Duke Energy Pre-Submittal Meeting
October 28, 2024

DUKE ENERGY®

Pre-Submittal Meeting

License Amendment Request

to

Address the Adoption of the Westinghouse Performance Analysis and Design Model (PAD5™) Code, the FULL SPECTRUM™ Loss-of-Coolant Accident Methodology, and AXIOM™ Fuel Rod Cladding (with Associated Exemption Request)

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 – Design and Operation
- Proposed Technical Specification (TS) Changes
- Reason for the Proposed Changes
- AXIOM™
- FULL SPECTRUM™ Loss-of-Coolant Accident Analyses
- Fuel Performance and Design Model (PAD5)
- Regulatory Requirements and Guidance
- Precedent
- Schedule

Background – Design and Operation

- Catawba Nuclear Station (CNS) and McGuire Nuclear Station (MNS) are both two-unit sites, each a pressurized water reactor Nuclear Steam Supply System (NSSS) with four coolant loops furnished by Westinghouse Electric Corporation.
- Rated Thermal Power (RTP)
  - 3469 MWt – CNS Unit 1, MNS Units 1 & 2
  - 3411 MWt – CNS Unit 2
- Steam Generator Design
  - Babcock and Wilcox International (BWI) vertical U-tube replacement steam generator (RSG) units containing alloy 690 tubes - CNS Unit 1 and MNS Units 1 & 2
  - Westinghouse vertical U-tube steam generator units containing alloy 600 tubes - CNS Unit 2

Proposed Technical Specification (TS) Changes

Duke Energy is planning on utilizing AXIOM cladding on fuel for MNS and CNS and is proposing the following changes for MNS and CNS TS:

- Revise Reactor Core Safety Limit 2.1.1.2 to implement Westinghouse Performance Analysis and Design Model (PAD5) methodology for peak fuel centerline temperature.
- Revise TS 4.2.1, "Fuel Assemblies," to add AXIOM™ as a fuel assembly cladding material and delete reference to Zircalloy.
- Revise 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.

Proposed Technical Specification (TS) Changes

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

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

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

- 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 reflect only applicable to Unit 1

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Proposed Technical Specification (TS) Changes

- 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 Optimized ZIRLO™ fuel is discharged, and all AXIOM™ fuel 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]

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Reason for the Proposed Changes

- AXIOM™ provides additional hydrogen pickup margin relative to Optimized ZIRLO™, which aids corrosion analysis margin management for the transition to 24-month fuel cycle and/or power uprate core designs
- Duke Energy plans to implement AXIOM™ cladding on a schedule that supports full cores of AXIOM™ clad fuel during the initial 24-month fuel cycles or power uprate cycles at MNS and CNS
  - CNS Unit 1 (Spring 2026; first 24-month fuel cycle in Spring 2029)
  - MNS Unit 1 (Fall 2026; first 24-month fuel cycle in Fall 2029)
  - CNS Unit 2 (Spring 2027; first 24-month fuel cycle in Spring 2030)
  - MNS Unit 2 (Fall 2027; first 24-month fuel cycle in Fall 2030)

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AXIOM™

- Compared to ZIRLO™ and Optimized ZIRLO™, AXIOM™ cladding is designed to exhibit:
  - Improved corrosion resistance
  - Lower hydrogen pickup (HPU)
  - Lower creep
- Niobium-bearing alloy with reduced tin content
- Alloying elements including vanadium and copper
- 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].

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- Limitations and Conditions
  - ✓ 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

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- 10 CFR 50.12 Exemption Request

The requested exemption would permit the use of AXIOM™ fuel rod cladding material. The regulations in 10 CFR 50.46 contain acceptance criteria for the emergency core cooling system (ECCS) for reactors that have fuel rods fabricated either with zircaloy or ZIRLO fuel rod cladding material.

Therefore, an exemption is required from specific portions of 10 CFR 50.46 to support the use of AXIOM™ fuel rod cladding at CNS/MNS. This exemption request relates solely to the specific cladding material identified in these regulations (fuel rods with zircaloy or ZIRLO cladding) and will provide for the application of 10 CFR 50.46 to the use of AXIOM™ fuel rod cladding at CNS/MNS.

FULL SPECTRUM™ Loss-of-Coolant Accident Analyses

- Westinghouse FULL SPECTRUM™ Loss-of-Coolant Accident (FSLOCA™) Evaluation Model (EM) analysis explicitly addresses AXIOM cladding
- Separate FSLOCA™ EM analyses are required for MNS/CNS Unit 1 (BWI RSGs) and CNS Unit 2 (Westinghouse SG Model D5) due to different steam generator design
- A single composite FSLOCA™ analysis will cover the 3 units with RSGs
  - Will address AXIOM™ cladding only. Optimized ZIRLO™ cladding will continue to be covered by existing CQD and NOTRUMP LOCA analyses.
  - Will also address the proposed Extended Power Uprate to 3700 MWt for the 3 RSG units
    - All plants will operate at current RTP limits until EPU implementation (2029-2031)
  - Will not address 24-month fuel cycles – separate analyses to be developed later for fuel exposures > 62 GWD/MTU
  - Assumes a five-minute reactor coolant pump (RCP) trip time upon loss of subcooling in place of Duke Energy's current two-minute time critical operator action time

FULL SPECTRUM™ Loss-of-Coolant Accident Analyses

- FSLOCA™ Analysis for RSG plants to be submitted as a supplement to the AXIOM™ LAR
- Peaking factor limits for AXIOM™ cladding with FSLOCA™ will be contained in the Core Operating Limits Reports (COLRs)
- Current peaking limits for Optimized ZIRLO™ cladding will also be retained in the COLRs for transition cycles
- Following discharge of all Optimized ZIRLO™ cladding fuel from the core designs, WCAP-12945-P-A (CQD) and WCAP-10054-P-A (NOTRUMP) can be removed from the TS COLR Methods Section 5.6.5.
- 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). FSLOCA and PAD5 methodologies explicitly consider TCD effects. [ADAMS Accession No. ML16271A329]

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Fuel Performance and Design Model (PAD5)

- PAD5 supports advanced fuel designs and analysis methods
  - AXIOM cladding
  - FSLOCA
  - Duke Energy's Rod Ejection Accident analyses
- 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 SE [ADAMS Accession No. ML17090A443].
- CNS/MNS will meet the constraints identified in limitations and conditions of the TR and NRC staff SE.

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”

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

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

Precedent

PAD5

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)

Schedule

- Submit License Amendment Request (LAR) in January 2025
- Supplement LAR with FSLOCA™ analyses in July/August 2025
  - Calculations available for regulatory audit
  - Westinghouse Engineering Report available October 2025
- Requesting approval in December 2025 to support CNS Unit 1 Spring 2026 refueling outage
  - MNS Unit 1 refueling outage Fall 2026
  - MNS Unit 2 refueling outage Fall 2027
- Submit LAR for CNS Unit 2 for AXIOM™ and FSLOCA™ by April 2026 to support Spring 2027 refueling outage

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