



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
WASHINGTON, D.C. 20555-0001

October 6, 2021

Ms. Camille Zozula  
Manager, Infrastructure & Facilities Licensing  
Westinghouse Electric Company  
1000 Westinghouse Drive, Building 1, Suite 165  
Cranberry Township PA 16066

SUBJECT: OCTOBER 18-21, 2021, REGULATORY AUDIT PLAN FOR THE  
WESTINGHOUSE ELECTRIC COMPANY TOPICAL REPORT  
WCAP-18456-P/NP, "WESTINGHOUSE AXIOM® CLADDING FOR USE IN  
PRESSURIZED WATER REACTOR FUEL" (EPID: L-2021-TOP-0009)

Dear Ms. Zozula:

By a letter dated March 31, 2021, Westinghouse Electric Company, submitted to the U.S. Nuclear Regulatory Commission (NRC) Topical Report (TR), WCAP-18546-P/NP, "Westinghouse AXIOM Cladding for Use in Pressurized Water Reactor Fuel" (Proprietary/Non-Proprietary) for review and approval.

The NRC staff's technical review of this TR is ongoing. The NRC staff determined that a regulatory audit is needed in order to facilitate the review. The NRC staff will perform a virtual regulatory closed audit on October 18 through 21, 2021. The audit plan that the NRC staff will follow during the audit is enclosed.

If you have any questions, please contact Ekaterina Lenning via phone at 301-415-3151 or via email at [Ekaterina.Lenning@nrc.gov](mailto:Ekaterina.Lenning@nrc.gov).

Sincerely,

A handwritten signature in blue ink that reads "D. Morey".

Signed by Morey, Dennis  
on 10/06/21

Dennis C. Morey, Chief  
Licensing Projects Branch  
Division of Operating Reactor Licensing  
Office of Nuclear Reactor Regulation

Docket No. 99902038

Enclosure: Audit plan

SUBJECT: OCTOBER 18-21, 2021, REGULATORY AUDIT PLAN FOR THE WESTINGHOUSE ELECTRIC COMPANY TOPICAL REPORT WCAP-18456-P/NP, "WESTINGHOUSE AXIOM® CLADDING FOR USE IN PRESSURIZED WATER REACTOR FUEL" (EPID: L-2021-TOP-0009) DATED OCTOBER 6, 2021

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**U.S. NUCLEAR REGULATORY COMMISSION**  
**OFFICE OF NUCLEAR REACTOR REGULATION**  
**DIVISION OF SAFETY SYSTEMS**  
**REGULATORY AUDIT PLAN IN SUPPORT OF**  
**REVIEW OF WESTINGHOUSE ELECTRIC COMPANY TOPICAL REPORT**  
**WCAP-18456-P/NP, “WESTINGHOUSE AXIOM® CLADDING**  
**FOR USE IN PRESSURIZED WATER REACTOR FUEL”**  
**DOCKET NO. 99902038 EPID: L-2021-TOP-0009**

## **1. Introduction and Background**

By a letter dated March 31, 2021, Westinghouse Electric Company (WEC), submitted to the U.S. Nuclear Regulatory Commission (NRC) Topical Report (TR), WCAP-18546-P/NP, “Westinghouse AXIOM Cladding for Use in Pressurized Water Reactor Fuel” (Proprietary/Non-Proprietary) (Ref. 1). AXIOM® cladding is a niobium-bearing zirconium alloy like the ZIRLO™ alloy, with reduced tin content to increase corrosion resistance like the Optimized ZIRLO alloy. Addition of Vanadium and Copper is expected to improve specific properties like Hydrogen pickup. The AXIOM alloy has been processed to be in the partially recrystallized annealed (pRXA) condition similar to the Optimized ZIRLO cladding.

The TR describes in detail how the properties and performance are incorporated into existing NRC-approved analytical methods for use in plant-specific safety analyses. The TR provides fuel performance models for AXIOM cladding, characterization of material/mechanical properties, irradiation programs, in-core behavior of AXIOM cladding, licensing criteria assessment for AXIOM cladding, and safety analyses for AXIOM clad fuel.

The application references several analyses or documents that are not provided as a part of the application or are not provided in the reference section. To confirm that the analyses and references support the requested licensing action, the NRC staff performed a virtual audit of the listed documents related to fuel and cladding related areas of AXIOM cladding in the Section 4, “Information Request,” of this audit plan.

## **2. Regulatory Audit Bases**

The regulatory audit is based on the WCAP-18456-P/NP TR. The format of the regulatory audit is based on the Nuclear Reactor Regulation Office Instruction, LIC-111, “Regulatory Audits.”

The NRC staff considered Criterion 10 of Appendix A to Part 50 General Design Criteria (GDC) of Title 10 of the *Code of Federal Regulations* for Nuclear Power Plants regulatory requirement during its review of the TR. Criterion 10 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.*

The guidance in Standard Review Plan (SRP) Section 4.2 is established to provide assurance of the following:

- (1) the fuel system is not damaged as a result of normal operation and anticipated operational occurrences (AOOs)
- (2) fuel system damage during postulated accidents is never so severe as to prevent full control and shutdown rod insertion within the assumed rod drop time when it is required
- (3) the number of fuel rod failures is not underestimated for postulated accidents
- (4) core coolability is always maintained.

The acceptance criteria listed in SRP sections that are applicable to the review of the TR are:

#### Section 4.2

II.1.A (Fuel System Damage) – See Sections 6.1, 6.2, and 6.4 of the TR.

II.1.B (Fuel Rod Failure) – See Sections 6.1, 6.2, and 6.4 of the TR.

II.1.C (Fuel Coolability) – See Sections 6.1, 6.2, and 6.4 of the TR.

II.2 (Description and Design Drawings) – See Sections 1 and 3 of the TR.

II.3.A/B (Operating Experience/Prototype Testing) – See Sections 3 through 5 of the TR.

II.3.C (Analytical Predictions) – See Sections 6.1 through 6.4 of the TR.

II.4 (Testing Inspection and Surveillance Plans) – No difference than other zirconium cladding.

Section 4.3 Nuclear Design – See Section 6.3 of the TR.

Section 4.4 Thermal Hydraulics Design – See Section 6.4 of the TR.

Review of the TR is also based on the SRP Chapter 6.2.1 related to containment integrity following postulated loss-of-coolant accident (LOCA), steam line, or feedline break accidents.

### **3. Regulatory Audit Scope**

The regulatory audit will focus on the following:

- Details of applicability of Westinghouse Fuel Criteria Evaluation Process (FCEP) on fuel performance and safety analysis analytical modeling for AXIOM cladding: Fuel assembly design and cladding materials, Nuclear design methods, Thermal hydraulic design, Safety analysis, LOCA and non-LOCA, Radiological consequence,

- Microstructure of AXIOM with Niobium, Vanadium,
- Thermal properties of AXIOM fuel,
- Mechanical properties of AXIOM,
- Metal-Water reaction, Corrosion, and hydrogen pickup,
- Cladding burst,
- Irradiation programs-, Dimensional variations,
- Fuel fragmentation, relocation, and dispersal (FFRD),
- Reactivity initiated accidents (RIA) and related tests,
- Licensing applications – fuel performance models, fuel design criteria,
- LOCA and non-LOCA analyses with AXIOM clad fuel,
- Uncertainty calculations,
- Calibration, verification, and validation of reported data in the TR.

#### **4. Information Request**

Most of the performance characteristics of AXIOM, including, cladding thermal-mechanical properties, microstructure, irradiation experience, and licensing application are summarized in the TR. However, details such as calculations, data analysis, uncertainty calculations, validation and verification of data, details of the tests, are not given in the TR. The related calculations, and data analysis shall be provided during the audit.

The NRC staff requests the following documents/data analysis/calculations related to topics/areas listed below:

1. PAD5 TR (Ref. 2) was approved for pressurized water-reactor fuel and clad design with a range of fuel/clad design parameters and several limitations and conditions:
  - a. Please provide documentation for use of PAD5 within the approved ranges of parameters and have complied with all PAD5 limitations and conditions.
2. Please provide documents supporting Thermal Properties discussed in Section 3.2 of the TR.
3. Provide documentation for the mechanical properties discussed in Section 3.3 of the TR.
4. Please provide documentation with details of data analysis for irradiation programs described in Section 4; specifically ramp and bump testing, creep and growth, and AXIOM lead test assembly programs.

5. Please provide documentation and data analysis for corrosion, hydrogen pickup models and during normal operation and accident conditions, fuel rod axial growth, creep models, and mechanical properties under irradiation (Section 5).
6. Please provide documents related to licensing applications described in Section 6 of the TR: AOO analyses, Safety analyses, and thermal-hydraulic design analysis (DNB).
7. Please provide details of uncertainty analyses and details of validation and verification of the test results.

## 5. Specific Requests

1. Please provide plots of yield strength (YS) and ultimate tensile strength (UTS) as a function of burnup for both AXIOM and Optimized ZIRLO.

Reasoning: To understand the relationship of burnup to the changes in AXIOM and Optimized ZIRLO strengths described in the TR.

2. Please provide any rod bow data collected for AXIOM cladding and documentation on the AXIOM rod bow models.

Reasoning: PNNL-29368, "Fuel Performance Considerations for Burnup above 62 GWd/MTU," states that empirical rod bow models are expected to have a greater uncertainty at high burnup, so "Some testing or assessment would be useful to assess the applicability of the rod bow correlation used for high burnup fuel." There is not a significant level of detail of in the TR concerning rod bow data or models.

3. For the plots in Section 5.4.1, "Fuel Rod Axial Growth Model," of the TR where fluence is the independent variable, please provide plots where peak rod average is the independent variable or indicate on the plot the 62 and 68 gigawatt-days per metric ton of uranium (GWd/MTU) peak rod average equivalent.

Reasoning: To get a better understanding and representation of the fuel rod axial growth data above 62 GWd/MTU and near the requested BU limit of 68 GWd/MTU.

## 6. Team Assignments

The review team will consist of the following staff:

Mathew Panicker, NRC technical reviewer (DSS/SFNB)  
Joseph Messina NRC Technical Reviewer (DSS/SFNB)  
Ekaterina Lenning, NRC Project Manager (DORL)  
Robert Lukes, Chief, Nuclear Methods, and fuel Analysis Branch (DSS/SFNB)

## 7. Logistics

The audit will be virtual conducted via electronic reading room, which is requested to be open from October 18-21, 2021. The staff NRC requests Westinghouse to provide

access to the documents a few days earlier than the beginning of the audit.

The electronic reading room or portal should employ measures to prevent the downloading, copying, or otherwise storing of any online portal documents by the NRC staff accessing the portal.

As necessary, clarification calls will be requested regarding the documents under audit.

## **8. Special Requests**

None

## **9. Deliverables**

A regulatory audit summary and request for additional information (RAI) on open audit issues will be completed after the closure of the audit.

## **10. References**

1. WCAP-18456-P/NP, Revision 0, "Westinghouse AXIOM Cladding for Use in Pressurized Water Reactor Fuel," Westinghouse, May 2021 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML21090A110).
2. WCAP-17642-P-A, Revision 1, "Westinghouse Performance Analysis and Design Model (PAD5)," Westinghouse, November 2017 (ADAMS Accession No. ML17335A334).