BWXT Advanced Nuclear Reactor (BANR) Regulatory Update

BANR-LTR-23-0488

Enclosure 2 (Redacted Slides)

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Agenda

1. Goals and Objectives
2. Fuel Qualification Plan White Paper
3. TRISO Fuel and Core Analysis
4. Fuel Manufacturing Development
5. Irradiation Testing
6. Fuel PIRT
7. Review, Questions, Actions

1 – Goals and Objectives

- BWXT to provide NRC Staff with technical updates
  - Progress on white paper
  - Fuel Manufacturing
  - Core Design / Neutronics
  - Irradiation Testing
  - Post Irradiation Examination
  - PIRT
- BWXT/NRC Open Discussion
  - Technology Development
  - Fuel Qualification approach
- BWXT listen to comments, feedback, areas of concern from NRC Staff

2 – Fuel Qualification Plan White Paper

- Provide the framework and methodology for Fuel Qualification Topical Report
  - Focus on our *approach* to fuel qualification methodology
  - Contents adjusted after June BWXT/NRC meeting
  - Possible follow-on Topical Reports:
    - Fuel Qualification Methodology
    - Fuel Qualification for BWXT ARDP BANR
- BWXT Fuel Qualification White Paper to be submitted in December 2024

2 – Fuel Qualification Plan White Paper

- Contents and Format Informed by
  - Fuel Qualification Assessment framework (AQFK)
  - Evaluation Model Development and Assessment Process and Graded Approach (RG1.203)
  - Accelerated fuel Qualification (AFQ)
  - BWXT Design Verification and Validation Process [[4]]
  - Past fuel qualification submittals
    [[4]]
  - Methodology supports Requirements
    - 10 CFR 50 43(e)(1)(i), 43(e)(1)(iii), and 34(a)(1)((ii)(D)
    - 10 CFR 52 47(a)(2)(iv) and 79(a)(1)(vi)
    - General Design Criteria (GDC) contained in Appendix A to 10 CFR Part 50: 2, 10, 27, 35

2 – Fuel Qualification Plan White Paper – Contents (1/2)

- Introduction
  - Objectives (*specific feedback desired from NRC*)
  - Discussion of our high-level approach and basis for fuel qualification
- Regulatory Drivers
  - Summary of relevant Regulations and Guidance
  - Summary of US precedence with TRISO (Fuel Qualification, reactors)
- TRISO particle discussion
  - Details of critical characteristics
- PIRT for Fuel Qualification
  - Comparison to historical fuels, e.g. AGR
  - Comparing and differentiating BANR fuel and the AGR fuel
  - Expected Mechanical and structural performance
  - Effects of chemical, thermal, and irradiation
  - Manufacturing process

2 – Fuel Qualification Plan White Paper – Contents (1/2)

- Fuel performance modeling
  - Defined analytical approach
    - Consider mechanical and structural performance
    - Consider chemical, thermal, and irradiation effects
- Fuel fabrication specifications
  - Define the manufacturing envelope
  - Tolerances
  - Quality assurance and quality control
- Test plans
  - Modeling and simulation
  - Manufacturing
  - Irradiation
  - Detailed irradiation test plan
  - Post-irradiation Examination
- Fuel Performance
  - Irradiation history
  - Comparison of performance envelope to test envelope
  - Benchmark models for code V&V

2 – Fuel Qualification Plan White Paper – Approach (1/2)

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- BWXT Design Verification-Validation

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2 – Fuel Qualification Plan White Paper – Approach (2/2)

- EMDAP Principles

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- Accelerated Fuel Qualification (AFQ)

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- Existing EMs supporting qualification

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Review of particle architecture

	Metric	[[4]]	AGR TRISO	unit
	Kernel diameter		425 ± 10	micron
thickness	C-Buffer		100 ± 15	micron
thickness	IPyC		40 ± 4	micron
thickness	SiC		35 ± 3	micron
thickness	OPyC		40 ± 4	micron
	Kernel/Particle volume ratio		0.1228	-

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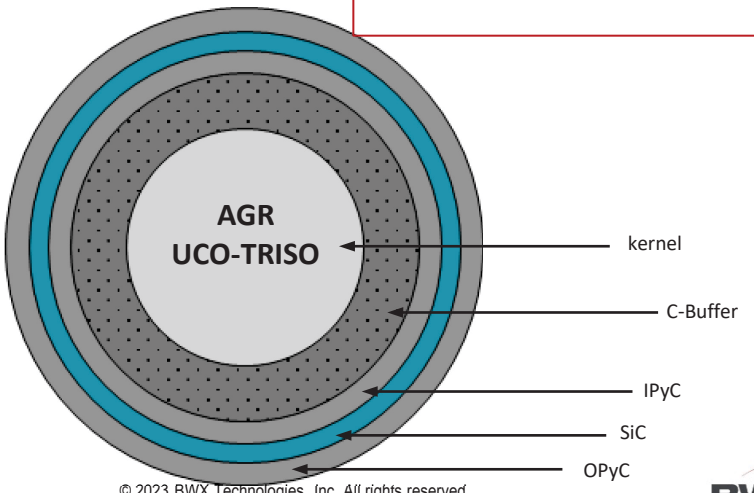

3 – TRISO Fuel Design and Core Analysis

Objective

- Core Analysis tasks in support of fuel qualification are:
  - Fuel element design
  - Assessment of neutronic, thermal, and mechanical fuel performance
  - Development of operational range of the reactor
- [[4]] models are used to confirm core designs operate and fuel damage does not occur within the range of conditions of the fuel irradiation program:
  - Burnup
  - Fluence
  - Time-averaged temperature and time-at-temperature
  - Power density
  - Packing Fraction

Example Fuel Element Geometries and Thermal Results

Parameter	[[ ]]
Geometry	
dP/P (%)	
Boundary Layer dT (K)	

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Example of Core Parameters

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Example of Operational Envelope

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4 - Fuel Manufacturing Development

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4 - Fuel Manufacturing Development

UN-TRISO Particle Design Optimization

TRISO Coating Modeling

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4 - Fuel Manufacturing Development

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4 - Fuel Manufacturing Development

- Producing large quantities of practical geometries for CVI development and optimization
  - Vital to reduce variance and characterize CVI relevant characteristics
- Leveraging CT Scanning to investigate 3D-printed green bodies

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4 - Fuel Manufacturing Development

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Understand Particle Packing

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Understand Particle Packing

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BWXT BANR-1 ATR Irradiation Test Objectives and Example

- Collect continuous fission gas measurements released from the fuel
- Irradiate fuel under a range of conditions, specifically:
  - Burnup range:
  - Time-averaged fuel temperature:
  - Maximum instantaneous peak fuel temperature:
  - Fast neutron fluence:
  - Target endurance:
- Fuel specimens:
  - UN-TRISO: SiC matrix, carbon matrix

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5 – Irradiation Testing: Post Irradiation Examination (PIE)

Post Irradiation Examination (PIE) Provides Fuel Performance and Characterization Data to Support Fuel Qualification

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Primary PIE Goal

PIE is intended to supplement in-pile data to verify or contradict the hypothesis that the ARDP novel fuel form is safe for commercial/industrial use.

Secondary PIE Goal

To better understand the physical phenomena that underpin the safety of the fuel and/or the mechanisms by which the fuel failed during testing.

5 – Irradiation Testing: Post Irradiation Examination (PIE)

PIE activities for UN-TRISO/CVI-SiC specimens

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5 – Irradiation Testing: Post Irradiation Examination (PIE)

PIE activities for TRISO/CVI-C specimens

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Integral Fuel Performance Criteria – PIRT Gap Analysis

- Gap analysis is part of the stakeholder requirements analysis in BWXT-AT design verification-validation approach
- The gap analysis is applied to a “modified” fuel or fuel form designs in order to assess the critical phenomena and methods associated with fuel performance.
- The procedure is designed to inform upon
  - Experimental data (ED) – fuel qualification
  - Evaluation Model (EM) - fuel qualification
  - Manufacturing – specification, SET/IET test specimens
- The procedure output is designed to inform and assess:
  - The modified fuel designs risks reduction strategy
  - Design based decisions

Phenomena Modification Identification

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- Decision on whether the phenomena or method has been modified
- Compile available applicable literature or database(s) covering:
  - Experimental
  - Analytical
  - Physical process data, for the specific phenomena or method

PIRT Modification, Importance, Knowledge, Closure criteria

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- Rank the magnitude and give a rationale for the modified phenomena or method in order to establish a phenomenological hierarchy of the changes in the modified fuel design.
- Modified importance ranking and rationale
- Modified knowledge ranking and rationale
- Closure Criterion: Identify key studies, test, databases and or deliverables needed to fill in gaps in the phenomena or method.

Open Discussion, Questions, Actions, and Feedback