UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

November 23, 2021

Daniel H. Dorman
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: NUREG–2246, “FUEL QUALIFICATION FOR ADVANCED REACTORS: DRAFT REPORT FOR COMMENT”

Dear Mr. Dorman:

During the 690th meeting of the Advisory Committee on Reactor Safeguards (ACRS), November 2 - 5, 2021, we reviewed NUREG–2246, “Fuel Qualification for Advanced Reactors: Draft Report for Comment.” Our Future Plant Designs Subcommittee also reviewed this matter on February 2, 2021. We had the benefit of discussions with representatives of the U.S. Nuclear Regulatory Commission (NRC) staff, outside experts, and other stakeholders. We also had the benefit of the referenced documents.

CONCLUSIONS AND RECOMMENDATIONS

1. The draft NUREG report provides a logical approach to fuel qualification. The top-down approach is methodical and provides some assurance of completeness when a claim is made that a nuclear fuel is qualified. Key parts of the approach are identifying relevant experimental data and assessing associated safety margins.

2. After the comments provided in this letter are addressed, the draft NUREG report should be finalized.

BACKGROUND AND DISCUSSION

NUREG-2246 provides a fuel qualification assessment framework that would satisfy regulatory requirements. This framework constitutes a top-down approach where high-level regulatory requirements, criteria, and relevant regulatory guidance are identified. The approach is similar to the Codes Scaling, Applicability and Uncertainty, and Evaluation Model Development and Assessment Process approaches. It starts with a top-level goal and breaks it down into sub-goals and further sub-elements as necessary to completely define requirements to meet the higher-level goal. The bases for the identified goals and clarifying examples for the expected evidence used to satisfy those goals are provided. The report describes what the requirements are but does not delve into how these requirements can be met given the range of different advanced fuel systems under consideration.

The document reviews the existing regulatory basis surrounding fuel qualifications (e.g., General Design Criteria, Advanced Reactor Design Criteria) and summarizes additional supplemental guidance provided in NUREG-0800 for light water reactor (LWR) based fuels, ATF-ISG-2020-01 for accident tolerant fuels, Regulatory Guide (RG) 1.232 for advanced reactors, and new specific guidance under development by NRC for molten salt fueled reactors. Requirements contained within these documents are discussed in specific sections of this draft NUREG document.

Key to this process is evaluating the adequacy of the fuel to maintain critical safety functions. We observe that the draft NUREG relies on RG 1.232 for identifying these safety functions. We recommend that the draft NUREG address the misalignment between those safety functions and the safety functions that are being developed in ongoing Title 10 of the *Code of Federal Regulations* (10 CFR) Part 53 discussions.

The following sections summarize each of the major pieces of the framework and our comments about their completeness.

Fuel Qualification Assessment Framework

The highest-level goal for the framework is to have a fuel system that is qualified for its intended use. This means high confidence exists that the fuel: (a) will be fabricated in accordance with its specification, and (b) will perform as described in the applicable licensing safety case.

This fabrication goal has two sub-goals: (a) establishing a fuel manufacturing specification that controls/affects fuel performance, and (b) demonstrating that safety criteria can be satisfied with high confidence. The manufacturing specification should specify key dimensions and tolerance, impurity levels, and relevant microstructural attributes. The safety case goal requires establishing margins to fuel design limits under normal operation and Anticipated Operational Occurrences, margins to radionuclide release limits under accidents, and assurance of the ability to achieve and maintain safe shutdown.

The wording on fuel life-limiting failure and other degradation mechanisms should be expanded beyond irradiation and/or irradiation-assisted effects to consider other environmental effects. In addition, chemical effects on the fuel (e.g., corrosion, oxidation) that challenge its role in maintaining safety functions should be addressed in the relevant parts of the draft NUREG.

Accelerated Fuel Qualification

The draft NUREG also discusses the concept of accelerated fuel qualification (AFQ). AFQ is an approach involving closer integration of separate effects tests and modeling/simulation than has historically been used in reactor fuel development. The goal is to reduce the amount of rework required in the fuel development and qualification process when problems arise from testing that require changes in the fuel design.

An issue associated with AFQ is the amount of separate effects testing needed to sufficiently inform the models and provide confidence that the model can predict the integral effects tests. Historically, a more empirical approach was used with significant amounts of integral effects testing, albeit sometimes with a lot of scatter. The proper balance of testing in the AFQ approach depends on the complexity of the fuel system and the associated accident response. Given the importance of AFQ to the design community, additional discussion about the pros, cons, and risks of this approach relative to the assessment framework could be a useful addition to the draft NUREG. Specifically, the report should emphasize that the AFQ methodology may be useful to help interpolate inside the test envelope so that not all combinations of test conditions must be tested. However, the test envelope should be developed to include the relevant design service conditions plus margin such that extrapolation is not necessary.

Ultimately, integral effects tests are still necessary to validate engineering scale fuel performance models and to confirm the performance and safety of the fuel system under prototypic conditions. This approach is consistent with the NRC experimental data assessment framework discussed in the draft document.

Assessment Framework for Evaluation Models

The draft document provides an assessment framework for evaluation models used to describe the fuel system. The top-level goal is to assure that the model is acceptable. This goal has two sub-goals: (a) the model contains appropriate modeling capabilities, and (b) it has been adequately assessed against experimental data including addressing uncertainties. Meeting these subgoals requires assurance that the model captures the necessary physics and chemistry associated with fuel performance, is capable of describing the fuel system and associated geometry, and can predict fuel failure and degradation mechanisms over the test envelope.

The approach discusses the evaluation model as an integral part of the overall fuel qualification effort. However, in the past, more empirical approaches have been used to describe fuel performance. This section should address if a more empirical approach could also be acceptable focusing mostly on the data and less on a structured modeling framework.

Assessment Framework for Experimental Data

The draft NUREG also provides a framework to establish if the experimental data are appropriate including the following four sub-goals: (a) the model assessment data are independent of data used to develop/train the model, (b) data have been collected over a test envelope that covers the fuel performance envelope, (c) experimental data have been accurately measured, and (d) test specimens are representative of the fuel design. Meeting these subgoals requires using established measurement techniques with appropriate accuracy and quality assurance, accounting for sources of uncertainty. It also requires that the test specimens are representative of the fuel design and fabricated consistent with the manufacturing specification. Any test distortions must be justified and accounted for in the overall qualification effort.

Many fuel qualification efforts will depend on both legacy data and more current qualification testing. We support using a commercial grade dedication-like process to accept the pedigree of legacy data not performed under a recognized quality program, but more current testing should supplement legacy data as appropriate and be performed using an accepted quality program (e.g., ASME NQA-1 or equivalent). This should be made clear in the draft NUREG.

The draft NUREG does not directly address the nature of the specimens to be used. While many of the separate effects tests can be done using fuel produced at laboratory scale, the final integral effects tests should use fuel produced at pilot or production scale under prototypic fabrication conditions, using prototypic procedures and trained staff. A sentence addressing this concern should be added to the draft document.

SUMMARY

The draft NUREG provides a logical approach to fuel qualification. The top-down approach is methodical and provides some assurance of completeness when a claim is made that a nuclear fuel is qualified. Key parts of the approach are identifying relevant experimental data and assessing associated safety margins.

Our comments on the draft NUREG include:

1. Addressing the misalignment in the safety functions in the draft NUREG with those being developed as part of draft 10 CFR Part 53

2. Rewording to accommodate other environmental degradation mechanisms beyond irradiation and discussing relevant chemical phenomena, as appropriate

3. Assuring empirical approaches are acceptable as an evaluation model

4. Expanding on the use of AFQ in the overall assessment framework

5. Applying appropriate quality standards to fuel qualification activities

6. Assuring that the final integral effects tests should use fuel produced at pilot or production scale under prototypic fabrication conditions with prototypic procedures and trained staff.

After addressing these items, the report should be finalized.

Sincerely,

M W Sunseri Signed by Sunseri, Matthew on 11/23/21

Matthew W. Sunseri, Chairman

REFERENCES

1. U.S. Nuclear Regulatory Commission, NUREG-2246, "Fuel Qualification for Advanced Reactors: Draft Report for Comment," June 2021. (ML21168A063)

2. U.S. Nuclear Regulatory Commission, NUREG/CR-5249, "Quantifying Reactor Safety Margins: Application of Code Scaling, Applicability, and Uncertainty Evaluation Methodology to a Large-Break, Loss-of-Coolant Accident," Revision 4, December 1989. (ML030380473)

3. U.S. Nuclear Regulatory Commission, Regulatory Guide (RG) 1.203, "Transient and Accident Analysis Methods," December 2005. (ML053500170)

4. U.S. Nuclear Regulatory Commission, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," March 2007. (ML070810350)

5. U.S. Nuclear Regulatory Commission, ATF-ISG-2020-01 "Supplemental Guidance Regarding the Chromium-Coated Zirconium Alloy Fuel Cladding Accident Tolerant Fuel Concept," January 2020. (ML19343A121)

6. U.S. Nuclear Regulatory Commission, RG 1.232, "Guidance for Developing Principal Design Criteria for Non-Light-Water Reactors," April 2018. (ML17325A611)

7. American Society of Mechanical Engineers, NQA-1, 2019 Edition, "Quality Assurance Requirements for Nuclear Facility Applications," December 2019.

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