidents Resulting From Spectrum of Postulated Piping Breaks Within the Reactor Coolant Pressure Boundary’” (ADAMS Accession No. ML070550016), March 2007.
11. U.S. Nuclear Regulatory Commission, “Regulatory Guide 1.203, ‘Transient and Accident Analysis Methods’” (ADAMS Accession No. ML053500170), December 2005.
12. U.S. Nuclear Regulatory Commission, “Research Information Letter 2021-13, ‘Interpretation of Research on Fuel Fragmentation, Relocation, and Dispersal at High Burnup’” (ADAMS Accession No. ML21313A145), December 2021.
13. Westinghouse, “WCAP-16996-P-A, Revision 1, ‘Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology),’ Volumes I-III” (ADAMS Accession Nos. ML17277A132, ML17277A133, ML17277A134, (non-proprietary) and ML17277A143, ML17277A144, ML17277A149 (proprietary)), November 2016.
14. Westinghouse, “WCAP-16996-P-A, Revision 1, Supplement 1, ‘Extension of FULL SPECTRUM LOCA (FSLOCA) Evaluation Methodology o 2-loop Westinghouse Pressurized Water Reactors (PWRs) with Information to Satisfy Limitations and Conditions Specific to 2-loop Plant Types’” (ADAMs Accession Nos. ML25057A399

- (non-proprietary) and ML25057A398 (proprietary)), February 2025.
15. U.S. Nuclear Regulatory Commission, “NUREG-1829, ‘Estimating Loss-of-coolant Accident (LOCA) Frequencies Through the Elicitation Process,’” April 2008 (ML082250436 – Volume 1, main report; ML081060300 – Volume 2, Appendices A – M).
 16. Westinghouse, “WCAP-17642-P-A, Revision 1, ‘Westinghouse Performance Analysis and Design Model (PAD5)’” (ADAMS Accession Nos. ML17338A396 (non-proprietary) and ML17334A841 (proprietary)), November 2017.

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