

Proposed Rulemaking Plan for Revision of RPV Embrittlement Monitoring and Prediction in Long-Term Operation

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NRC/Industry Materials Exchange Meeting
May 25, 2022

Topics

- Discussion of Issues
 - Regulatory Guide 1.99 Rev 2 (RG 1.99) and 10 CFR 50.61 embrittlement trend curve
 - Appendix H surveillance testing
- Discussion of RPV Embrittlement Rulemaking Plan ([SECY-22-0019](#))
 - Refers to “Impacts of Embrittlement on Reactor Pressure Vessel Integrity from a Risk-Informed Perspective,” Final Report (ADAMS Accession No. [ML21314A228](#))

More information on PDF pages 198-221 of [ACRS slides](#) from April 6, 2022

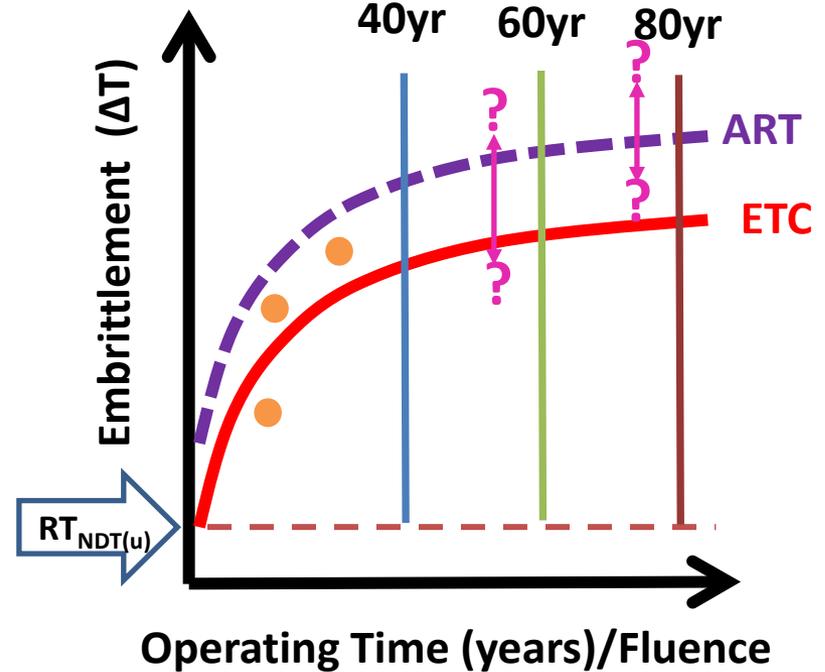
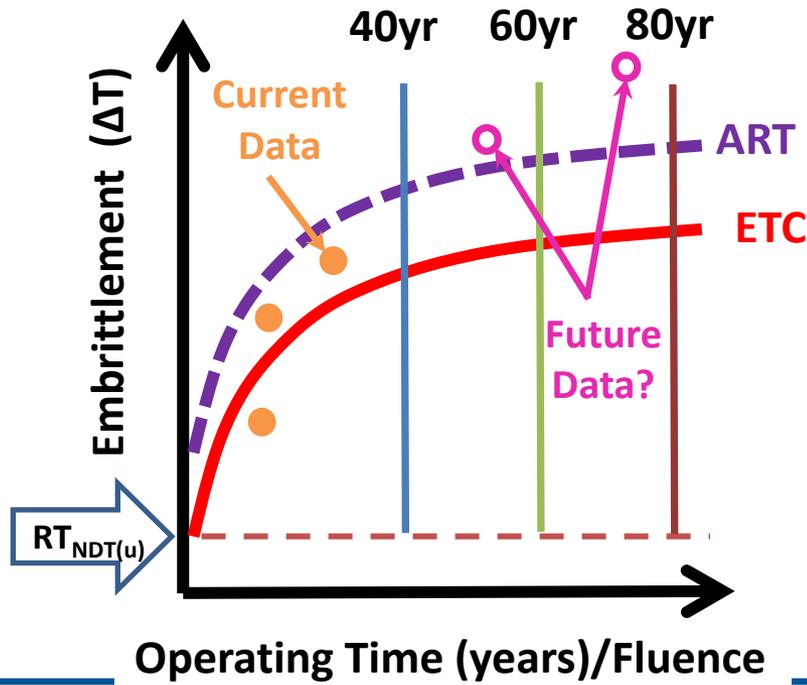
Ideal Scenario

- ETC provides conservative predictions of embrittlement
- Surveillance data covers all operating periods

Potential Uncertainty Sources

IF ETC under-predicts measurements

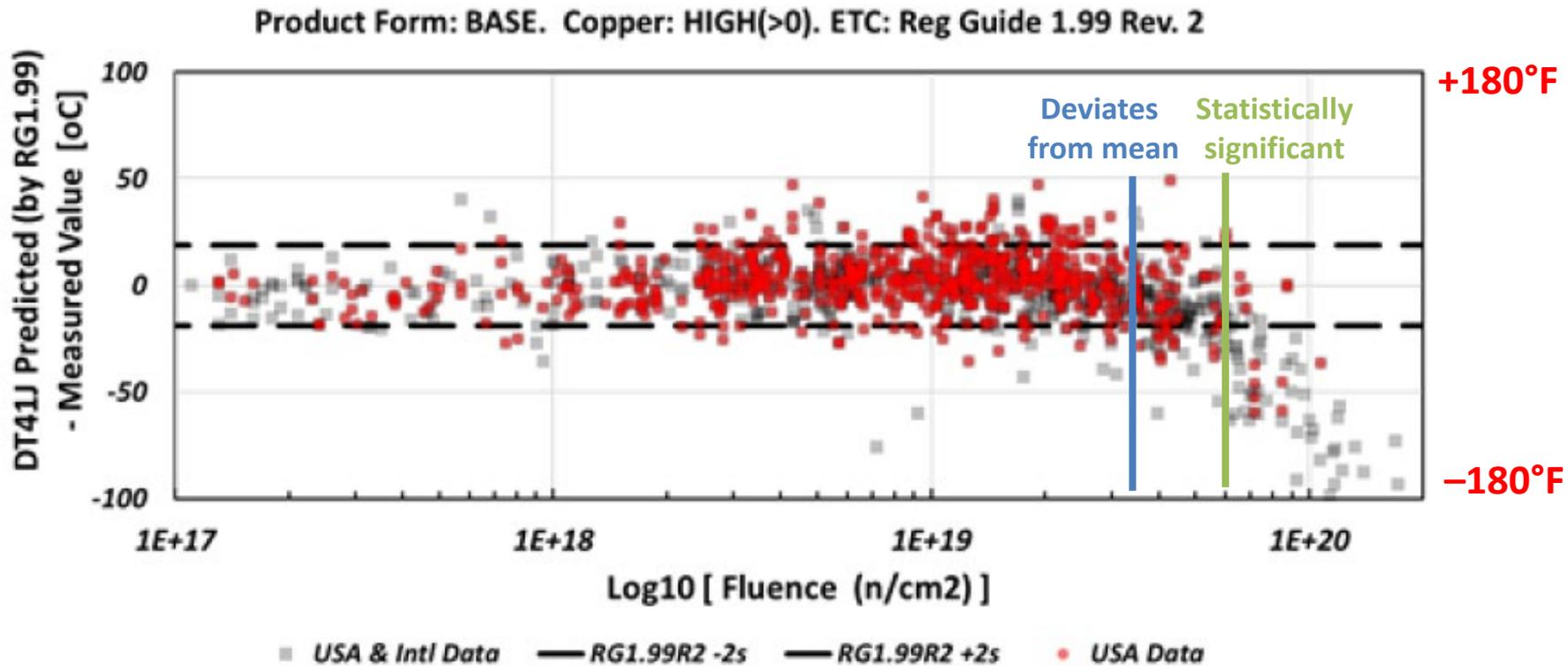
IF Limited Surveillance Data is Available



Embrittlement Trend Curve

- May 1988, NRC published RG 1.99, which contained an improved embrittlement trend curve (ETC)
 - Fit based on 177 datapoints
- June 1991, NRC updated 10 CFR 50.61 to include the ETC from RG 1.99
 - Addressed lower than measured predictions (up to 60°F) of embrittlement in some vessels
- This ETC was re-evaluated for continued adequacy in 2014 (ML13346A003) and in more detail in 2019 ([ML19203A089](#))

Issue – ETC



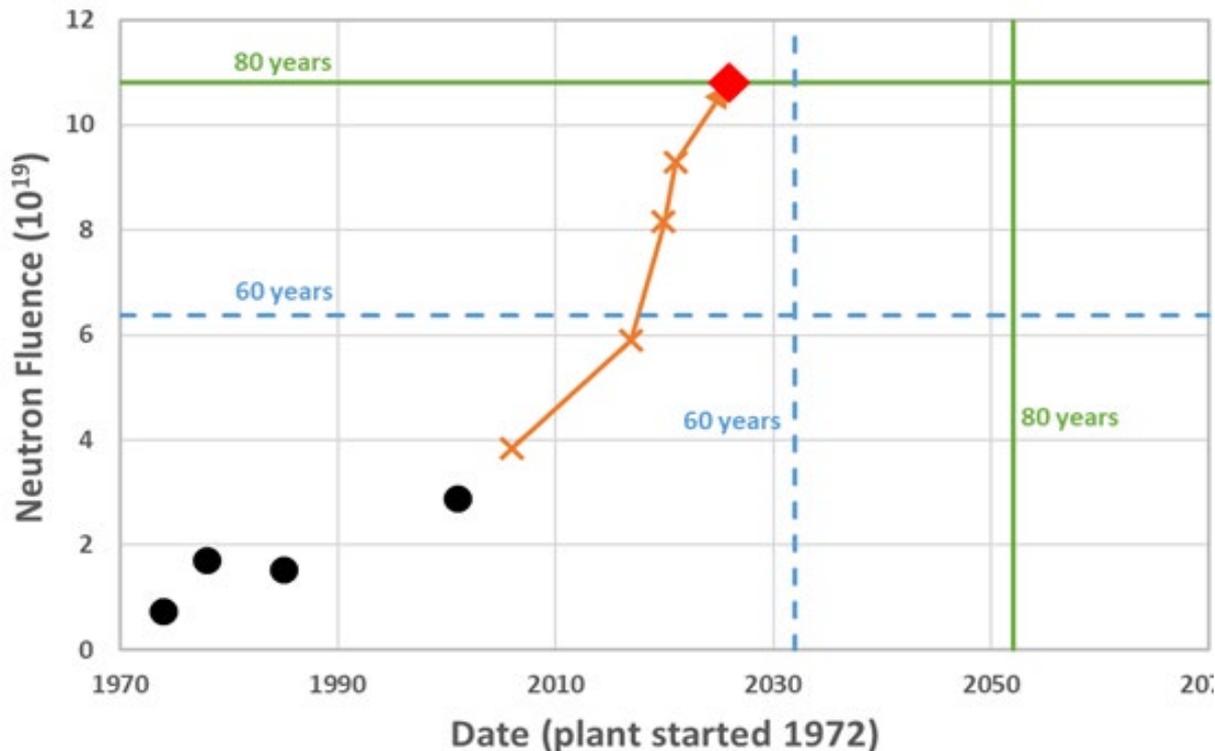
DT41J = ΔT_{41J} is a measurement of embrittlement representing the shift in transition temperature from brittle to ductile fracture at an impact toughness of 41J

Surveillance Capsule Delays

- Appendix H to 10 CFR Part 50 requires periodic monitoring of changes in fracture toughness caused by neutron embrittlement
 - ASTM standard (E185-82) allows final capsule fluence to be 2X RPV “design” fluence – plants change (intended 40-year) design fluence to current license length (e.g., 60 or 80 years)
 - ASTM standard (for 40 years) permits holding last capsule without testing
- Commission finding (“[Perry decision](#),” NRC [Administrative Letter 97-04](#)) that staff review of requests to change capsule withdrawal schedules is limited to verification of conformance with the ASTM standard (i.e., not based on technical or safety considerations)
 - Capsule withdrawal and testing repeatedly delayed in some cases to achieve higher fluence

Issue – Appendix H

Performance Monitoring



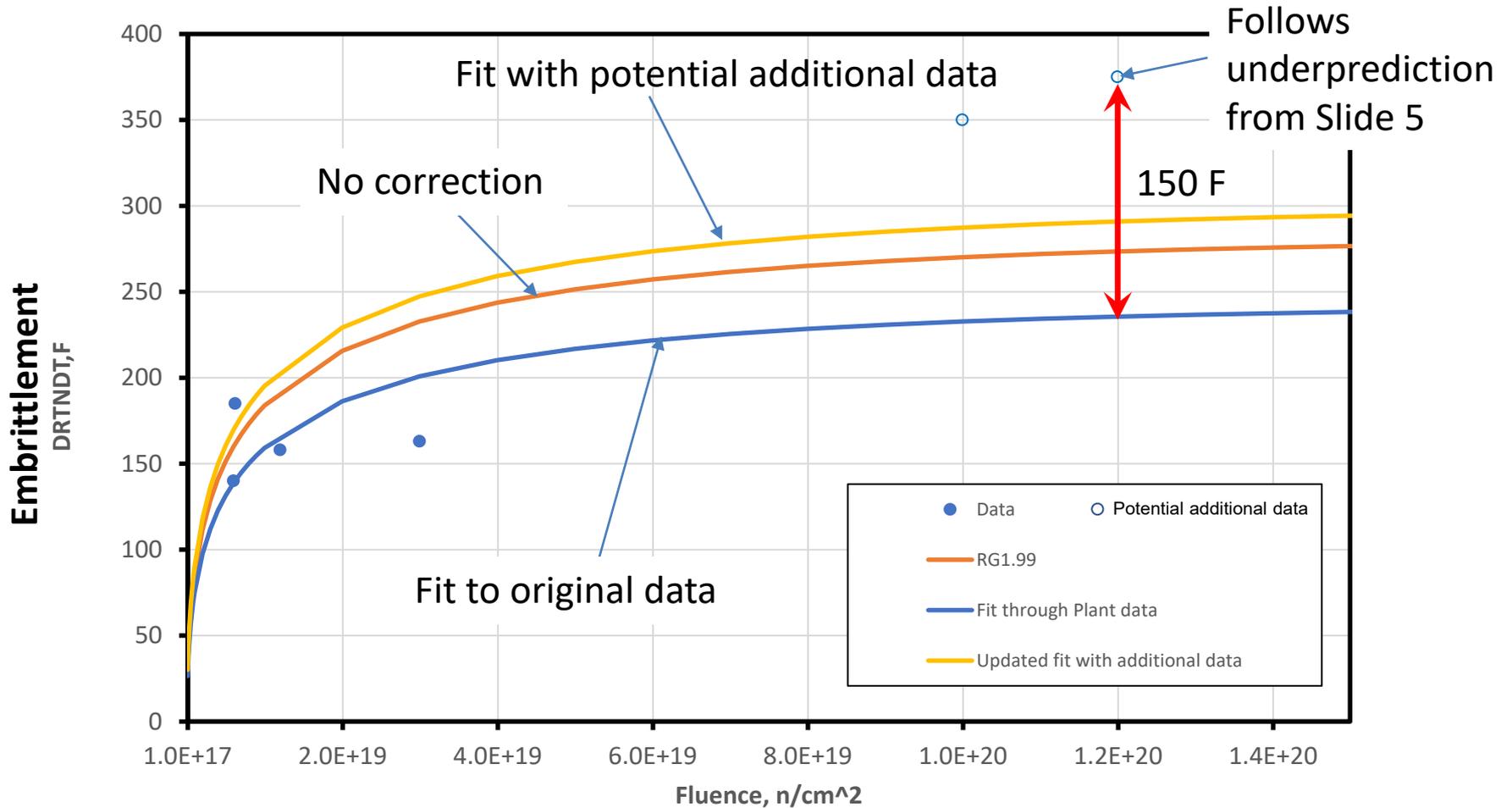
Capsule withdrawal schedule changes include delays in both time and/or fluence

Many licensees have delayed capsules (time and/or fluence), some recent examples:

Plant	Capsule #	# of times delayed
Turkey Point	5	4
Robinson	5	2
Surry U1	5	2
Surry U2	5	2
North Anna U1	4	2
North Anna U2	4	2
St. Lucie U2	4	1
Point Beach	5	1

Not all plants have delayed withdrawal of capsules

Potential Impact of Issue



Safety Case

- **Risk of Failure**

- Conditional probability of failure during normal operation may increase several orders of magnitude (e.g., 3 orders of magnitude at 50F), but expected transient frequency makes overall risk low.
- Some plants may exceed Pressurized Thermal Shock screening limit in 10 CFR 50.61, but analyses suggest risk is low
- Large uncertainty exists – many plant specific details not evaluated

- **Safety Margins**

- Inaccurate embrittlement prediction and increasing uncertainty due to lack of surveillance decreases safety margins to failure – plant specific

- **Performance Monitoring**

- Delaying capsule testing does not provide adequate performance monitoring to ensure embrittlement trends are reasonable

Pressurized Thermal Shock Considerations

- 10 CFR 50.61 uses ETC from RG 1.99
- RT_{PTS} from 10 CFR 50.61 might be impacted
 - Limits of 270 °F for plates, forgings, and axial weld materials, and 300 °F for circumferential weld materials
- However, through-wall crack frequency calculated with corrected embrittlement less than 1×10^{-6} for all cases investigated

Safety Margins

- Uncertainties in risk calculations are high and increasing with time
- Even though the risk appears low, resolving these issues will help maintain the fundamental safety principles that are the basis of plant design and operation
- Safety margins, as provided by regulations and current license bases, provide reasonable assurance against brittle fracture

Analysis Summary

- With the current state of knowledge, a generalized analysis suggests the overall risk of brittle fracture is low
- The uncertainty in these results is high and increases with time
 - Plant specific details not considered
- Under certain conditions, safety margins are impacted and are decreasing as uncertainty increases
- Delays in testing of high fluence capsules represents a lack of sufficient performance monitoring
- Issues are plants with fluences $> 6 \times 10^{19}$ n/cm²

Who is Impacted?

- Embrittlement Underprediction

Percentage of Fleet Surpassing Fluence Levels			Percentage of PWRs Surpassing Fluence Levels	
Year\Fluence	$6 \times 10^{19} \text{ n/cm}^2$	$8 \times 10^{19} \text{ n/cm}^2$	$6 \times 10^{19} \text{ n/cm}^2$	$8 \times 10^{19} \text{ n/cm}^2$
60 years	6%	0%	9%	0%
80 years	22%	10%	34%	15%

- Plant specific details (e.g., limiting material, etc.) may contribute to which plants are impacted
 - More work is needed to determine which plants are impacted
- Lack of Surveillance Data
 - Impacts any plant that renews its license and delays last capsule testing

Staff Alternatives

- Alternative 1 – **Status Quo**: Make no changes to Appendix H to 10 CFR Part 50, 10 CFR 50.61, or RG 1.99. Handle issues through plant-specific action and generic communications.
- Alternative 2 – **Focused Solution**: Revise Appendix H to 10 CFR Part 50 to include additional surveillance testing requirements for long-term operation, revise fluence function fit for only impacted RPV materials.
- Alternative 3 – **Comprehensive Solution**: 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 radiation effects, update RG 1.99 to contain an ETC with one that appropriately accounts for radiation effects, and update implementing guidance.

Staff Recommendation

- Alternative #2 – Focused Solution
 - Address issues in a focused and risk-informed manner
 - Target those plants with materials that are impacted by the underprediction issue
 - Modify current surveillance testing requirements to ensure periodic performance monitoring
 - Details of implementation to be worked out during regulatory basis effort

Summary

- High confidence that currently operating plants remain safe, and recent licensing actions remain valid
- Issued proposed rulemaking plan for Commission approval ([SECY-22-0019](#)) on March 8, 2022
 - Status: No Commission response