Duke Energy Pre-Submittal Meeting
January 16, 2025

DUKE ENERGY®

Pre-Submittal Meeting

Strategy for the Sequencing of Proposed License Amendment Requests to Facilitate the Utilization of AXIOM Fuel Rod Cladding

Catawba Nuclear Station (CNS)

McGuire Nuclear Station (MNS)

Duke Energy Attendees

Ryan Treadway (Director, Nuclear Fleet Licensing)

Dennis Earp (Lead Nuclear Engineer, Licensing)

Roger Thomas (Manager, Fuel Mechanical Performance)

Charles Stroupe (Manager, Safety Analysis Applications)

Jeff Abbott (Manager, Safety Analysis Models)

Geoff Pihl (Manager, Nuclear Fuels Engineering – PUMA)

Mark Handrick (Principal Nuclear Engineer – Safety Analysis Applications)

Stan Hayes (Principal Nuclear Engineer – Fuel Mechanical Performance)

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Agenda

- Background
- Proposed Strategy
- Reason for Proposed Changes
- Proposed Technical Specification (TS) Changes
- LAR 1: Reactor Core Safety Limit Revision
- LAR 2: AXIOM and FSLOCA TR Adoption
- Milestones/Schedule
- Regulatory Requirements and Guidance

Background

- First pre-submittal meeting was conducted on October 28, 2024 (ADAMS Accession No. ML24302A070).
- Proposed submittal of a singular license amendment request (LAR) to cover the adoption of Westinghouse Topical Report (TR) WCAP-18546-P/NP, “Westinghouse AXIOM Cladding for Use in Pressurized Water Reactor Fuel,” Westinghouse TR WCAP-16996-P-A, “Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology (FSLOCA)),” and the peak fuel centerline temperature specified in Westinghouse TR WCAP-17642-P/NP, “Westinghouse Performance Analysis and Design Model (PAD5).”
- Supporting FSLOCA analysis to be complete in July 2025.
  - Composite bounding analysis for CNS Unit 1 and MNS Units 1 and 2
  - CNS Unit 2 will have a separate FSLOCA analysis to be covered by a separate submittal
- All three TRs are necessary to support utilization of AXIOM-clad fuel by CNS and MNS
  - First reload starting April 2026 with CNS Unit 1

Proposed Strategy

- Multi-LAR strategy to support adoption of necessary Topical Reports and limits to support utilization of AXIOM-clad fuel
  - LAR 1 – Revise Reactor Core Safety Limit 2.1.1.2 to Reflect Peak Fuel Centerline Temperature from PAD5 TR
    - Applicable to CNS Units 1 and 2 and MNS Units 1 and 2
    - Submittal in February 2025
  - LAR 2 – Adoption of AXIOM TR and FSLOCA Methodology TR
    - Applicable to CNS Unit 1 and MNS Units 1 and 2
    - Revises TS 4.2.1, “Fuel Assemblies,” to add AXIOM as a fuel assembly cladding material and delete reference to Zircalloy
    - Revises TS 5.6.5, “Core Operating Limits Report (COLR),” to include the FULL SPECTRUM™ Loss-of-Coolant Accident (FSLOCA™) Evaluation Model (EM) and the Topical Report for AXIOM™ and clean up the current list of approved analytical methods used to determine the core operating limits
    - Includes 10 CFR 50.12 Exemption Request addressing AXIOM and 10 CFR 50.46 requirements
    - Submittal in August 2025
- A third LAR will focus on CNS Unit 2 adoption of the AXIOM TR and FSLOCA Methodology TR separately to support implementation in Spring 2027.

Reason for Proposed Changes

- CNS and MNS will begin utilizing AXIOM cladding instead of Optimized ZIRLO cladding for feed batches starting with CNS Unit 1 in Spring 2026.
- This will support a full core of AXIOM cladding during the initial 24 month or power uprate cycles at CNS and MNS.
- AXIOM provides additional hydrogen pickup margin relative to Optimized ZIRLO, which aids corrosion analysis margin management for the transition to 24 month and/or power uprate core designs.

Proposed Technical Specification (TS) Changes

LAR 1 - CNS & MNS

2.1.1 Reactor Core SLs

In MODES 1 and 2, the combination of THERMAL POWER, Reactor Coolant System (RCS) highest loop average temperature, and pressurizer pressure shall not exceed the limits specified in the COLR for four loop operation; and the following SLs shall not be exceeded:

2.1.1.1 The departure from nucleate boiling ratio (DNBR) shall be maintained $\geq$ 1.14 for the WRB-2M CHF correlation.

2.1.1.2 The peak fuel centerline temperature shall be maintained < 5080 degrees F, decreasing ~~58~~ degrees F for every 10,000 MWd/mtU of fuel burnup. 9

Proposed Technical Specification (TS) Changes

LAR 2 - MNS

4.2 Reactor Core

4.2.1 Fuel Assemblies

The reactor shall contain 193 fuel assemblies. Each assembly shall consist of a matrix of either ~~Zircalloy,~~ ZIRLO®, ~~or~~ Optimized ZIRLO™ clad fuel rods with an initial composition of natural or slightly enriched uranium dioxide (UO_2) as fuel material. Limited substitutions of ZIRLO®, Optimized ZIRLO™, zirconium alloy or stainless steel filler rods for fuel rods, in accordance with approved applications of fuel rod configurations, may be used. Fuel assemblies shall be limited to those fuel designs that have been analyzed with applicable NRC staff approved codes and methods and shown by tests or analyses to comply with all fuel safety design bases. A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.

, or AXIOM™

AXIOM™,

Proposed Technical Specification (TS) Changes

LAR 2 - CNS

4.2 Reactor Core

, or AXIOM™ (Unit 1 only)

AXIOM™ (Unit 1 only),

4.2.1 Fuel Assemblies

The reactor shall contain 193 fuel assemblies. Each assembly shall consist of a matrix of either ~~Zircalloy,~~ ZIRLO®, ~~or~~ Optimized ZIRLO™ clad fuel rods with an initial composition of natural or slightly enriched uranium dioxide (UO_2) as fuel material.* Limited substitutions of ZIRLO®, Optimized ZIRLO™, zirconium alloy, or stainless steel filler rods for fuel rods, in accordance with approved applications of fuel rod configurations, may be used. Fuel assemblies shall be limited to those fuel designs that have been analyzed with applicable NRC staff approved codes and methods and shown by tests or analyses to comply with all fuel safety design bases. A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.

* A maximum of four lead assemblies containing mixed oxide fuel and M5™ cladding may be inserted into the Unit 1 or Unit 2 reactor core.

Proposed Technical Specification (TS) Changes

- LAR 2 - Changes to CNS/MNS Technical Specifications Section 5.6.5.b (i.e., analytical methods used to determine the core operating limits)
  - Delete the following two methods:
    2. WCAP-10266-P-A, "The 1981 Version of the Westinghouse Evaluation Model using the BASH Code" (W Proprietary)
    3. BAW-10168-P-A, "B&W Loss-of-Coolant Accident Evaluation Model for Recirculating Steam Generator Plants" (B&W Proprietary)
  - Add the following methods to support the analyses of AXIOM fuel with FSLOCA:
    xx. WCAP-16996-P-A, "Realistic LOCA Evaluation Methodology Applied to the Full Spectrum of Break Sizes (FULL SPECTRUM LOCA Methodology)" (W Proprietary)
    xy. WCAP-18546-P-A, "Westinghouse AXIOM Cladding for Use in Pressurized Water Reactor Fuel" (W Proprietary)

    NOTE: CNS TS will include [Unit 1 Only – per License Amendment XXX]

Proposed Technical Specification (TS) Changes

(Continued)

- Changes to CNS/MNS Technical Specifications Section 5.6.5.b (i.e., analytical methods used to determine the core operating limits)
  - Annotate the following methods that can be removed from the COLR methods list after all the fuel with Optimized ZIRLO™ cladding is discharged, and all fuel with AXIOM™ cladding is covered by FSLOCA™:

    13. WCAP-10054-P-A, "Westinghouse Small Break ECCS Evaluation Model using the NOTRUMP Code" (W Proprietary) [Shall not be used to determine core operating limits after XYZ]

    15. WCAP-12945-P-A, Volume 1 and Volumes 2-5, "Code Qualification Document for Best-Estimate Loss of Coolant Analysis" (W Proprietary) [Shall not be used to determine core operating limits after XYZ]

  Where XYZ reflects the first refueling cycles corresponding to full cores of AXIOM-clad fuel.

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LAR 1: Reactor Core Safety Limit Revision

- NRC review of Westinghouse TR WCAP-17642-P/NP, “Westinghouse Performance Analysis and Design Model (PAD5),” found it acceptable for referencing in licensing applications to the extent specified and under the limitations and conditions delineated in the NRC staff’s Safety Evaluation (SE) [ADAMS Accession No. ML17090A443].
- PAD5 supports advanced fuel designs and analysis methods
  - AXIOM cladding is modeled with PAD5
- NRC SE also concluded that the fuel melting limits in PAD5 are acceptable.
- Ability to utilize PAD5 by CNS/MNS requires updating TS SL 2.1.1.2 to reflect the updated burnup-dependent term of the fuel melting limits provided in the PAD5 code.
- CNS/MNS will meet the pertinent constraints identified as Limitations and Conditions by:
  - Application of PAD5 within the limits specified for cladding, fuel and reactor parameters
  - Limit the peak fuel centerline temperature (per this proposed amendment request)

LAR 1: Reactor Core Safety Limit Revision (Continued)

Precedent

Revised Reactor Core Safety Limit 2.1.1.b peak fuel centerline temperature in accordance with WCAP-17642-P-A, Revision 1, “Westinghouse Performance Analysis and Design Model (PAD5)”

- Millstone Power Station Unit 3 (ADAMS Accession No. ML21326A099)
- Turkey Point Nuclear Generating Unit Nos. 3 and 4 (ADAMS Accession No. ML19031C891)

LAR 2: AXIOM and FSLOCA TR Adoption

AXIOM

- NRC review of Westinghouse TR WCAP-18546-P/NP, “Westinghouse AXIOM Cladding for Use in Pressurized Water Reactor Fuel,” found it acceptable for referencing in licensing applications to the extent specified and under the limitations and conditions delineated in the TR and the NRC staff’s Safety Evaluation (SE) [ADAMS Accession No. ML22306A248].
- PAD5 TR applicability was expanded to include AXIOM cladding material.
- Implementation of AXIOM cladding is contingent on the use of PAD5; therefore, LOCA analyses are expected to be performed using the FSLOCA methodology.
- CNS/MNS will meet the constraints identified as Limitations and Conditions of the AXIOM TR and corresponding NRC staff SE.

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LAR 2: AXIOM and FSLOCA TR Adoption (Continued)

- Limitations and Conditions in AXIOM TR and NRC SE:
  - ✓ Use with NRC-approved PWR design
  - ✓ Use with NRC-approved Westinghouse and CE fuel design with corresponding pellet and assembly dimensions
  - ✓ Use with NRC-approved fuel materials and pellet coatings or additives (e.g., ADOPT IFBA, gadolinium)
  - ✓ Fuel burnup currently limited to 62 GWd/MTU peak rod average for all cladding types
    - Higher limit may be allowed once additional information specific to increased burnup is submitted and approved by the NRC
  - ✓ Best Estimate Oxide Thickness < 100 µm
  - ✓ Best Estimate HPU within limit

LAR 2: AXIOM and FSLOCA TR Adoption (Continued)

Precedent - AXIOM

- Turkey Point Nuclear Generating Unit Nos. 3 and 4 (ADAMS Accession No. ML23320A028) [Under Review by NRC]
  - Proposed the incorporation of AXIOM into the licensing basis
    - Also proposed incorporating advanced fuel features ADOPT fuel pellets and a PRIME fuel skeleton, as well as extending TS surveillance intervals, modifying TS Allowable Values and a Trip Setpoint to facilitate a transition to 24-month fuel cycles, but that is beyond the scope of the Duke Energy proposed LAR.
  - Included exemption request from certain requirements of 10 CFR 50.46 to support application of AXIOM cladding

Note: CNS/MNS LAR only proposing the adoption of AXIOM cladding material.

LAR 2: AXIOM and FSLOCA TR Adoption (Continued)

FSLOCA

- NRC review of Westinghouse TR WCAP-16996-P/WCAP-16996-NP, Volumes I, II, and III, Revision 1, "Realistic Loss-Of-Coolant Accident Evaluation Methodology Applied to the Full Spectrum of Break Sizes," found it acceptable for referencing in licensing applications for use of the FSLOCA evaluation methodology to perform best-estimate analyses for the entire spectrum of LOCAs including small break LOCA, intermediate break LOCA, and large break LOCA scenarios in Westinghouse designed three- and four-loop pressurized-water reactor plants with cold leg injection only provided that the limitations and conditions stipulated in the NRC final SE are met along with the proper documentation.
- CNS/MNS will meet the constraints identified as Limitations and Conditions per NRC staff SE.
- Duke Energy has an existing commitment to NRC to re-analyze Large Break LOCA with methods that explicitly consider fuel pellet Thermal Conductivity Degradation (TCD). The FSLOCA methodology explicitly considers TCD effects. [ADAMS Accession No. ML16271A329]

LAR 2: AXIOM and FSLOCA TR Adoption (Continued)

Precedent - FSLOCA

Content for the FSLOCA analysis will be similar to that provided by the following:

- Watts Bar Nuclear Plant, Units 1 and 2 (ADAMS Accession No. ML21034A169)
- Turkey Point Nuclear Generating Unit Nos. 3 and 4 (ADAMS Accession No. ML22028A066)

Basis for composite FSLOCA analysis for MNS/CNS:

- MNS – ADAMS Accession No. ML003753895
- CNS – ADAMS Accession No. ML003756631

Milestones/Schedule

Milestone	Date
Submit LAR 1 addressing TS SL revision	February 28, 2025
Receipt by Duke of FSLOCA Analysis	July 31, 2025
Submit LAR 2 addressing adoption of AXIOM TR and FSLOCA Methodology TR	August 29, 2025
Audit of AXIOM/FSLOCA Analysis content	Late October or Early November 2025
Completion of any associated RAI	December 2025
Requested approval of both LARs	By March 31, 2026
CNS Unit 1 Outage Start Date	April 2026

Regulatory Requirements and Guidance

Regulations

- 10 CFR 50.36, “Technical specifications”
- 10 CFR 50.46, “Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors”
- 10 CFR 50 Appendix A, “General Design Criteria for Nuclear Power Plants”
  - GDC 10, “Reactor design”
  - GDC 35, “Emergency core cooling”


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