Enclosure 3

Supplement to WCAP-18446-P/NP, "Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs," to Extend Applicability to Include AXIOM® Cladding

(Non-Proprietary)

May 2023

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APPENDIX C AXIOM CLADDING SPECIFIC CONSIDERATIONS

C.1 BACKGROUND

Westinghouse Electric Company has developed **AXIOM**® advanced fuel rod cladding material to provide enhanced corrosion resistance when compared to current zirconium-based fuel cladding materials. The **AXIOM** alloy is the next generation of robust alloys targeting very high fuel duties. The Topical Report for **AXIOM** cladding (Pan et al., 2023) received the licensing approval of **AXIOM** cladding for use in pressurized water reactor (PWR) nuclear fuel.

The purpose of this appendix is to provide the necessary information to obtain U.S. Nuclear Regulatory Commission (NRC) approval for the application of **AXIOM** cladding up to **[ ]**^{a,c} peak rod average burnup using the NRC approved methodology within this incremental burnup topical report. Only the cladding-specific requirements and/or models from this topical report are addressed in this appendix. The requirements and limits established for the incremental burnup extension remain applicable to its application with **AXIOM** cladding.

(Pan et al., 2023) contains information supporting the application of **AXIOM** cladding as fuel cladding in PWR nuclear fuel. Results of extensive testing were used to describe and establish the properties of **AXIOM** cladding. (Pan et al., 2023) also describes how **AXIOM** cladding will be incorporated into analytical codes and methods. As described in Section 4 of (Pan et al., 2023), the licensing of **AXIOM** cladding includes rods that support the incremental burnup extension, and in some circumstances **AXIOM** clad rods were irradiated past the **[ ]**^{a,c} peak rod average burnup limit established within this topical report. This appendix specifically addresses the application of **AXIOM** cladding in the various supplemental analytical work described in Section 7 of WCAP-18446, and does not change or invalidate the conclusions drawn in (Pan et al., 2023) regarding fuel that adheres to the 62 GWd/MTU burnup limit.

The **AXIOM** cladding fuel performance models affected by burnup were developed using data that bounds a rod average burnup of **[ ]**^{a,c}. The cladding corrosion model includes data up to **[ ]**^{a,c} , as shown in Table 5.1-2 of (Pan et al., 2023). The rods used to derive the hydrogen pickup fraction had burnups over 70 GWd/MTU, as described in Section 5.2 of (Pan et al., 2023). The data used to develop the fuel rod growth model includes rod average burnups up to **[ ]**^{a,c} , as shown in Table 5.4-1 of (Pan et al., 2023). The creep model includes data from unfueled samples up to an equivalent burnup of **[ ]**^{a,c} , as shown in Table 5.5-1 of (Pan et al., 2023). The remaining steady-state mechanical properties of **AXIOM** cladding do not change with increased burnup. Because the irradiation data used to characterize **AXIOM** cladding behavior in (Pan et al., 2023) remain applicable for the incremental burnup extension, the models and limits established in (Pan et al., 2023) are not revisited in this appendix. Only the cladding-specific aspects of the high burnup fuel LOCA cladding rupture calculations described in the incremental burnup extension are addressed. The requirements and limits established in (Pan et al., 2023) and this topical report remain applicable to the application of the **AXIOM** cladding incremental burnup extension.

For the non-LOCA transients such as rod ejection accident (REA), locked rotor, steamline break and radiological consequences, the computer codes and methods currently used in the analyses remain valid for the **AXIOM** cladding incremental burnup extension. The individual impacts will be accounted for via the analysis inputs and the application of the appropriate acceptance criteria.

C.2 CLADDING SPECIFIC ASPECTS OF THE LOCA CLADDING RUPTURE CALCULATIONS

The main impacts of the incremental burnup extension on loss-of-coolant accident (LOCA) analyses were found to be **[**

]^{a,c} Since the prediction of fuel rod rupture can be dependent on the cladding material, the fuel cladding related aspects of the LOCA methodology within this incremental burnup topical report are addressed. Aspects of the Incremental Burnup methodology that could be impacted by the application of **AXIOM** cladding include cladding deformation and the conditions for rupture. Deformation of the cladding can influence the thermal-hydraulic conditions in the fuel bundles. It can also change the free volume and hence the pressure inside the fuel rod cladding. The conditions leading to rupture will directly influence whether or not the cladding is predicted to fail for a given LOCA transient. The cladding deformation and rupture models are discussed below.

Consideration of **AXIOM** Cladding Deformation

Based on the discussion in Section 4.4.2, **[**

]^{a,c}

As discussed in Section 6.2.1.2.1 of (Pan et al., 2023), the strain rates **[**

]^{a,c}

Consideration of **AXIOM** Cladding Rupture

For analyses with the **FSLOCA** EM (Kobelak et al., 2016), the burst temperature **[**

]^{a,c}

[

][a,c]

C.3 SUMMARY

The irradiation data used to characterize **AXIOM** cladding behavior in (Pan et al., 2023) remains applicable for the incremental burnup extension. Only the cladding-specific aspects of the high burnup fuel LOCA cladding rupture calculations are addressed. The requirements and limits established in (Pan et al., 2023) and the incremental burnup extension remain applicable to the application of the **AXIOM** cladding incremental burnup extension to **[ ]**[a,c] peak rod average burnup for **AXIOM** cladding.

Application of the incremental burnup extension methodology with **AXIOM** cladding **[**

][a,c]

a,c

Figure C.2-1 [ ]a,c

a,c

Figure C.2-2 [

]a,c

C.4 REFERENCES

1. Harper, Z. S., 2022, "Submittal of Set 1 of Responses to the Second Round of 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)," LTR-NRC-22-47.

2. Kobelak, J. R., et al., 2016, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)," WCAP-16996-P-A, Revision 1 and WCAP-16996-NP-A, Revision 1.

3. Pan, G., et al., March 2023, "Westinghouse AXIOM® Cladding for Use in Pressurized Water Reactor Fuel," WCAP-18546-P-A, Revision 0 and WCAP-18546-NP-A, Revision 0.