Enclosure 3

Set 3 of Responses and Clarifications to Requests for Additional Information on Westinghouse Topical Report WCAP 18446-P/NP, "Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs."

(Non-Proprietary)

(20 pages including this cover page)

June 2022

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Request for Additional Information (RAI) 11:

Over a significant portion of its range relevant to fuel rods in the requested extended burnup region, the rupture stress curve presented in Figures 4.4-10 through 4.4-12 of WCAP-18446- P/WCAP-18446-NP, Revision 0, appears to be based upon a best-fit to the data rather than a conservative or bounding fit. Hence, even at cladding temperatures when the model predicts non-rupture, in fact, a substantial fraction of high-burnup fuel rods in the reactor core at the predicted stress condition may have ruptured. The uncertainty associated with the determination of the rupture temperature at a given hoop stress appears to be significant; for example, as shown in the example results in Table 4.8-1, the **[**

]^{a,c} Because the total number of high-burnup fuel rods in the core of a large pressurized-water reactor may reach approximately 10,000, the treatment of uncertainty and variation in rupture temperature could affect the calculated rupture state for hundreds, or perhaps thousands, of fuel rods. Please justify how the use of best-fit curves without allowance for uncertainty along with the deterministic method proposed in WCAP-18446-P/WCAP-18446-NP, Revision 0, would be consistent with a demonstration of the intended proposition that no fuel rods in the extended burnup region will burst during a postulated loss-of-coolant accident or revise the methodology to include allowance for uncertainty in the determination of the rupture temperature.

Response to RAI 11:

The deterministic approach to the cladding rupture calculations **[**

]^{a,c} For analyses with the **FULL SPECTRUM™** LOCA **(FSLOCA™)** evaluation model (EM) (WCAP-16996-P-A, Revision 1 [11-2]), the burst temperature is **[** **]**^{a,c} when addressing the peak cladding temperature (PCT), maximum local oxidation (MLO), and core-wide oxidation (CWO) acceptance criteria. In the case of the cladding rupture calculations under the incremental burnup extension, cladding rupture (or margin to rupture) is the figure of merit (FOM). As such, the cladding rupture curve is **[**

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It was noted in Section 4.4.3.2 of WCAP-18446-P [11-3] that the burst testing database included samples that were **[**

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Based on these comparisons, it is concluded that the updated burst curve serves as an appropriate **[** **]a,c** for precluding rupture in the peripheral assemblies.

Reference(s)

11-1) LTR-NRC-22-4, Revision 0, "Submittal of Set 1 of Responses to Requests for Additional Information on Westinghouse Topical Report WCAP-18446-P/NP, 'Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs.' (Proprietary/Non-Proprietary)," February 2022.

11-2) WCAP-16996-P-A, Revision 1, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (**FULL SPECTRUM** LOCA Methodology)," November 2016.

11-3) WCAP-18446-P, Revision 0, "Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs," December 2020.

11-4) PNNL-19400, Volume 1, Revision 2, "FRAPTRAN-2.0: A Computer Code for the Transient Analysis of Oxide Fuel Rods," May 2016.

RAI 19:

Use of a statistical approach based on the Full Spectrum methodology described in WCAP-16996 as an alternative to the deterministic option is permitted for rupture calculations, as described in Section 4.7.3.1 of WCAP-18446-P/WCAP-18446-NP, Revision 0. The safety evaluation for WCAP-16996-P-A/WCAP-16696-NP-A, Revision 1, documents that the Full Spectrum™ evaluation model is limited to a burnup range of **[ ]**^{a,c} Because the WCAP-18446-P/WCAP-18446-NP, Revision 0, methodology focuses solely upon the extended burnup range of **[ ]**^{a,c} it is not clear whether the statistical uncertainty treatments for burnup-dependent parameters should be identical to those of WCAP-16996-P-A/WCAP-16696-NP-A, Revision 1. Please clarify the following points concerning the proposed statistical approach:

a. Please describe how the WCAP-18446-P/WCAP-18446-NP, Revision 0, methodology would sample **[ ]**^{a,c} as is done in WCAP-16996-P-A/WCAP-16696-NP-A, Revision 1, it is not clear that the simulation results would be applicable to the WCAP-18446-P/WCAP-18446-NP, Revision 0, methodology's intended statistical conclusion.

b. Some fuel related parameters could experience increased uncertainties at higher burnups. Furthermore, many parameters may correlate with **[ ]**^{a,c} As such, it is not clear whether the uncertainty distributions in WCAP-16996-P-A/WCAP-16696-NP-A, Revision 1, are adequately representative of fuel rod and core-wide conditions during the time period that the core contains fuel rods within the specific **[ ]**^{a,c} burnup range that is the focus of WCAP-18446-P/WCAP-18446-NP, Revision 0. Considering the subset of sampled parameters from WCAP-16996-P-A/WCAP-16696-NP-A, Revision 1, that may correlate with burnup, please justify that the uncertainty distributions from WCAP-16996-P-A/WCAP-16696-NP-A, Revision 1, apply within the extended burnup range or propose modifications to ensure appropriate representation of the uncertainty distributions within the extended burnup range associated with WCAP-18446-P/WCAP-18446-NP, Revision 0.

c. Considering the subset of sampled parameters from WCAP-16996-P-A/WCAP-16696-NP-A, Revision 1, that may correlate with burnup, please provide justification that data exists to support the proposed uncertainty treatments in the extended range of burnup proposed in WCAP-18446-P/WCAP-18446-NP, Revision 0.

d. Please demonstrate the full statistical option proposed in WCAP-18446-P/WCAP-18446-NP, Revision 0, to illustrate a comparison of the results of its predictions of margin to burst against the results of the deterministic calculation (without crediting optional discretionary conservatisms, as discussed above in RAI 18) for an identical set of plant conditions.

Response to RAI 19a:

In analyses performed using the **FSLOCA** EM (WCAP-16996-P-A, Revision 1 [19-1]), because the **[**

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Response to RAI 19b:

The **FSLOCA** EM explicitly considers fuel thermal conductivity degradation (TCD) and other burnup-related phenomena. The uncertainties considered in analyses with the **FSLOCA** EM are described in Section 29 of WCAP-16996-P-A, Revision 1. However, a more concise table of the various biases / flags / uncertainties available within the **FSLOCA** EM and their associated descriptions is provided in Table I starting on page B-1019 of the appendices to WCAP-16996-P-A, Revision 1. The majority of the parameters are system or model-related biases / flags / uncertainties with no relationship to burnup or time-in-cycle. The following uncertainty parameters fall into this category (Table 19-1). Note that any non-uncertainty parameters are not included in the table (none of which are burnup-related).

Table 19-1: Uncertainty Parameters with No Relationship to Burnup

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A number of the parameters in Table I starting on page B-1019 of the appendices to WCAP-16996-P-A, Revision 1 are only relevant after fuel rod burst is predicted. These parameters, shown in the following table (Table 19-2), are similarly not discussed further.

Table 19-2: Parameters Only Important Post-Burst

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The remaining parameters to be considered are then the following (Table 19-3).

Table 19-3: Remaining Parameters Potentially Influenced by Burnup

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Each of these items is discussed in-turn.

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Response to RAI 19c:

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Response to RAI 19d:

A demonstration analysis was performed for a 3-loop Westinghouse-design pressurizer water reactor (PWR) using the large-break LOCA (LBLOCA) statistical analysis method, including updates resulting from the various RAI responses in LTR-NRC-22-4 [19-9] and LTR-NRC-22-15 [19-10]. Note that the results from this demonstration analysis cannot be directly compared to the results from the demonstration analysis discussed in Section 4.8 of WCAP-18446-P because of various differences. For example, **[**

]a,c In addition, slightly different (more limiting) Nuclear Design inputs were used. This approach differs slightly from the RAI which requested a more direct comparison against the **[**

]a,c as discussed in the response to RAI #12 (LTR-NRC-22-4).

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]a,c For an actual plant application, the nuclear design and fuel rod design inputs, as well as the associated limitations on each cycle of operation, would be determined on a plant-specific basis. Those parameters would be checked each reload to ensure continued applicability of the cladding rupture calculations.

Per the response to RAI #19 Part A, the [

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Section 4.8 of WCAP-18446-P will be updated to reflect this revised demonstration analysis.

Table 19-4: [

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Reference(s)

19-1) WCAP-16996-P-A, Revision 1, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (**FULL SPECTRUM** LOCA Methodology)," November 2016.

19-2) CNL-19-051, "Application to Implement the **FULL SPECTRUM** LOCA (**FSLOCA**) Methodology for Loss-of-Coolant Accident (LOCA) Analysis and New LOCA-specific Tritium Producing Burnable Absorber Rod Stress Analysis Methodology (WBN-TS-19-04)," December 2019 (ADAMS Accession # ML20017A337).

19-3) Letter from Kimberly J. Green (NRC) to James Barstow (TVA), "Watts Bar Nuclear Plant, Units 1 and 2 – Issuance of Amendment Nos. 143 and 50 Regarding Implementation of FULL SPECTRUM™ Loss-of-Coolant Accident Analysis (LOCA) and New LOCA-Specific Tritium Producing Burnable Absorber Rod Stress Analysis Methodology (EPID L-2020-LLA-0005)," February 2021 (ADAMS Accession # ML21034A169).

19-4) WCAP-18446-P, "Incremental Extension of Fuel Rod Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs," December 2020.

19-5) LTR-NRC-21-16, "Submittal of Voluntary Supplement to WCAP-18446-P / WCAP-18446-NP, 'Incremental Extension of Fuel Rod Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs' (Proprietary/Non-Proprietary)," May 2021.

19-6) WCAP-16045-P-A, "Qualification of the Two-Dimensional Transport Code PARAGON," August 2004.

19-7) NUREG/CR-6967, "Cladding Embrittlement During Postulated Loss-of-Coolant Accidents," June 2008 (ADAMS Accession # ML082130389).

19-8) WCAP-8691-R1, Revision 1, "Fuel Rod Bow Evaluation", July 1979.

19-9) LTR-NRC-22-4, Revision 0, "Submittal of Set 1 of Responses to Requests for Additional Information on Westinghouse Topical Report WCAP-18446-P/NP, 'Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs.' (Proprietary/Non-Proprietary)," February 2022.

19-10) LTR-NRC-22-15, Revision 0, "Submittal of Set 2 of Responses to Requests for Additional Information on Westinghouse Topical Report WCAP-18446-P/NP, 'Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs.' (Proprietary/Non-Proprietary)," April 2022.

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Figure 19-1: [

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Figure 19-2: [

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a,c

Figure 19-3: [

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a,c

Figure 19-4: Cladding Temperature and Burst Temperature Near Limiting Elevation for the [ ]a,c

Clarifications to the Responses to RAIs 4, 5, 28, and 29

Responses to the RAIs on the incremental burnup topical report (WCAP-18846-P [C-1]) were previously transmitted in LTR-NRC-22-4 [C-2] and LTR-NRC-22-15 [C-3]. The following clarifications are provided to the previously transmitted responses.

Clarification Regarding the Responses to RAIs 4 and 5

The response to RAI #4 provides the topical report position relative to the fuel assembly design criteria. The response to RAI #5 provides the method used to assess fuel assembly growth. Specifically: for Westinghouse-designed PWRs, empirical data is provided which supports the fuel assembly growth curve established and reviewed by the NRC; for Combustion Engineering-designed PWRs, the approved SIGREEP computer code is utilized in combination with empirical data confirming the code prediction accuracy.

The response to RAI #5 also provides the assessment of fuel assembly growth for the Westinghouse 17x17 OFA fuel design. As such, application of the incremental burnup extension to the 17x17 OFA fuel assembly design has been justified within this topical report.

For the application of the incremental burnup extension to PWRs with fuel designs other than 17x17 OFA, it will be demonstrated that the fuel assembly growth is acceptable following the method described in the response to RAI #5 and clarified herein. This demonstration will be performed and submitted as part of the application once for each fuel assembly design, and referenced in subsequent applications of the incremental burnup extension to PWRs with the same fuel assembly design.

Clarification Regarding the Fuel Performance Code for Incremental Burnup (Topical Report and Prior RAI Responses such as RAI 28 and 29)

There is some inconsistency in referencing the source of the fuel performance data within the incremental burnup topical report and associated RAI responses. In some instances PAD5 is referenced directly, and in other instances the reference is to the most up-to-date fuel performance code available within Westinghouse (which is currently PAD5). The following clarifications are provided relative to the fuel performance code for application of the incremental burnup extension.

1) The LOCA cladding rupture calculations which are required for implementation of the incremental burnup extension will utilize the latest version of the latest NRC approved fuel performance code that is applicable for LOCA analysis (which must include the effects of fuel thermal conductivity degradation and its attendant effects

on fuel rod behavior). Currently this requirement would result in the use of the PAD5 fuel performance code.

2) Analyses apart from LOCA will utilize an NRC-approved fuel performance code that is applicable within the limitations of this topical report, and which explicitly accounts for the effects of fuel thermal conductivity degradation (such as the PAD5 fuel performance code).

References to PAD5 or a fuel performance code within WCAP-18446-P will be updated to reflect this clarification.

Reference(s)

C-1) WCAP-18446-P, Revision 0, “Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs,” December 2020.

C-2) LTR-NRC-22-4, Revision 0, “Submittal of Set 1 of Responses to Requests for Additional Information on Westinghouse Topical Report WCAP-18446-P/NP, ‘Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs’ (Proprietary/Non-Proprietary),” February 2022.

C-3) LTR-NRC-22-15, Revision 0, “Submittal of Set 2 of Responses to Requests for Additional Information on Westinghouse Topical Report WCAP-18446-P/NP, ‘Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs’ (Proprietary/Non-Proprietary),” April 2022.