Enclosure 3

Presentation Slides to Support the Westinghouse-NRC Pre-Submittal Meeting on Westinghouse Topical Report WCAP-18483-P/NP (Non-Proprietary)

June 2025

Westinghouse Electric Company
1000 Westinghosue Drive
Cranberry Township, PA 16066

NRC Pre-Submittal Meeting:

WCAP-18483-P, "EnCore® Chromium Coated Cladding for Use in Pressurized Water Reactors"

June 5, 2025

9:30 AM – 12:00 PM

Westinghouse

Meeting Purpose

- Elaborate on January 22 meeting contents to present **EnCore** Chromium Coated Cladding in formal pre-submittal meeting
- Present overview of material performance that enables enhancements beyond current cladding alloys:

[ ] a,c

- Description and justification for fuel performance model updates for enhancements:

[ ] a,c

- Description of how properties and performance of **EnCore** Chromium Coated Cladding are incorporated into existing NRC-approved analytical methods
- Discuss submittal and review schedules

Obtain NRC alignment and feedback on planned licensing topical report submittal

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Licensing Strategy & Topical Report Overview

WCAP-18483 Overview

- This Westinghouse topical report gives the mechanical design description and safety case for the application of a dense, adherent Cr coating applied to the outer diameter of **[ ]**[a,c] fuel cladding in Westinghouse fuel designs.

- The topical report is written and organized similar to the NRC-approved **AXIOM®** cladding topical report WCAP-18546-P-A.

Requested Limitations & Conditions

- To be used with NRC-approved:
  - PWR reactor designs
  - Westinghouse and Combustion Engineering fuel designs
  - Fuel materials and pellet coatings (IFBA, Gad, etc.)
  - [ ]a,c

- Operating Domain:
  - [ ]a,c rod avg. burnup core-wide
  - [ ]a,c

Cr Coated Cladding Details

Cr Coated Cladding Production

- Coating applied to [ ] a,c by cold spray including use of [ ] a during deposition process
- Coating process and characteristics controlled by Westinghouse Quality Assurance processes to ensure product performance

[ ] a,c

- Materials tested and presented throughout topical report made to existing manufacturing requirements and produced under commercial dedication process
  - Same manufacturing requirements for [ ] a cold sprayed coatings
  - Select non-safety related testing of uncertified Westinghouse supplied materials noted in report

Coated Cladding Benefits – Near Term Submittals

- Several benefits over licensed, uncoated cladding are foreseen but confirmation of some requires additional laboratory and PIE data
  - Minor adjustment from January 2025 meeting

a,c

Ex-Reactor Performance Comparison

a,c

[ ] a,c

Simulated PWR Autoclave

PIE Visuals and Metallography

PIE Hydrogen Content

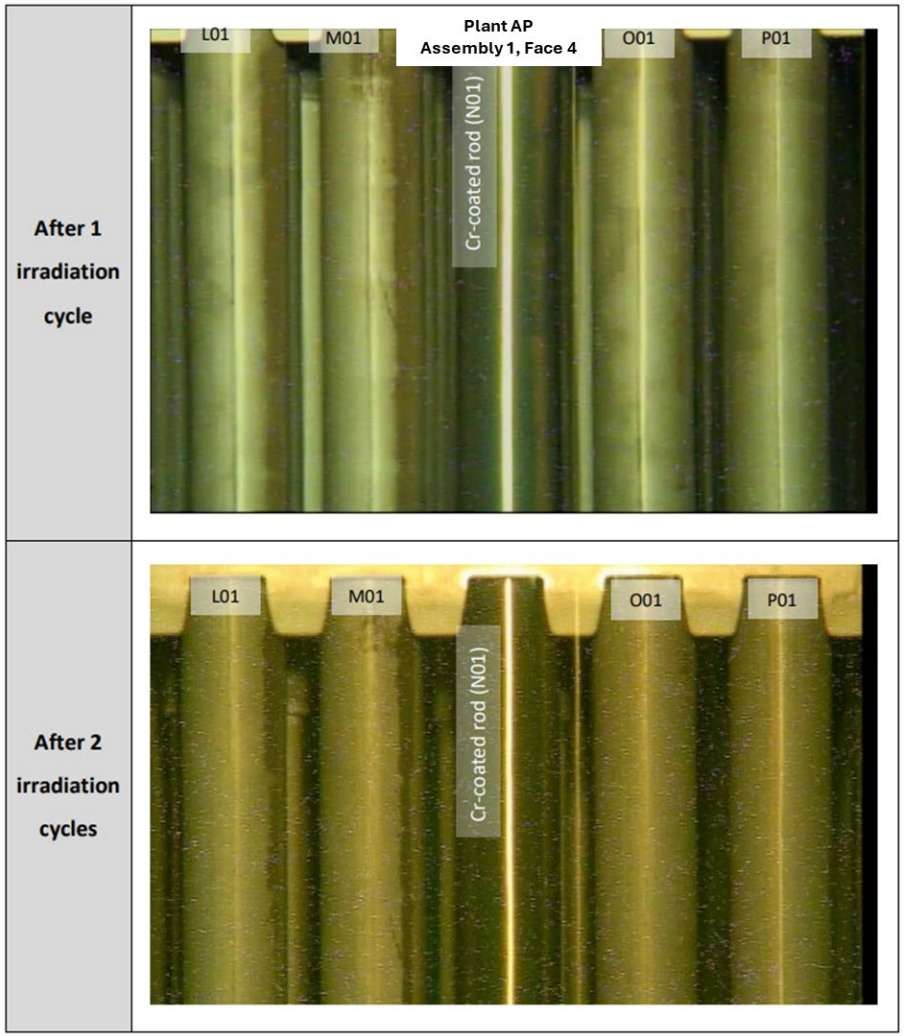
High Temperature Oxidation

[ ]a,c Simulated PWR Autoclave

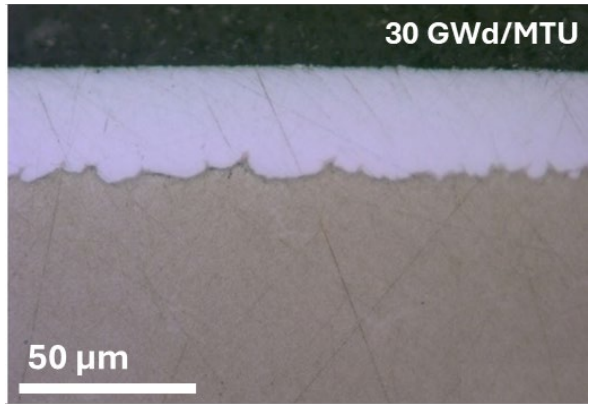
a,b,c

[Examinations] a,c Post-Irradiation

- The coating was fully intact with no evidence of peeling, cracking, or spalling
  - Confirmed metallographically
- Cr coated rods had less evidence of cladding oxidation and crud appeared to easily flake off
- Poolside eddy current scans confirm comparable Cr thickness to as-manufactured condition
  - Negligible oxidation



a,b



a,b

[ ] a,c Post-Irradiation Examinations

a,b,c

[ ]a,c Oxidation Kinetics

a,b,c

Other Data

Cladding Fatigue

[ ]a,c

Cladding Fatigue

a,b,c

[ ]a,c

a,b,c

[ ] a,c

a,b,c

[ ] a,c

a,b,c

PAD5 Methodology Update for Cr Coated Cladding

Corrosion Update

- The performance of Cr coated [ ]^{a,c} cladding has been evaluated by
  - Ex-core autoclave testing exposing cladding to simulated PWR Conditions at 680 °F for [ ]^{b,c} exposure.
  - Inspection of Cr coated fuel rods following in-core irradiation (PIE).
    - Poolside exams
    - Hotcell exams
- Poolside exams show the Cr coated rods have good surface condition with less crud deposits.
- Hotcell metallography results demonstrate full protection of the [ ]^{a,c} substrate with no oxidation under the Cr layer. There is negligible loss of Cr coating.

Treatment of [ ]a,c

- The standard corrosion limits from the **Optimized ZIRLO** corrosion topical are: [ ]a,c
- Negligible oxidation of the **EnCore** Cr coated cladding has been observed during normal operation. Thus, the **[ ]** a,c
- Limit on cladding hydrogen content. **[ ]** a,c

FSLOCA Methodology Update for Cr Coated Cladding

Introduction

- Design basis Loss-of-Coolant Accident (LOCA) analyses seek to demonstrate that the emergency core cooling system (ECCS) meets the requirements of 10 CFR 50.46
- Introduction of chromium-coated cladding to the fuel design does not affect the overall goal of the LOCA analysis, but does introduce potentially different physical effects which can change the analysis results

[ ]a,c

Cladding Emissivity

a,c

Thermal and Mechanical Properties

Other models

- [ ]a,c which are modeled in Westinghouse best-estimate LOCA methodologies
- Conservative to [ ]a,c
- Conclusions to be drawn on a per property basis

[ ]a,c

High Temperature Creep

a,c

Cladding Rupture Temperature

a,c

Cladding Rupture Strain

a,c

High Temperature Oxidation Kinetics

a,c

Assessment of Oxidation Kinetics

a,c

ECCS Acceptance Criteria

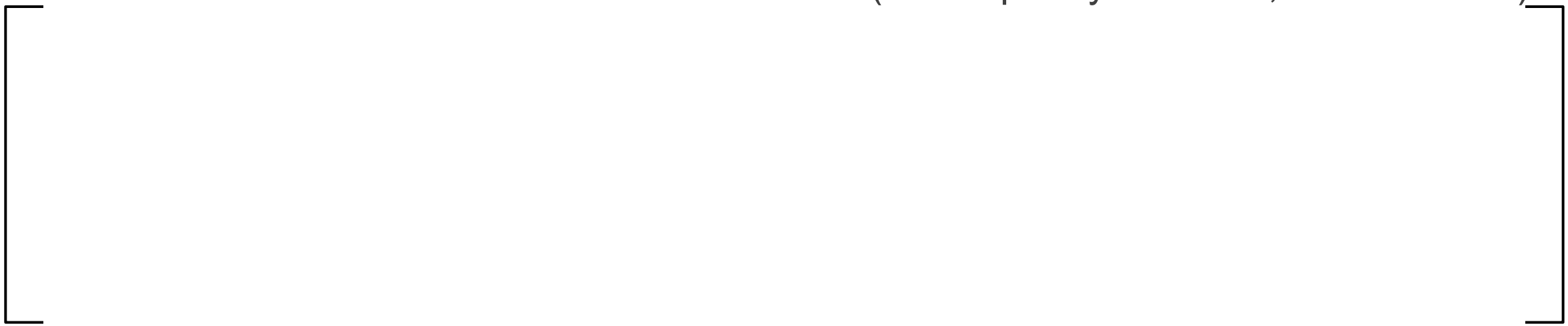
- The existing 10 CFR 50.46 analysis acceptance criteria
  - Peak Cladding Temperature (PCT) less than 2200°F,
  - Maximum Local Oxidation (MLO) less than 17%, and
  - Core-Wide Oxidation (CWO) less than 1%
  - Coolable geometry
  - Long-term cooling

- [

]a,c

ECCS Acceptance Criteria - PCT

- The current PCT limit of 2200°F (1204°C) for Zr cladding is in place to (1) avoid temperatures at which exothermic reaction of zirconium with steam can lead to 'runaway' heatup of the cladding, and (2) ensure that temperatures utilized in testing to establish time-at-temperature (oxidation) limits are not exceeded.
  - Exothermic oxidation with steam is reduced (and explicitly modeled, as discussed)



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ECCS Acceptance Criteria - Embrittlement

a,c

ECCS Acceptance Criteria – Hydrogen Generation

- Core-Wide Oxidation (CWO) is used as a surrogate for hydrogen generation
  - 10 CFR 50.46 limit of 1% was established for oxidation of zirconium alloy fuel rods
  - ECR is assumed to be proportional to the hydrogen release (i.e., CWO < 1%)
- Updates required for Cr oxidation
  - 1 mole of H_2 is produced per mole of O (H_2O) reacted for both Zr and Cr

[ ] a,c

Implementation within Existing NRC-Approved Analytical Methods

Thermal-Hydraulic Methodology

- No change to any existing NRC-approved T/H topical reports for coated cladding design applications

[a,c]

Transient Analysis Methodology

[ ] a,c

- Regulatory Guide 1.236 acceptance criteria separately addressed for 3DRE analyses
- Secondary impacts from other disciplines (e.g., RSAC violations) will be addressed, as needed

Containment Analyses - LOCA

- Long-term and short-term LOCA mass and energy (M&E) release analyses, long-term containment integrity, and short-term subcompartment response analyses considered for some plants.
- Short-Term LOCA M&E releases and subcompartment response are 1 to 3 seconds and not influenced by a fuel product or fuel performance aspects.
- No methodology changes needed for any of the 3 approved long-term LOCA M&E methodologies:
  - WCAP-10325-P-A
  - WCAP-17721-P-A
  - CENPD-132P
- No projected impact on the decay heat.
- Initial core stored energy determined on a plant-specific basis by Fuel Rod Design

[ ] a,c

Radiological Analyses

- LOCA / MHA LOCA
  - RG 1.183 Rev. 1 and pre-decisional/public version of draft regulatory guide DG-1425 (proposed Rev. 2 to RG 1.183) specifically note applicability to chromium-coated cladding (thicknesses less than 50 µm)
  - RG 1.183 Rev. 0 and RG 1.195 (for current licensed enrichment and burnup limits) are applicable to coated cladding.
- Non-LOCA Steady-State Gap Fractions
  - [

] a,c

The codes and methods currently used in the analyses of radiological consequence of design basis accidents [ ] a,c

Summary / Timelines

Summary

- Laboratory testing and PIE confirms **EnCore** Chromium Coated Cladding performance
- Data from **[ ] [a]** cold sprayed Cr coatings included supports **[ ] [a]** to be used in coating manufacturing process
  - Samples tested conform to Westinghouse QA controlled production specifications
- Data are presented to support **PAD5** and **FSLOCA** model updates for performance improvements
- Existing NRC-approved analytical methods remain applicable for thermal-hydraulics, transient analysis, containment analysis, and radiological analysis

The [ ] [a] submittal of the *EnCore* Chromium Coated Cladding topical provides the necessary data and analysis to ensure safe operation in commercial PWRs

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Requested Timeline for Coated Cladding Topical

- Pre-Submittal Meeting
- Submittal of Topical Report
- Acceptance for Review
- Draft SER Issuance

[ ] a

Thank You

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