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Current Fuel System Regulatory Guidance and its Relation to Advanced Reactor Fuel Development

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Guidance Overview

- NUREG-0800 (SRP) Section 4.2 provides fuel system designs review guidance
- Addresses fuel, fuel clad, reactivity control elements and components which make up the fuel assembly or bundle
- Provides reviewer guidance to assure that,
  - The fuel system is not damaged during normal operation and anticipated operational occurrences (AOOs)
  - Postulated accident fuel failures are not underestimated
  - Coolability and reactivity control is maintained for all Design Basis Events (DBE)
- Currently LWR-centric

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Guidance and Regulation Relation

- The fuel system is not damaged during normal operation and anticipated operational occurrences (AOOs)
  - 10 CFR 50 Appendix A, General Design Criteria (GDC) 10
- Postulated accident fuel failures are not underestimated
  - 10 CFR Part 100, 10 CFR 50.67 or 10 CFR 52.47(a)(2)
- Coolability and reactivity control are maintained for all Design Basis Events (DBE)
  - 10 CFR 50 Appendix A, General Design Criteria (GDC) 27 and 35

Guidance and Advanced Fuels

- The staff reviews:
  - Fuel system design bases
  - Description and design drawings
  - Design Evaluation methods
  - Testing, inspections and surveillance plans

- The challenge of licensing advanced fuel designs primarily deals with establishing the fuel system design bases and design evaluation methods

Guidance and Advanced Fuels (cont)

- Fuel system design bases establish damage mechanisms and important limiting values to prevent exceeding acceptable limits based on the DBE classification

- Design evaluation method reviews address analytical models, operating experience, direct experimental comparisons to ensure the design bases are satisfied

Design Bases

- Fuel testing and qualification program is the key to developing the design bases and the tools to evaluate those bases
- Establishment of fuel design bases can be supported by:
  - 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 establish design bases
- Testing and qualification program should address exposure-dependent thermal, mechanical, chemical and nuclear properties

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Design Basis Evaluation

- Methods of demonstrating the design bases include:
  - Operating experience
  - Prototype Testing
  - Analytical Predictions
- Operating experience
  - Usually used for criteria associated with normal operation and supported by post irradiation fuel examinations
- Prototype testing used to evaluate evolutionary design changes

Design Basis Evaluation (cont)

- Out of reactor tests should be performed when practical
  - Usually associate with fuel components
- In-reactor tests of new fuel designs are evaluated
  - In research reactors such as Halden
  - Through the used of lead test rods or assemblies in commercial reactors
    - Limits may be placed on the number and fuel duty
    - Usually associated with a post irradiation examination program
  - No detailed guidance on in-reactor prototype constraints
- Validated analytical models used to predict fuel behavior under DBEs

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Design Basis Evaluation (cont)

- Reasonable assurance of predicting fuel behavior must be demonstrated for any licensing approach (e.g., prototype plant)

- Commercial licensing applications require
  - 10 CFR 50 Appendix B QA program
  - Qualified software quality assurance program

HTGR Fuel Licensing Perspective

- NRC Feedback on NGNP Fuel Qualification and Mechanistic Source Terms White Papers (ML14174A845)
  - No obvious impediments to licensing NGNP fuel were identified
- Staff recommended that confirmatory tests be performed in NGNP prototype plant including:
  - Special surveillance of fuel conditions, circulating activity, and plateout activity
  - Post-Irradiation Examination and Accident Heat-up Testing of fuel discharged from NGNP prototype plant

HTGR Fuel Licensing Perspective (cont)

- Assumes release rates from NGNP heat-up accidents will bound those from reactivity transients
- Ongoing and planned TRISO fuel development and qualification activities for NGNP are reasonable to support NGNP prototype plant
- Successful TRISO fuel qualification programs in Germany, Japan, and China have included real-time irradiations in HTGRs

SFR Fuel Licensing Perspective

- Pre-Application Safety Evaluation Reports NUREG-1369 (SAFR) and NUREG-1368 (PRISM)
  - Generally no obvious impediments to licensing were identified.
  - Needs were noted for additional design, analysis, testing, and research and development.
- Most recent pre-application interactions (Toshiba 4S and PRISM) have proposed metallic fuel

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SFR Fuel Licensing Perspective (cont)

- Experience with characterizing some metallic fuel designs available from EBR-II and FFTF test programs
- Amount of additional characterization dependent on similarity of fuel and deviation from EBR-II operating parameters
- Behavior under transient conditions esp. fast reactivity transients needs further study

Conclusions

- SRP 4.2 covers fuel and fuel system
- SRP 4.2 currently LWR-centric
  - Identifies LWR fuel damage mechanisms
- SRP 4.2 philosophy still valid
  - Limited or no additional fuel failures during AOOs
  - Maintain reactivity control and coolability under PAs
- Advanced fuel design basis and evaluation methods need to be established
- NRC has pre-application experience primarily in the area of SFR and HTGR fuel designs