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

April 28, 2022

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 6×10^{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 6×10^{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 6×10^{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 6×10^{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 6×10^{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 6×10^{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 6×10^{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,

Signed by Rempe, Joy on 04/28/22

Joy L. Rempe
Chairman

REFERENCES

1. SECY-22-0019, "Rulemaking Plan for Revision of Embrittlement and Surveillance Requirements for High-Fluence Nuclear Power Plants in Long-Term Operation," March 8, 2022 (ML21314A215).

2. ACRS Letter Report, "Assessment of the Continued Adequacy of Revision 2 of Regulatory Guide 1.99," November 27, 2019 (ML19331A231).

3. Assessment of the Continued Adequacy of Revision 2 of Regulatory Guide 1.99 Technical Letter Report, TLR-RES/DE/CIB-2019-2, July 31, 2019 (ML19203A089).

4. Assessment of Predictions of RTNDT and Upper Shelf Energy Made Using Branch Technical Position 5-3, March 23, 2017 (ML16341B108).

5. NRC, Regulatory Guide 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials," May 31, 1988 (ML003740284).

6. NRC, NUREG-1806, Vol. 1, "Technical Basis for Revision of the Pressurized Thermal Shock (PTS) Screening Limit in the PTS Rule (10 CFR 50.61)," August 2007 (ML072830074).

7. NRC, Generic Letter 88-11, "NRC Position on Radiation Embrittlement of Reactor Vessel Materials and Its Impact on Plant Operations," July 12, 1988 (ML031150357).

8. COMSECY-18-0016: Request Commission Approval to use the Direct Final Rule Process to Revise the Testing and Reporting Requirements in 10 CFR Part 50, Appendix H, Reactor Vessel Material Surveillance Program Requirements (RIN-3150-AK07), August 17, 2018 (ML18057A000).

9. NRC, Reactor Vessel Integrity Database Version 2.0.1, https://www.nrc.gov/reactors/operating/ops-experience/reactor-vessel-integrity/database-overview.html.

10. NRC, Technical Letter Report, TLR-RES/DE/CIB-2020-09, "RG 1.99 Revision 2 Update: FAVOR Scoping Study," October 26, 2020 (ML20300A551).

11. ASTM International, ASTM E185-82, “Standard Practice for Conducting Surveillance Tests for Light-Water Cooled Nuclear Power Reactor Vessels,” West Conshohocken, PA, 1982.

12. ASTM International, ASTM E185-16, “Standard Practice for Design of Surveillance Programs for Light-Water Moderated Nuclear Power Reactor Vessels,” West Conshohocken, PA, 2016.

13. ASTM International, ASTM E2215-16, “Standard Practice for Evaluation of Surveillance Capsules from Light-Water Moderated Nuclear Power Reactor Vessels,” West Conshohocken, PA, 2016.

14. ASTM International, ASTM E900-15e1, “Standard Guide for Predicting Radiation-Induced Transition Temperature Shift in Reactor Vessel Materials,” West Conshohocken, PA, April 2015 (editorial correction approved April 2017).

15. ASTM International, “Adjunct for E900-15: Technical Basis for the Equation Used to Predict Radiation-Induced Transition Temperature Shift in Reactor Vessel Materials,” West Conshohocken, PA, September 18, 2015.

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