

# U.S. BWR Fleet Integrated Surveillance Program (ISP)

## ISP Capsule Withdrawal Schedule Optimization



U.S. Nuclear Regulatory Commission (NRC) Meeting

April 23, 2024

# Agenda

- Background on NRC-Approved ISP
- Approach for the ISP
- ISP Test Matrix
- Current ISP for U.S. BWRs
- U.S. BWR ISP References
- Purpose & Approach for Updated Withdrawal Schedule
- Status of U.S. BWR Surveillance Capsule Withdrawals
- Current State of Knowledge
- Initial Results
- Proposed Activities
- ISP(E) Capsule Withdrawal Schedule Optimization

# Background on NRC-Approved ISP (1/3)

- Reactor Pressure Vessel (RPV) materials surveillance programs serve several purposes:
  - Monitor the embrittlement of RPV materials and provide data that can be used in the development of plant pressure-temperature (P-T) limit curves and leak test temperatures
  - Provide data for the development of embrittlement trend curves that can then be used to predict the embrittlement of RPV materials not included in surveillance programs
  - Enable the validation of fluence projections
- BWRVIP initiated a project in 1999 to develop a BWR integrated surveillance program (ISP) and was patterned after other integrated programs using host reactor units to gather surveillance data for the fleet of U.S. BWR vessels
- Many U.S. BWR surveillance programs were designed prior to Regulator Guide 1.99, Revision 1 (1975) when the embrittling effects of copper were not yet known
- As a result, many BWR reactor vessel surveillance capsules did not include the limiting vessel materials that are now predicted to be limiting by improved embrittlement correlations

# Background on NRC-Approved ISP (2/3)

- Materials in plant surveillance programs (i.e., surveillance plates and welds) often do not match limiting vessel beltline materials
- Specific identity of surveillance materials is not known in some cases, so the surveillance data cannot be used directly. Examples include:
  - Unknown heat numbers for weld materials
  - Lack of baseline (unirradiated) data
  - Limited remaining archival materials representing the limiting reactor vessel beltline materials
- Such limiting surveillance material information prohibits use of Regulatory Guide 1.99, Rev. 2 (1988) and application of data to predict RPV embrittlement

## Why did BWRVIP Develop an ISP?

- Address regulatory concerns regarding some cases of inadequate or missing unirradiated baseline data
- Increase technical quality and make the most effective use of existing BWR reactor vessel materials surveillance capsules specimen test results

# Background on NRC-Approved ISP (3/3)

## Why did BWRVIP Develop an ISP? *(continued)*

- To improve overall quality of the BWR fleet surveillance data by including the BWRVIP Supplemental Surveillance Program (SSP) capsule data
- To collectively monitor and manage embrittlement in BWR vessels
  - Share data between all U.S. BWR utilities
  - Avoid surprises from surveillance specimen data
  - Avoid excess conservatism in pressure test temperatures

# Approach for the ISP

- Identified all available U.S. BWR reactor vessel surveillance materials that have baseline data
  - Plant surveillance capsules (vessel wall capsules only)
  - Supplemental Surveillance Program (SSP) capsules
- Identify up to 6 candidate materials
- Document the final selection of best representative in an Individual Vessel Evaluation (IVE)
  - The candidate materials listed in the IVEs provide the contingency plan required by 10CFR50 Appendix H III.C.1.d if the selected material is affected by future plant shutdowns, etc.
- Selection of the final best representative in an IVE was an iterative process
  - Find the best solution that optimizes the overall number of surveillance materials in ISP
  - Consider NRC Staff recommendations (e.g., exact heat match to the RPV fabricator)
- The final pairing of representative materials to the target vessel plate and target vessel weld in each U.S. BWR which constitutes the ISP Test Matrix

# ISP Test Matrix

- For each plant there is a:
  - Target vessel plate and a target vessel weld
  - Representative surveillance material heat number for each target vessel material
  - Representative surveillance material source capsules for each target vessel material

Vessel Target Material

Source of Representative Material	Plant 1 Limiting Weld	Plant 1 Limiting Plate	Plant 2 Limiting Weld	Plant 2 Limiting Plate	Plant 3 Limiting Weld	Plant 3 Limiting Plate	Plant 4 Limiting Weld	Plant 4 Limiting Plate
Plant 1 Capsules								
Plant 2 Capsules								
Plant 3 Capsules								
Plant 4 Capsules								
Plant 5 Capsules								
SSP Capsule								

# Current ISP for U.S. BWRs

- No changes to the approved regulatory structure of the ISP were needed to accommodate a Subsequent License Renewal (SLR)
  - No changes to ISP Test Matrix and assigned representative surveillance materials
- 80-year surveillance data for the U.S. BWR fleet is provided by a combination of existing ISP data, SSP data, and new reconstituted specimens (SSLR Capsule installed in Peach Bottom Unit 3)
- 13 host plants, 9 SSP capsules and the PB3 SSLR capsule constitute the ISP
- The ISP was extended into the first License Renewal (LR) period by testing one additional capsule from each of the 13 host plants, for a total of 26 plant capsules with specimens tested (or to be tested) through the extended life period
- 2 ISP(E) capsules for the first LR have been completed and published with no unexpected results from a radiation embrittlement standpoint



# U.S. BWR ISP References

- BWRVIP-86, Revision 1-A, “Updated BWR Integrated Surveillance Program (ISP) Implementation Plan”
  - Provides basis for the ISP
  - Contains the ISP test matrix and capsule withdrawal schedule
  - NRC approved
- BWRVIP-135, Revision 4, “Integrated Surveillance Program (ISP) Data Source Book and Plant Evaluations”
  - Contains data for all ISP materials and any SSP materials that are in a U.S. BWR vessel, even if not selected as a representative surveillance material
    - For example, “fitted” chemistry factor (CF) in accordance with Regulatory Guide 1.99, Revision 2 (1988)
  - Provides recommendations and guidance for plant-specific use of ISP data
  - Delineates responsibilities of the BWRVIP and utilities under the ISP

# Purpose & Approach for Updated Withdrawal Schedule

- The purpose of this meeting is for the BWRVIP to present results, technical bases and recommendations for a revision to the remaining U.S. BWR fleet ISP(E) capsule withdrawal schedule and solicit the NRC's perspective and receptiveness on EPRI's approach.
- The number of specimens in the ISP(E) capsules is limited. The BWRVIP objective is to maximize the value of the capsules to provide BWR surveillance data for the possibility of plants operating to >80 years. The plan is to preserve specimens to the extent possible, rather than testing on a predefined schedule (i.e., one capsule every 20 years)

The technical justifications are based on evaluation and analysis results from the following approach:

1. Estimation of the likelihood of future surveillance data providing more conservative results than previously obtained surveillance data (i.e., higher shift in the adjusted reference temperature) rather than that from Regulatory Guide 1.99, Revision 2 (1988)
2. Estimation of the likelihood of future reactor vessel materials surveillance data providing lesser conservative results than previously obtained surveillance data
3. The potential for either more or less conservative surveillance data that impact plant operation and determine the change associated with the impact on plant operation (e.g., P-T limits and ASME Section XI pressure test temperatures during reactor coolant pressure boundary VT-2 leak inspections)

# Status of U.S. BWR Surveillance Capsule Withdrawals

- BWRVIP-86, Rev. 1-A**, Tables 4-5 & 7-1 are the current NRC-approved ISP & ISP(E) Surveillance Capsule Withdrawal Schedules to meet 10 CFR 50, Appendix H for the U.S. BWR Fleet

ISP Capsule Host Plant	Year of Capsule Withdrawal																																		
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	
Browns Ferry 2					VIP-271																														
Cooper																																			
Dresden 3																																			
Duane Arnold																																			
Hatch 1																																			
Hatch 2																																			
Hope Creek																																			
LaSalle 1																																			
Monticello																																			
Peach Bottom 2																																			
Perry																																			
River Bend																																			
Susquehanna 1																																			
Peach Bottom 3 (SSLR)																																			
	Original ISP from BWRVIP-86, Rev. 1-A, Table 4-5																																		
	ISP(E) from BWRVIP-86, Rev. 1-A, Table 7-1 and BWRVIP-321, Rev. 1-A, Table 4-5																																		
	Note 1: Supplemental SLR (SSLR) Capsules - 80 years (Re: BWRVIP-321, Revision 1-A, April 2023)																																		

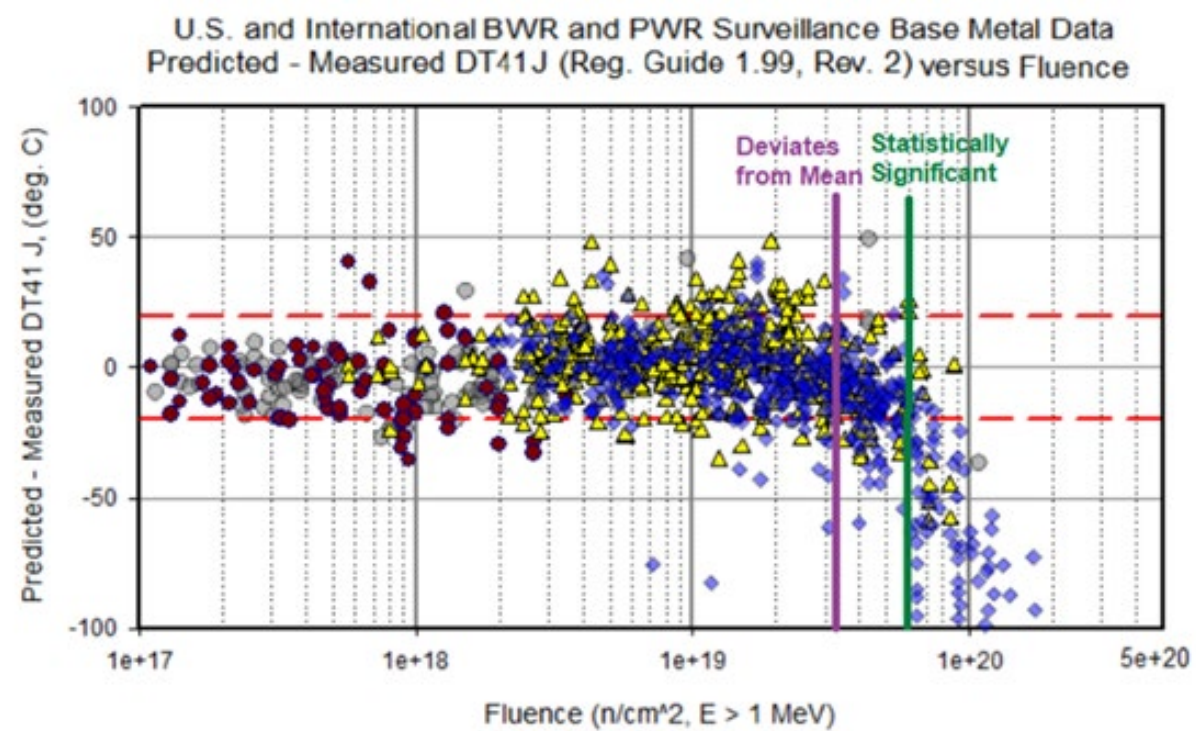
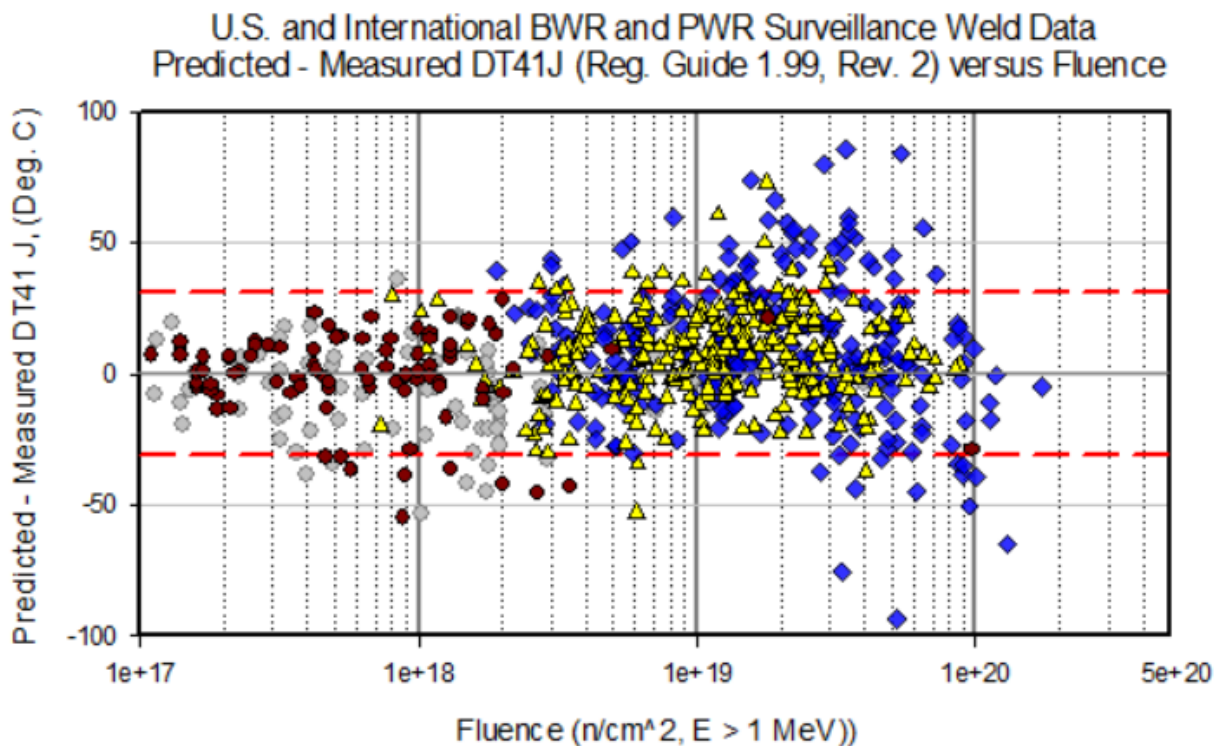
# Current State of Knowledge (1/2)

- The BWRVIP has been developing a strategy for optimizing the remaining U.S. BWR surveillance capsule withdrawals
  - i. Demonstrate that Regulatory Guide 1.99, Revision 2 (1988) is adequate and conservative when compared to test data for the range of U.S. BWR fluence levels for extended operations
  - i. Prioritize reactor pressure vessel (RPV) materials surveillance specimens testing based on consideration of the relationship between leak test temperature and shift in the Adjusted Reference Temperature (ART) values due to irradiation exposure
  - i. Evaluation considers the impacts associated with Charpy testing, dosimetry wire testing, fluence analysis and reporting requirements

# Current State of Knowledge (2/2)

Weld Metal

Base Metal



○ U.S. BWR (Plus ISP/SSP) Data ● Int'l. BWR Data ▲ U.S. PWR Data ◆ Int'l. PWR Data

Source: E900-15 PLOTTER Database plus additional U.S and International Surveillance Capsule Test Data

Comparison of BWR/PWR Surveillance data with Regulatory Guide 1.99, Revision (1988)

# Initial Results

- Of the 11 remaining ISP(E) capsules, there are technical justifications for not testing the following 6 capsules:

Hatch Unit 2 (2027), Dresden Unit 3 (2028), Susquehanna Unit 1 (2028).

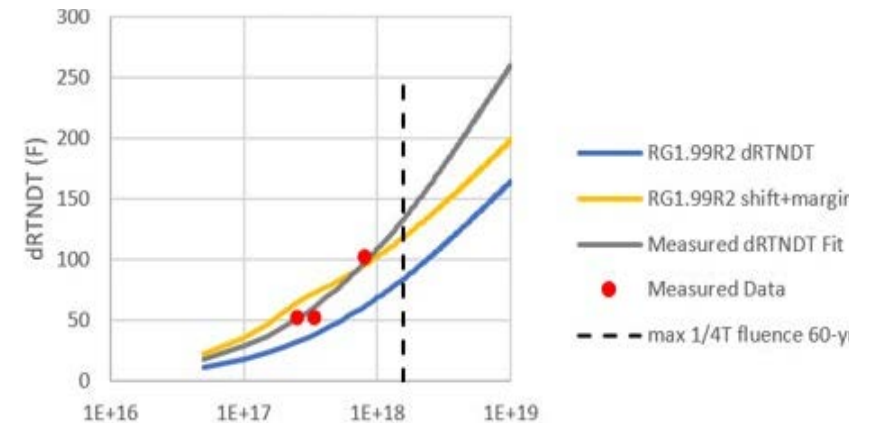
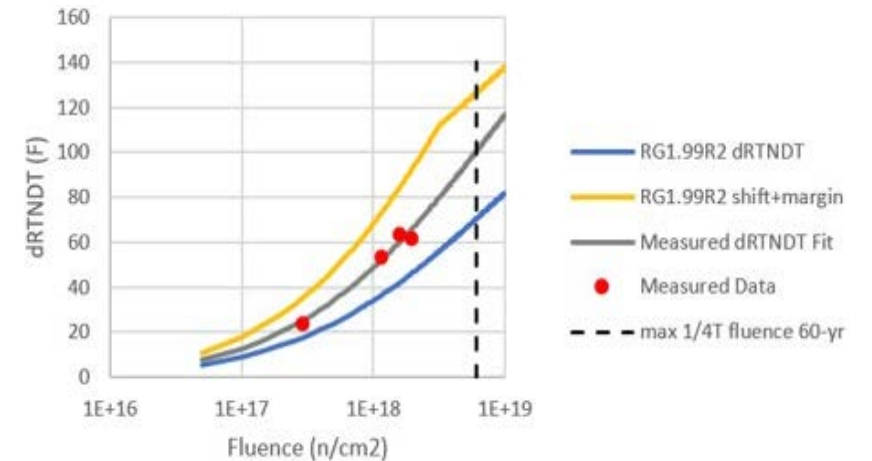
River Bend (2030), Peach Bottom Unit 2 (2030). Perry (2039)

[The capsules above do not need to be tested since the target plant materials associated with the corresponding capsule materials are either:

- RPV material is not limiting (i.e., the target material does not control the target plant's leak test temperature)

**- OR -**

- RPV material is limiting, but the  $\Delta RT_{NDT}$  shift calculated with RG1.99R2, Position 1 (Surveillance data not available) bounds the RG1.99R2, Position 2 (Surveillance data available) results at the 60-year 1/4T fluence and, thus, additional surveillance data is not expected to impact the leak test temperature]

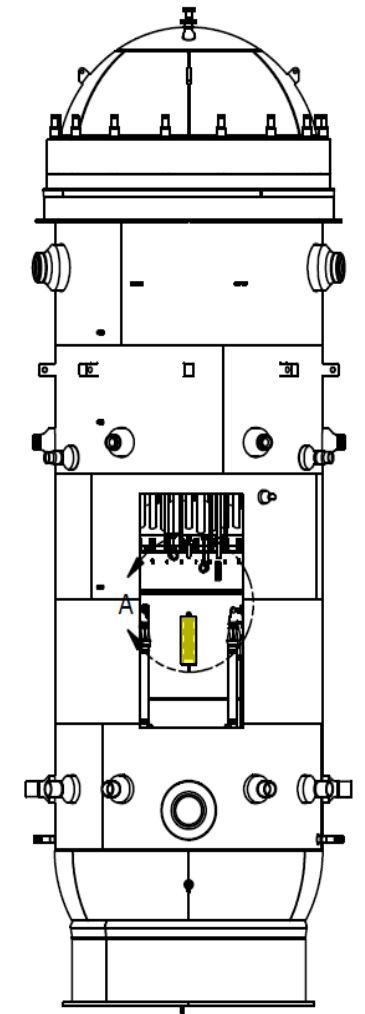


# Proposed Activities (1/2)

- **SSLR capsule** (12-year irradiation period) for representative plate and weld heats that bound the U.S. BWR fleet for extended operations at BWR fluence levels beyond licensee's projected fluence for extended operations (*BWRVIP-321, Revision 1-A, April 2023*)
- In the case of U.S. BWRs, fluence projections to the RPV is an order of magnitude lower than PWRs. Use of the ASTM E900-15 correlation will not be necessary

*(Reference: U.S. NRC Letter "Subject: Assessment of the Continued Adequacy of Revision 2 of Regulatory Guide 1.99" from Advisory Committee on Reactor Safeguards (ACRS) Chairman, Peter Riccardella, November 27, 2019)*

- Detailed basis for deferring certain ISP(E) capsule withdrawals, testing and analysis will address the following:
  - NRC concerns of deferring capsule withdrawals and specimen testing as stated in SECY-22-0019
  - Assessment of whether an RPV material heat-specific fitted Chemistry Factor (CF) and shift in  $RT_{NDT}$  based on surveillance data has significant impacts on plant operations
  - Plant-specific evaluations similar to those in BWRVIP-321, Revision 1-A for extending the ISP(E) using existing capsules with optimized testing for increased value
  - Consideration of testing additional or all of the SSLR capsule materials (The plan in BWRVIP-321, Revision 1-A was to only test materials for those plants that actually pursue SLR)
  - Prioritization of ISP(E) Capsule pulls within the 12 year SSLR capsule irradiation period and beyond the 12 years



# Proposed Activities (2/2)

## ■ Adequacy of RG1.99, Rev. 2 Embrittlement Prediction Methods for BWR Vessels

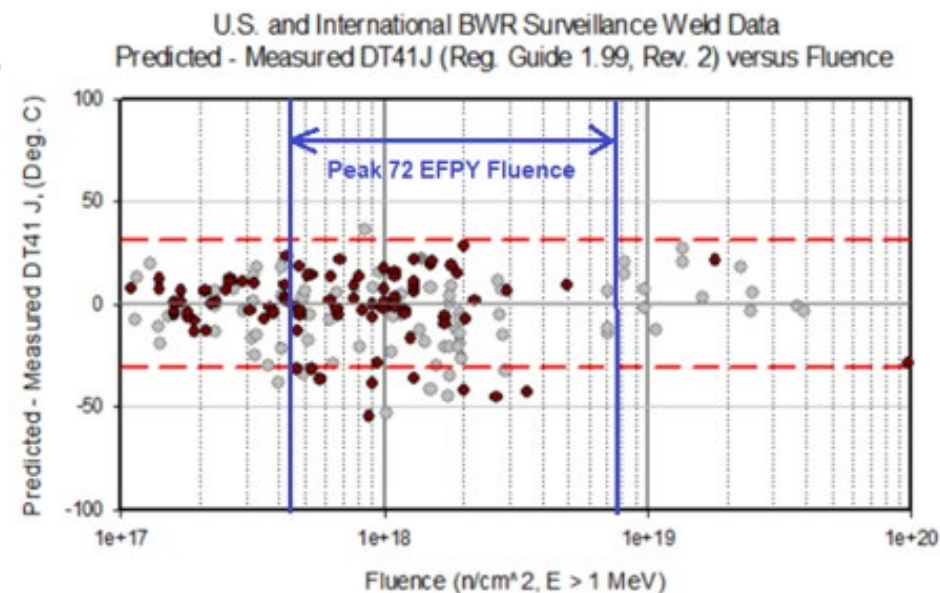
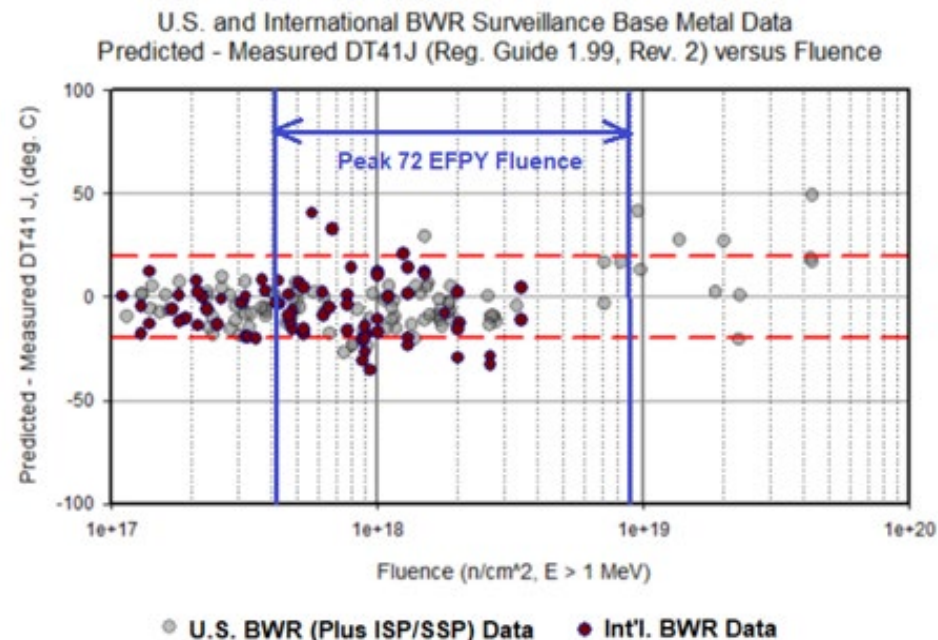
- Compile all U.S. BWR plant surveillance data and international BWR data and compare the predicted vs. measured results for both welds and plates as a function of fluence for both the RG1.99, Rev. 2 method and the ASTM E900-15 method. The scatter in the data comparisons will be evaluated and compared for the full range of projected U.S. BWR vessel fluence values for up to and beyond 72 EFPY.

## ■ Importance of Future Capsules for the BWR Fleet

- Further develop the logic for prioritization of future ISP capsule specimen testing. Weighting factors will be used based on importance and impact to define the priorities for testing. The methodology will address the issue of what is essential for the testing of the future ISP(E) and SSLR capsules.

## ■ Risk Significance

- Risk-informed methods have been used to determine the conditional probability of vessel failure for U.S. BWR operating and test conditions and found to be within NRC accepted values (e.g., BWRVIP-215 and BWRVIP-329)
- Risk significance will be evaluated to determine whether or not there is a safety concern for U.S. BWR reactor vessels, if the actual shift were higher than the RG 1.99R2 prediction





# ISP(E) Capsule Withdrawal Schedule Optimization

- Initial investigations are complete: Basis for changes to ISP(E) capsule withdrawals for extended operations
- Preliminary Conclusion: Defer several of the ISP(E) capsule withdrawals until beyond 2040 pending results of SSLR capsule specimen testing & analysis
- Maximizes the value of the capsules to provide BWR surveillance data for the possibility of plants operating to 80+ years. Preserves specimens to the extent possible for future use rather than testing on a predefined schedule (i.e., one capsule every 20 years)
- BWRVIP Topical Report for NRC review/approval



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