The Honorable Christopher T. Hanson  
Chairman  
U.S. Nuclear Regulatory Commission  
Washington, DC 20555-0001  

SUBJECT: RULEMAKING PLAN FOR THE REVISION OF EMBRITTLEMENT AND SURVEILLANCE REQUIREMENTS FOR HIGH-FLUENCE NUCLEAR POWER PLANTS IN LONG-TERM OPERATION  

Dear Chairman Hanson:  

During the 694th meeting of the Advisory Committee on Reactor Safeguards (ACRS), April 6-8, 2022, we completed our review of SECY-22-0019, “Rulemaking Plan for Revision of Embrittlement and Surveillance Requirements for High-Fluence Nuclear Power Plants in Long-Term Operation.” Our Fuels, Materials, and Structures Subcommittee (formerly the Metallurgy and Reactor Fuels Subcommittee) also reviewed this matter on November 15, 2021. During this review, we had the benefit of discussions with representatives of the NRC staff and the Electric Power Research Institute. We also benefited from the referenced documents.  

FINDINGS AND CONCLUSION  

1. The staff evaluation of the current state and future evolution of reactor pressure vessel (RPV) embrittlement provides a detailed discussion on the effect of neutron fluence above $6 \times 10^{19}$ n/cm$^2$ (E>1 MeV) and identifies three alternatives as options for a path forward.  

2. In SECY-22-0019, staff recommends Alternative 2 as a compromise between the status quo option (Alternative 1) and implementation of an enhanced RPV embrittlement correlation for all plants (Alternative 3).  

3. Alternative 2 allows for continued use of the existing Regulatory Guide (RG) 1.99, Revision 2, correlation as required by Title 10 of the Code of Federal Regulations (10 CFR) 50.61, “Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events,” if a plant’s end of life fluence to the RPV does not exceed a threshold of $6 \times 10^{19}$ n/cm$^2$ (E>1 MeV). For plants that will exceed this threshold, a new correlation, likely American Society for Testing and Materials (ASTM) E900-15, “Standard Guide for Predicting Radiation-Induced Transition Temperature Shift in Reactor Vessel Materials,” would become the new regulatory basis for estimating RPV embrittlement. In addition, higher fluence data would need to be obtained on a plant specific basis when in its extended period of operation.
4. We concur with the staff’s recommendation. This approach, if implemented, will increase assurance of adequate protection against RPV failure at higher fluences.

BACKGROUND

Many Pressurized Water Reactors (PWRs) have applied for subsequent license renewal (SLR) to continue operation up to 80 years. In such cases, the projected fast neutron fluence to the reactor vessel wall will exceed the data base for the embrittlement trend curve (ETC) in RG 1.99, Revision 2. The staff has evaluated predictions using RG 1.99, Revision 2 for higher fluences that will be experienced during SLR periods. The results show significant errors in the ETC that are non-conservative at higher fluence, including:

- Non-conservativism at high fluence for base metals
- Inaccuracies for reactor vessel materials with low copper content
- Underestimated uncertainty (standard deviation) relative to the current database

However, the adoption of new guidance may have significant impact on all operating PWRs that previously used RG 1.99, Revision 2, to develop pressure-temperature curves, low temperature overpressure protection setpoints, and pressurized thermal shock (PTS) limits.

In our November 2019 letter on this topic, we observed the following:

1. The embrittlement trend correlation in RG 1.99, Revision 2 (the RG), has several deficiencies, the most significant of which is increasing error beyond a fluence of $6 \times 10^{19}$ n/cm$^2$ ($E > 1$ MeV).

2. The ASTM Subcommittee E10.02, Behavior and Use of Nuclear Structural Material, has performed an extensive review of several ETCs. It concluded that the correlation in ASTM E900-15, that is based on a much more extensive database, overcomes the deficiencies in the regulatory guide and provides the best fit at higher fluences.

In addition, the staff informed us that a working group had been established to develop a path forward. We recommended that this working group consider each plant’s situation to minimize undue burden on plants that will not exceed the $6 \times 10^{19}$ n/cm$^2$ ($E > 1$ MeV) threshold. The proposed rulemaking is informed by evaluations performed by this working group.

DISCUSSION

SECY-22-0019 and its supporting documents provide a detailed discussion on the effect of neutron fluence above $6 \times 10^{19}$ n/cm$^2$ ($E > 1$ MeV) and identify options for a path forward. A key finding was that above this threshold fluence, the error in the RG 1.99, Revision 2, ETC prediction begins to significantly increase. The RG 1.99, Revision 2, ETC was an empirical fit of a limited number of data points (177). The number of data points available, especially at high fluence, has greatly increased since the RG 1.99, Revision 2, ETC was developed.

ASTM has recently completed a thorough analysis of the existing ETCs, including the ETC in RG 1.99, Revision 2, and has proposed a newer correlation, E900-15, that provides a much better prediction at high fluences. Additionally, the industry has implemented surveillance
programs that will fill in data gaps in RPV fluence that have resulted from allowed extensions of capsule removal times based on the requirements of ASTM E185-82, “Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels.”

As a result of their analysis, the staff has proposed the following:

“……initiate a rulemaking to revise the RPV embrittlement and surveillance requirements in 10 CFR Part 50. The rulemaking would revise Appendix H, "Reactor Vessel Material Surveillance Program Requirements," to 10 CFR Part 50 to include additional surveillance testing requirements for long-term operation and a revised fluence function fit (either a new embrittlement trend curve (ETC) or an update to existing trend curves) in the applicable regulations and implementing guidance for all materials that will experience high neutron fluence levels.”

The staff identified three possible options to address the RPV embrittlement issue:

**Alternative 1:** Make no changes to Appendix H to 10 CFR Part 50, 10 CFR 50.61, or RG 1.99. The staff would evaluate proposed plant-specific actions as a part of a license amendment request.

**Alternative 2:** Revise Appendix H to 10 CFR Part 50 to include additional surveillance testing requirements for long-term operation. A new ETC, likely E900-15, would be adopted for RPV materials that will experience high neutron fluence levels and would be appropriately implemented. As noted in SECY-22-0019, this alternative provides a long-term solution, balances the impact on operating plants, and ensures adequate margin and performance monitoring.

**Alternative 3:** Revise Appendix H to 10 CFR Part 50 to include additional surveillance testing requirements for long-term operation, update the applicable regulations (e.g., 10 CFR 50.61) to require all licensees to use an NRC-approved ETC that properly accounts for fluence effects and update implementing guidance. This alternative represents a comprehensive solution to the long term RPV issue. However, for plants that are not expected to exceed the $6 \times 10^{19}$ n/cm$^2$ (E>1 MeV) threshold, a reanalysis would be required to comply with the new rule, resulting in unnecessary burden with no appreciable safety benefit.

The staff recommends Alternative 2, and we concur. This approach, if implemented, will increase assurance of adequate protection against RPV failure at higher fluences.

**SUMMARY**

In SECY-22-0019, staff recommends Alternative 2, as a compromise between the status quo option (Alternative 1) and implementation of an enhanced RPV embrittlement correlation for all plants (Alternative 3). Alternative 2 allows for continued use of the existing RG 1.99, Revision 2, correlation as required by 10 CFR 50.61 if a plant’s end of life fluence to the RPV does not exceed a threshold of $6 \times 10^{19}$ n/cm$^2$ (E>1 MeV). For plants that will exceed this threshold, a new correlation, likely ASTM E900-15, would become the new regulatory basis for estimating RPV embrittlement. In addition, higher fluence data would need to be obtained on a plant specific basis when in its extended period of operation.
We concur with the staff's recommendation. This approach, if implemented, will increase assurance of adequate protection against RPV failure at higher fluences. We look forward to future interactions on this topic.

We are not requesting a formal response from the staff to this letter report.

Sincerely,

Joy L. Rempe  
Chairman

REFERENCES


9. NRC, Reactor Vessel Integrity Database Version 2.0.1, 


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