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Fuel Qualification for Advanced Reactor Designs

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Regulatory Philosophy

- NRC considers fuel to be the first barrier to fission product release
- Fission product release should be minimized for all conditions of operation (normal operation, AOOs and postulated accidents)
- Reactivity control should be ensured in the event of any fuel damage
- In order to address fission product release and safe shutdown concerns fuel performance must be characterized for all operating conditions
- Regulatory review is dependent on specific fuel design and potentially the licensing approach pursued

Applicable Regulations

- GDC 10 - Establishes specified acceptable fuel design limits (SAFDLs) to ensure the reactor core and associated coolant, control, and protection systems are designed with appropriate margin.
- GDC 27 - Requires that the RCSs have a combined capability, in conjunction with poison addition by the emergency core cooling system, of reliably controlling reactivity changes under postulated accident conditions, with appropriate margin for stuck rods.
- GDC 35 - Ensures emergency core cooling is adequate to prevent fuel and clad damage that could interfere with continued effective core cooling and limit clad metal-water reaction to negligible amounts

50.46 / 50.46c – ECCS performance requirements and fuel specific analytical limits and requirements

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Fuel Characterization

- To meet applicable fuel GDCs, fuel behavior must be characterized
  - Determine fuel behavior under design basis events
  - Identify fuel failure mechanisms
  - Determine analytical limits for identified fuel failure mechanisms for AOOs (e.g., SAFDLs) and postulated accidents
- Fuel characterization should be supported by data
  - Historical operational or pre-existing experimental data can be used if properly justified
  - If no existing or insufficient data is available, develop a test program to characterize the fuel behavior

Fuel Characterization (cont.)

- Scope of fuel characterization data is dependent on the degree of departure from previously evaluated fuel designs
- Existing data or test program should include exposure-dependent thermal, mechanical, chemical and nuclear properties
- Define lifetime limits for each component based upon fuel characterization
- Fuel surveillance programs should be considered to add confirmatory data and may be used to reduce uncertainties associated with fuel characterization data

Analytical Models and Methods

- Analytical models and methods need to be developed to predict fuel behavior under all operating conditions
- To qualify fuel codes design basis events (DBEs) and corresponding range of operating conditions needs to be considered
- Commercial licensing applications requires
  - 10 CFR 50 Appendix B Quality Assurance (QA) program
  - Qualified software quality assurance program
- Reasonable assurance of predicting fuel behavior must be demonstrated for any licensing approach (e.g., prototype)
  - Design margin aids in reasonable assurance finding when database is not extensive

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Guidance

- NUREG-0800 (Standard Review Plan) Section 4.2 provides review guidance of LWR fuel system designs
- Advanced fuel designs can differ significantly from LWR designs
  - Identified failure mechanisms and associated SAFDLs may not be applicable to advanced designs
- INL, ORNL and ANL have performed a regulatory gap analysis on the Chapter 4 SRPs including SRP 4.2 for SFR and mHTGR designs
- Noted that a “clean sheet of paper” was needed for mHTGR fuel
- Regulatory gap analyses are useful to the staff

NRC Interactions

- Early interactions with NRC aids review process
  - Pre-application technical meetings
  - Industry white-papers
  - Regulatory involvement in test plans
  - Potential pre-application review
  - Topical Reports
  - Pre-application schedule

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Conclusions

- Fuel operating characteristics including failure modes need to be determined
- Design margin, while conservatively accounting for uncertainties, can aid the staff in reaching a reasonable assurance finding
- Applicant should consider a fuel surveillance program which confirms uncertainties and may support future improved plant operating efficiency
- Regulatory gap analyses and white papers are useful to the staff as advanced fuels are typically significantly different
- Regulatory involvement in advanced fuel test plans should be considered