Enclosure 3

Supplement to WCAP-18546-P/WCAP-18546-NP, "Westinghouse AXIOM® Cladding for Use in Pressurized Water Reactor Fuel," to Extend Applicability to Include Westinghouse Advanced Doped Pellet Technology (ADOPT™) Fuel

(Non-Proprietary)

(8 Pages Including Coversheet)

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1 Introduction

The **AXIOM**® cladding topical report (WCAP-18546-P & WCAP-18546-NP, Reference 1) was submitted to the United States Nuclear Regulatory Commission (US NRC) in March 2021. This supplement to the topical report provides additional information to extend applicability of the topical report to **ADOPT™** fuel pellets.

The Westinghouse **ADOPT** fuel topical report (WCAP-18482-P & WCAP-18482-NP, Reference 2) was submitted to US NRC in May 2020. Upon approval of the topical report, **ADOPT** fuel will be used with all NRC-approved Westinghouse and Combustion Engineering pressurized water reactor mechanical fuel designs, including all NRC-approved zirconium-based cladding materials and fuel enrichments.

This supplement to WCAP-18546-P & WCAP-18546-NP provides additional information on the following subjects.

- Section 4.2.5 of the topical report provided details on the **AXIOM** cladding Lead Test Assembly (LTA) project in Plant T, which is the first **AXIOM** clad fuel rod irradiation program with **ADOPT** pellets in a Pressurized Water Reactor (PWR). The **AXIOM** cladding **/ADOPT** fuel irradiation experience is provided in the supplement.
- Section 5.4 of the topical report provided the rod growth model developed for **AXIOM** cladding. **ADOPT** fuel shows higher rod growth than standard UO_2 fuel. The supplement presents an adjusted rod growth model that addresses the enhanced growth observed with **ADOPT** fuel.

Other **ADOPT** fuel specific models and application are unchanged from the **ADOPT** fuel topical report in WCAP-18482-P / WCAP-18482-NP (Reference 2). The combination of **ADOPT** fuel with **AXIOM** cladding does not result in any other model impacts beyond those described herein.

Upon approval, the models and methods in References 1 and 2, along with additional changes described in this supplement, will be applicable to fuel rods with **AXIOM** cladding loaded with UO_2 and **ADOPT** fuel pellets.

The following sub-sections correspond to the section numbering in the **AXIOM** cladding topical report and are presented as revisions or additions to the topical report. As such, figure, table and reference numbering will be relative to the as-submitted topical report. Added content is reflected in blue font color. Deleted content is reflected in ~~red, strikethrough~~ font. Text written in ***italic, bold*** font are comments to the reader and are used to indicate where significant portions of the as-submitted topical report remain unchanged and are not repeated herein.

2 Description of Topical Report Changes for Supplement

4.2.5 Plant T LTA Project

Significant changes are made to this section to add AXIOM cladding /ADOPT fuel irradiation experience. Therefore, this section is presented as a new section.

The Plant T LTA project was designed to evaluate the Pellet Cladding Interaction (PCI) and corrosion resistance of advanced cladding and pellet materials and to collect in-reactor data necessary to qualify these materials. The Plant T LTA project includes the irradiation experience of the **AXIOM** clad fuel rods with **ADOPT** pellets in PWR.

The Plant T program contains LTAs of Westinghouse 17×17 RFA-2 fuel design. [ ]^{a,c} The **AXIOM** cladding-containing LTAs were inserted in Plant T in mid-2008. Plant T is the only commercial plant hosting **AXIOM** cladding LTAs with [ ]^{a,c} One LTA was discharged after [ ]^{a,c} The irradiation program was completed in 2019.

Poolside post irradiation examinations (PIE) including visual inspections, fuel assembly growth, fuel rod growth as well as fuel rod oxide were conducted after each cycle of irradiation. Inspection campaigns were conducted on one LTA after the first cycle of irradiation in 2009. The assembly growth data, the fuel rod growth and oxide of peripheral rods in this assembly are included in the database. In Summer 2013, inspections and rod extractions were conducted on third burned (~ 36 GWd/MTU) and twice burned (~ 23 GWd/MTU) assemblies. The inspection results (Fuel rod growth, fuel assembly growth and oxide thickness) are included in the database. In December 2014, FR (fuel rod) and FA (fuel assembly) growth inspections were conducted for assemblies after 4 cycles (~ 47.5 GWd/MTU). In January 2016, visual inspections and length measurements were done on fifth burned (~ 51 GWd/MTU) and fourth burned (~ 44 GWd/MTU) assemblies. In June 2016, oxide measurements were conducted on fifth-burned assembly and rods were extracted. The fuel assembly was inserted back for the 6-cycle irradiation during the 2018 outage and the oxide measurements data performed on peripheral rods in August 2019 are included in the database. For each inspection campaign, **AXIOM** clad rods with both UO_2 and **ADOPT** pellets as well as **Optimized ZIRLO** clad rods with both UO_2 and **ADOPT** pellets from the same assembly were included for side-by-side comparison.

In summary, the oxide data of **AXIOM** clad fuel rods with [ ]^{a,c} were included in the database for **AXIOM** cladding corrosion model development. Fuel rod growth data of **AXIOM** clad fuel rods with [ ]^{a,c} are included in the database for **AXIOM** cladding growth model development.

5.4 FUEL ROD AXIAL GROWTH

The **AXIOM** cladding rod growth database for **AXIOM** cladding growth model for standard UO_2 fuel pellets is composed of measurements from **[**

]^{a,c}. The data are summarized in Table 5.4-1.

The data are plotted against the **ZIRLO** and **Optimized ZIRLO** claddings single rod growth database in Figure 5.4-1. The measurements indicate that the fuel rod growth of **AXIOM** and **Optimized ZIRLO** cladding rods is similar to that of **ZIRLO** cladding rods for low to medium fast fluences up to 10×10^{21} n/cm^2 and is lower than that of **ZIRLO** cladding rods at higher fast fluences.

The rod growth database for **ADOPT** fuel in **AXIOM** cladding material is composed of **[**

]^{a,c}

AXIOM cladding continues to show stable growth behavior for burnups beyond 70 GWd/MTU with no indications of instability in growth trends. The axial growth of the **AXIOM** cladding at higher fast fluences appears nearly linear as a function of fast fluence, consistently less than the behavior of both **ZIRLO** and **Optimized ZIRLO** at high fast fluences. **[**

]^{a,c}

5.4.1 Fuel Rod Axial Growth Model for AXIOM Cladding / UO_2 Fuel Rods

No changes to content of subsection 5.4.1 from the as-submitted topical report.

5.4.2 Fuel Rod Axial Growth Model for AXIOM Cladding / ADOPT Fuel Rods

Figure 5.4-4 shows the rod growth data and model for **AXIOM** cladding with standard UO_2 fuel and with **ADOPT** fuel. The data for **ADOPT** fuel show values close to those for standard UO_2 fuel for low fluences, but at larger fluences it becomes apparent that **ADOPT** fuel produces an enhancement in rod growth. This is consistent with the behavior observed in data collected for **ADOPT** and UO_2 fuels pellets in other cladding materials. For example, Figure 5.4-5, taken from Reference 5.11, shows a similar effect in the rod growth data for Westinghouse BWR design with LK3 Zircaloy-2 cladding material.

This behavior is understood to be due to the reduced densification of **ADOPT** fuel, as compared to standard UO_2 fuel. The reduced densification will lead to earlier pellet-cladding gap closure and larger net fuel swelling. After gap closure, the pellet swelling enhances cladding elongation.

To address the enhancement in rod growth, a correction to the **AXIOM** cladding rod growth model for standard UO_2 fuel was developed. To obtain an appropriate estimate for the size of the enhancement, the data for **ADOPT** fuel were compared to **[**

]^{a,c}. This provides the closest comparison by isolating the differences due only to the behavior of **ADOPT** fuel from other possible differences due to variations in fabrication or operating conditions. The two datasets are presented in Figure 5.4-6 with trendline models fit to each.

[

]^{a,c} Figure 5.4-7 shows the dataset for **ADOPT** fuel and the resulting adjusted model (best estimate, upper bound, and lower bound).

In terms of the current **AXIOM** cladding model with UO_2 pellets, the resulting adjusted model is:

$$\left[\qquad \qquad \qquad \right]^{a,c} \quad \text{Equation 5.4-5}$$

Where $g(ADOPT)$ is the relative rod growth for **ADOPT** fuel in percent and $g(PAD5, BE)$ is the best-estimate model for standard UO_2 fuel in Equation 5.4-2.

The estimate obtained for the increase in rod growth due to the use of **ADOPT** fuel pellets is consistent with **[**

]^{a,c}

a,c

*Figure 5.4-4 Rod axial growth data for **AXIOM** rods loaded with **ADOPT** pellets compared to the model and data for standard UO_2 pellets*

a,c

Figure 5.4-5 Fuel rod growth data for BWR fuel designs with diametrical gap of 0.15 mm a,c

*Figure 5.4-6 Rod growth datasets used to estimate the enhancement due to **ADOPT** fuel*

a,c

*Figure 5.4-7 Rod axial growth data for **ADOPT** fuel pellets and the adjusted model rod growth model*

5.7 CHAPTER 5 REFERENCES

No changes to References 5.1 through 5.10

5.11 WCAP-18482-P & WCAP-18482-NP, "Westinghouse Advanced Doped Pellet Technology (ADOPT™) Fuel," May 2020.

5.12 LTR-NRC-21-34, "Submittal of 'Westinghouse Revised Responses to RAIs 7a, 11, and Supplemental Response to RAI 9 for WCAP-18482-P/WCAP-18482-NP,'" November 2021, NRC Accession Number ML21316A137.

3 References

1. WCAP-18546-P & WCAP-18546-NP, "Westinghouse **AXIOM**® Cladding for Use in Pressurized Water Reactor Fuel," March 2021.
2. WCAP-18482-P & WCAP-18482-NP, "Westinghouse Advanced Doped Pellet Technology (**ADOPT™**) Fuel," May 2020.