RIC Session T12 "Understanding the NRC's Review and Approval Process for New Fuels"

Licensing Advanced Reactor Fuel Designs

Jeff Schmidt
Sr. Reactor Engineer
Office of New Reactors
U.S. Nuclear Regulatory Commission

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

Fuel Characterization

- To meet applicable fuel GDCs, fuel behavior must be characterized
  - Determine fuel behavior under normal operations, AOO and postulated accidents
  - Identify fuel failure mechanisms
  - Determine analytical limits for identified fuel failure mechanisms for AOOs (e.g., SAFDLs) and postulated accidents

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Fuel Characterization (cont.)

- 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
- Scope of fuel characterization data is dependent on the degree of departure from previously evaluated fuel designs

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Fuel Characterization (cont.)

- 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

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Analytical Models and Methods

- Analytical models and methods need to be developed to predict fuel behavior under all operating conditions
- 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)

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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 form LWR designs
  - Identified failure mechanisms and associated SAFDLs may not be applicable to advanced designs
- Level of fuel characterization, analytical method qualification and licensing review could differ depending on licensing approach
  - NRC is currently developing prototype guidance

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NRC Interactions

- Early and frequent interactions with NRC aids review process
  - Pre-application technical meetings
  - Industry white-papers
  - Potential pre-application review
  - Topical Reports
  - Pre-application schedule

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Recent NRC History in Advanced Reactor Reviews

- NRC staff conducted pre-application activities and provided feedback in the form of Pre-Application Safety Evaluation Reports structured to follow RG 1.70, Standard Format and Content of Safety Analysis Report for:
  - SAFR (NUREG-1369)
  - PRISM (NUREG-1368)
  - MHTGR (NUREG-1338)
- Generally no obvious impediments to licensing were identified.
- Areas where additional design, analysis, testing, and research and development was needed were noted in the Pre-Application Safety Evaluation Reports.

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Conclusions

- Fuel is the first fission product barrier
- Full characterization of the fuel under all anticipated operating conditions is necessary
- The level of fuel characterization, analytical method qualification and licensing review could differ depending on licensing approach
- Early interactions with the NRC aid review process
- NRC has previous history in reviewing advanced fuel designs

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Acronyms

- AOO – Anticipated Operational Occurrence
- ECCS – Emergency Core Cooling System
- GDC – General Design Criteria
- mHTGR – Modular High Temperature Reactor
- PRISM – Power Reactor Innovative Small Module
- RCS – Reactor Coolant System
- SAFDLS – Specified Acceptable Fuel Design Limits
- SAFR – Sodium Advanced Fast Reactor