Xe-100 Fuel Qualification Update

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Agenda & Objectives

Open Portion:

- Overview of TRISO-X fuel
- Applicable Regulations & Review Guidance
- Review Current Status of X-energy fuel qualification
- Discuss X-energy's approach for future fuel testing

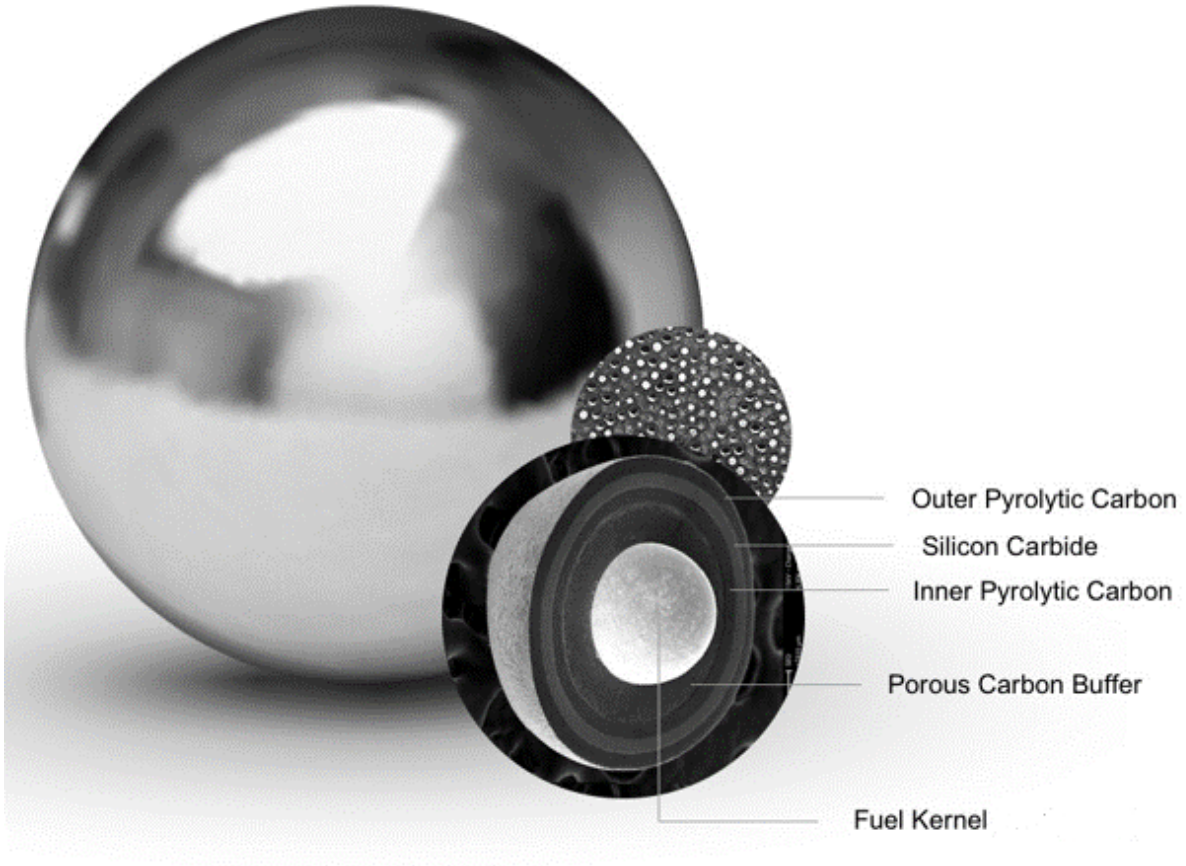
Closed Portion:

- Overview of X-energy test plans
- Discussion of future licensing submittals

Objectives:

- Provide NRC staff update on fuel qualification
- Receive feedback on testing approach
- Achieve alignment on licensing approach

Xe-100 Fuel Design – TRISO-Coated Particles & Fuel Pebble (TRISO-X)



- **TRISO / HALEU UCO**
  - HALEU UCO kernel coated with layers of carbon, pyrolytic carbon & silicon carbide to form a TRISO particle

- **TRISO-coated fuel particles**
  - TRISO-coated fuel provides robust efficient containment of radionuclides within the TRISO particles, based on extensive development and testing through the DOE's Advanced Gas Reactor (AGR) program

Applicable Regulations & Review Guidance

- NUREG-2246 “Fuel Qualification for Advanced Reactors”:
  - Objective of nuclear fuel qualification is to: *Demonstrate that a fuel product fabricated in accordance with a specification behaves as assumed or described in the applicable licensing safety case, and with the reliability necessary for economic operation of the reactor plant*
- DG-1404 “Guidance for a Technology-Inclusive Content-of-Application Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors”:
  - Provides Staff Position that NEI 21-07, Revision 1 provides an acceptable method for developing information related to the safety classification of SSCs:
    - Additional information on fuel qualification is provided, including:
      - The role of the fuel safety analysis is adequately described
      - The fuel qualification plan is adequate

Current Status of X-energy Fuel Qualification

- Xe-100 Licensing Topical Report: TRISO-X Pebble Fuel Qualification Methodology, Revision 3 (ML22216A179) received a safety evaluation (ML22327A201) March 2023 with three limitations:
  - #1 - Applicants referencing the Technical Report (TR) should provide a justification for releases from defect particles, contamination in the fuel matrix, and diffusion of volatile radionuclides in addition to the intact particle failure fraction derived from the testing to be used in a future licensing application. In effect, this methodology forms a portion of the fuel qualification for the final reactor fuel form, but not the entirety of the fuel qualification process for the performance of the fuel (e.g., cover the aspects cited above or the more comprehensive list of fuel qualification areas in NUREG-2246).
  - #2 - This approval is limited to the plan to test TRISO fuel and the operational envelope (temperature, burnup, and environmental conditions) outlined in the TR. Applicants referencing the TR should provide a set of fuel specifications and demonstrate how fuel to be used in the reactor will meet these specifications. Future licensing submittals will be needed to qualify the fuel for the totality of the operational regime, including but not limited to transient accident conditions and mechanical effects to the extent that these are not incorporated within the scope of the TR.
  - #3 - An applicant referencing the TR is subject to the limitations and conditions associated with the approved EPRI TRISO TR

Current Status of X-energy Fuel Qualification

- Limitation #1:
  - Applicants referencing the TR should provide a justification for releases from defect particles, contamination in the fuel matrix, and diffusion of volatile radionuclides in addition to the intact particle failure fraction derived from the testing to be used in a future licensing application. In effect, this methodology forms a portion of the fuel qualification for the final reactor fuel form, but not the entirety of the fuel qualification process for the performance of the fuel (e.g., cover the aspects cited above or the more comprehensive list of fuel qualification areas in NUREG-2246).
- Current X-energy Status:
  - The “Xe-100 Licensing Topical Report - Mechanistic Source Term Approach” is planned to be submitted for NRC review prior to PSAR Submittal. This will address a portion of Limitation #1.
  - The remainder of Limitation #1 will be addressed by the test results discussed in the closed portion of this presentation

Current Status of X-energy Fuel Qualification

- Limitation #2:
  - This approval is limited to the plan to test TRISO fuel and the operational envelope (temperature, burnup, and environmental conditions) outlined in the TR. Applicants referencing the TR should provide a set of fuel specifications and demonstrate how fuel to be used in the reactor will meet these specifications. Future licensing submittals will be needed to qualify the fuel for the totality of the operational regime, including but not limited to transient accident conditions and mechanical effects to the extent that these are not incorporated within the scope of the TR.
- Current X-energy Status:
  - Current testing details are discussed in this closed portion of this presentation

X-energy Approach to Fuel Testing

- Separate testing campaigns are planned on the pebble form:
  - Unirradiated pebble mechanical testing
  - Irradiation of pebbles with subsequent Post Irradiation Examination (PIE) testing
  - Additional details provided in the closed portion of this presentation
- Development of analytical models of the fuel pebble are being considered. Test data would feed into the validation and verification of such models.
- Results will be used to confirm fuel particle and pebble mechanical performance for the Xe-100 design

Current Status of X-energy Fuel Qualification

- Limitation #3:
  - An applicant referencing the TR is subject to the limitations and conditions associated with the approved EPRI TRISO TR. (Safety Evaluation is ML20216A453)
- Current X-energy Status:
  - An overview of the preliminary Xe-100 operating regime is discussed in this closed portion of this presentation

Conclusion | Next Steps

- X-energy is preparing to execute a comprehensive testing plan to ensure the fuel is qualified for service in the Xe-100 reactor
- Guidance from NUREG-2246 and DG-1404 is being utilized to inform the plans and analysis of the results
- Tests are scheduled to complete in support of a revision to the TRISO-X Pebble Fuel Qualification Methodology Licensing Topical Report in support of Operating License Application
- Questions?

Closed Portion

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Overview of X-energy's Testing Plans

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- Additional details of each are provided in the following slides

Overview of X-energy's Testing Plans

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Overview of X-energy's Testing Plans

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Overview of X-energy's Testing Plans

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Overview of X-energy's Operating Regime

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Discussion of Future Licensing Submittals

- TRISO-X Pebble Fuel Qualification Methodology Licensing Topical Report:
  - X-energy currently intends to revise this document with:

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Conclusion

- Questions?