

BWR SCC CGRs

Updates to Existing Correlations and
Application of Field Inspection Data



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Presentation Outline

- Updates to Existing Stainless Steel and Ni-Base Alloy Laboratory Data Derived SCC CGR Models
- Application of Field Inspection Data to Evaluate SCC CGRs
- BWRVIP Perspective & Plans



**Updates to Existing Stainless Steel and Ni-Base Alloy
SCC CGR Models**

BWRVIP-14-A - Background

- BWRVIP-14-A provides K-dependent CGRs for non-irradiated stainless steel in both NWC and HWC environments
- BWRVIP-14-A correlation developed in the early years of the BWRVIP to address the critical need for SCC CGR correlations to be used as inputs to flaw evaluations
- Since the BWRVIP-14-A model was developed:
 - A significant amount of new CGR data has been generated
 - Testing procedures have been improved
 - Guidance has been developed for screening CGR data so that the final datasets used for model development are limited to high quality data

Objective

- Develop a technical basis for updated IGSCC CGR correlations for low fluence ($\leq 5E20$ n/cm²) stainless steel components using modern methods and CGR data from laboratory studies

Benefit

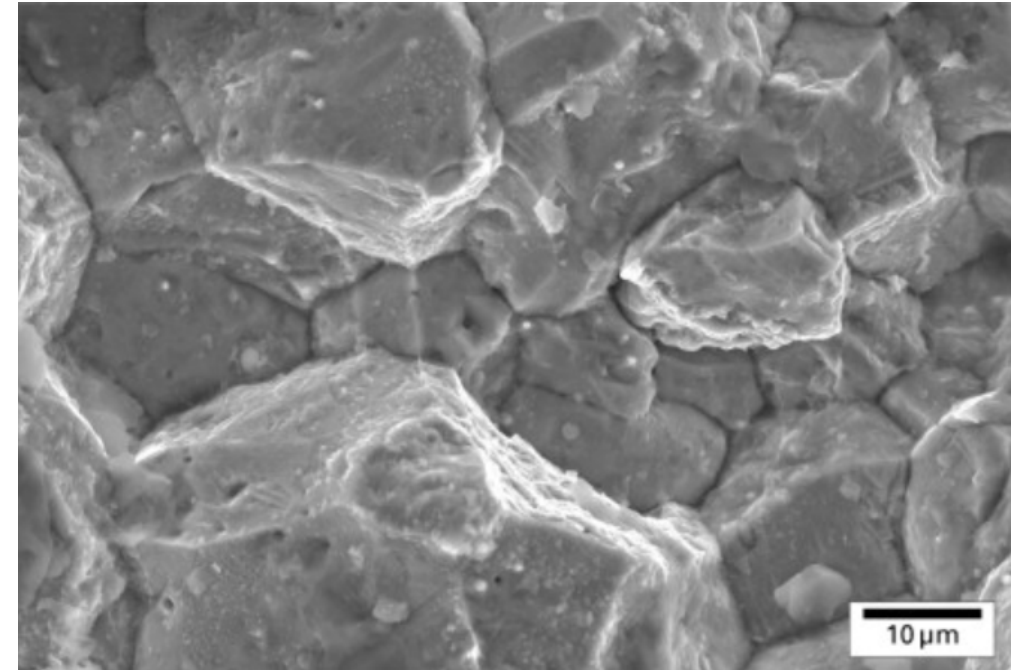
- Modern and more technically defensible model than the older BWRVIP-14-A model

Approach

- Expert panel-based scoring and screening of data
- Consistent with recent CGR correlation development efforts

Expert Panel

- International group of industry leading experts in SCC of SS CGR
- Members
 - Peter Andresen (JLN)
 - Katsuhiko Kumagai (TEPCO)
 - Tyler Moss (US NNL)
 - Anders Jenssen (Studsvik)
 - Stefan Ritter (PSI)
- Observers
 - Tomonori Abe (Toshiba)
 - Yun Wang (Hitachi)



Data Gathering and Tabulation

- Expert panel members have gathered CGR data along with the needed supporting information required for data scoring
- Data have been tabulated
- Several members have made available applicable data from other recent database efforts (US NNL, JSME, MRP-458, etc.)
- New database includes significantly more data than used previously

Database	CGRs
BWRVIP-14-A	122
New Database	>1500*

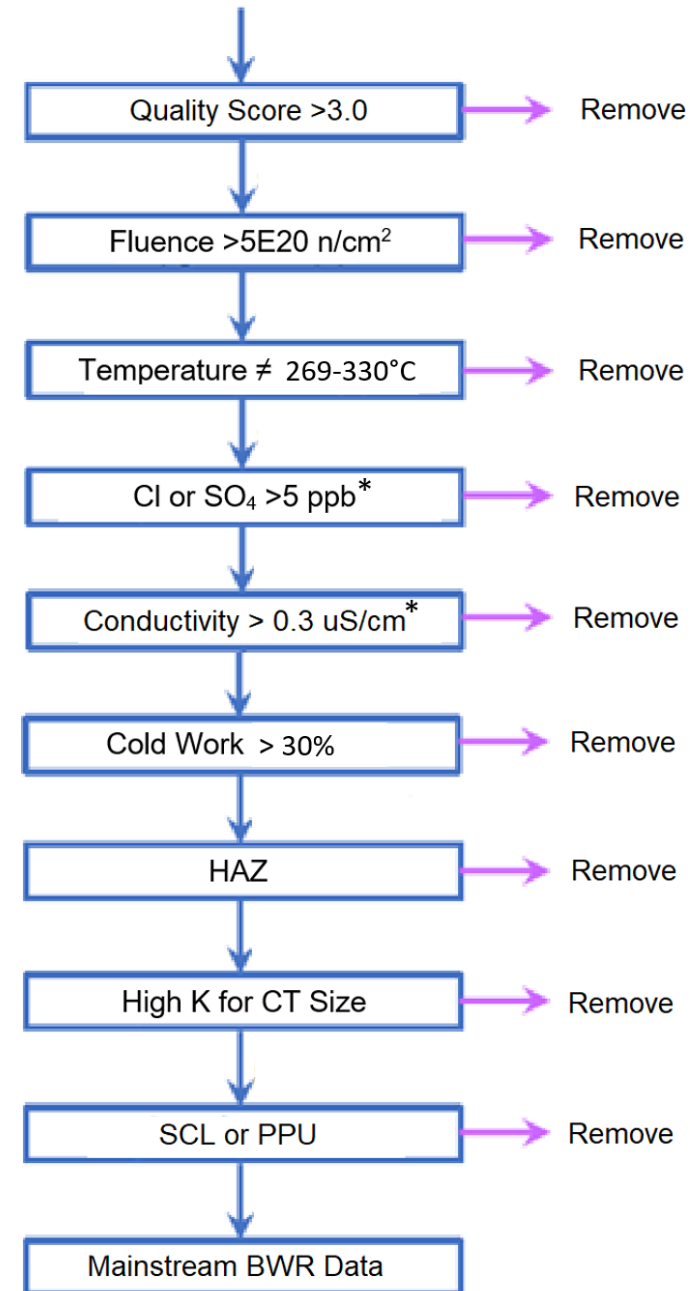
*Raw data: prior to scoring/screening process

Data Scoring and Screening

- Example of general process
 - Data quality scoring (1-5, 1 being the best)
 - Testing techniques
 - Fatigue pre-crack and intergranular transitioning
 - SCC growth increment, response, and signal-to-noise ratio
 - Fractography (crack front evenness, etc.)
 - Data applicability screening
 - Unirradiated, normal operation environment, constant SIF, material condition (base metal with CW representative of HAZ)

After scoring/screening/binning process

Database	NWC CGRs	HWC CGRs
BWRVIP-14-A	107	15
New Database	208	325



Low Fluence SS SCC CGR Correlation Development Approach

- Correlation Form

- Power law for K and Hv with Arrhenius for temperature

$$\text{CGR} = C K^n \text{Hv}^m \exp(-Q/RT)$$

- Highlighted terms are being determined considering linear regression and as-identical as possible (AIAP) variable trend comparisons (similar to MRP-458 process)
 - Guidance will be included regarding input selection in the update to BWRVIP-14-A
- There will be separate CGR correlations for both NWC and HWC

Future Plans

- After completion of updated SCC CGR model for low fluence stainless steels (update to BWRVIP-14-A):
 - New non-irradiated SS SCC CGR correlation will be evaluated against extensive field CGR datasets based on repeat inspections of SCC in core shrouds (see following slides)
 - New project initiated to evaluate Ni-base alloy (A82 / 182) SCC CGRs with the intent of developing updated correlations to ultimately replace the existing correlations in BWRVIP-59-A
 - Existing SCC CGR correlations for irradiated SS (BWRVIP-99-A and Code Case N-889) will be reviewed to determine if updates are appropriate




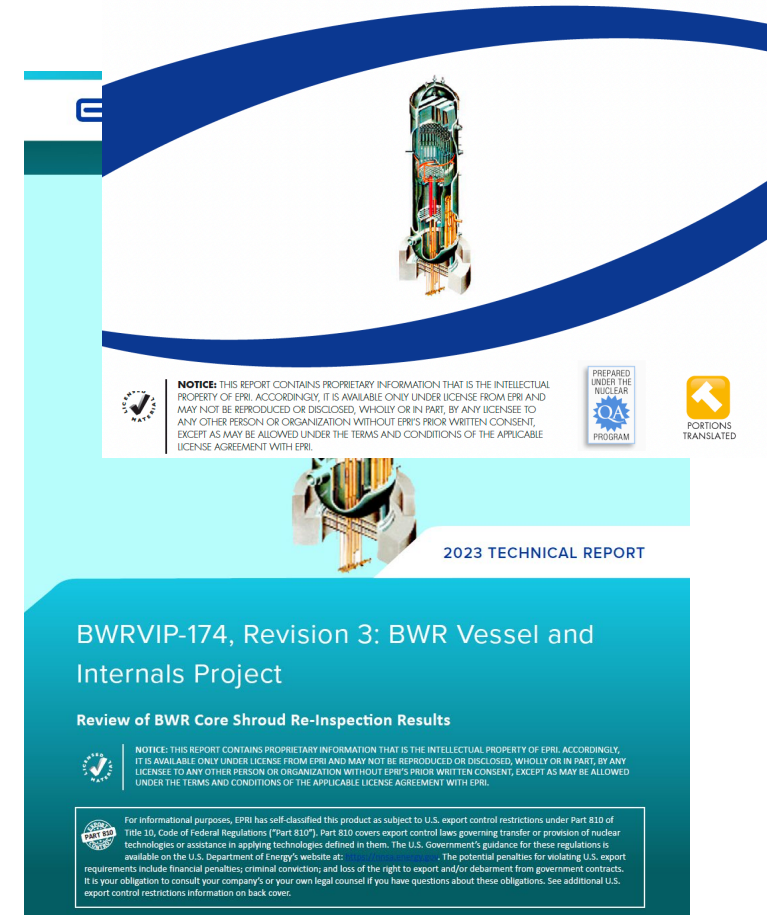
Application of Field Inspection Data to Evaluate SCC CGRs

Background

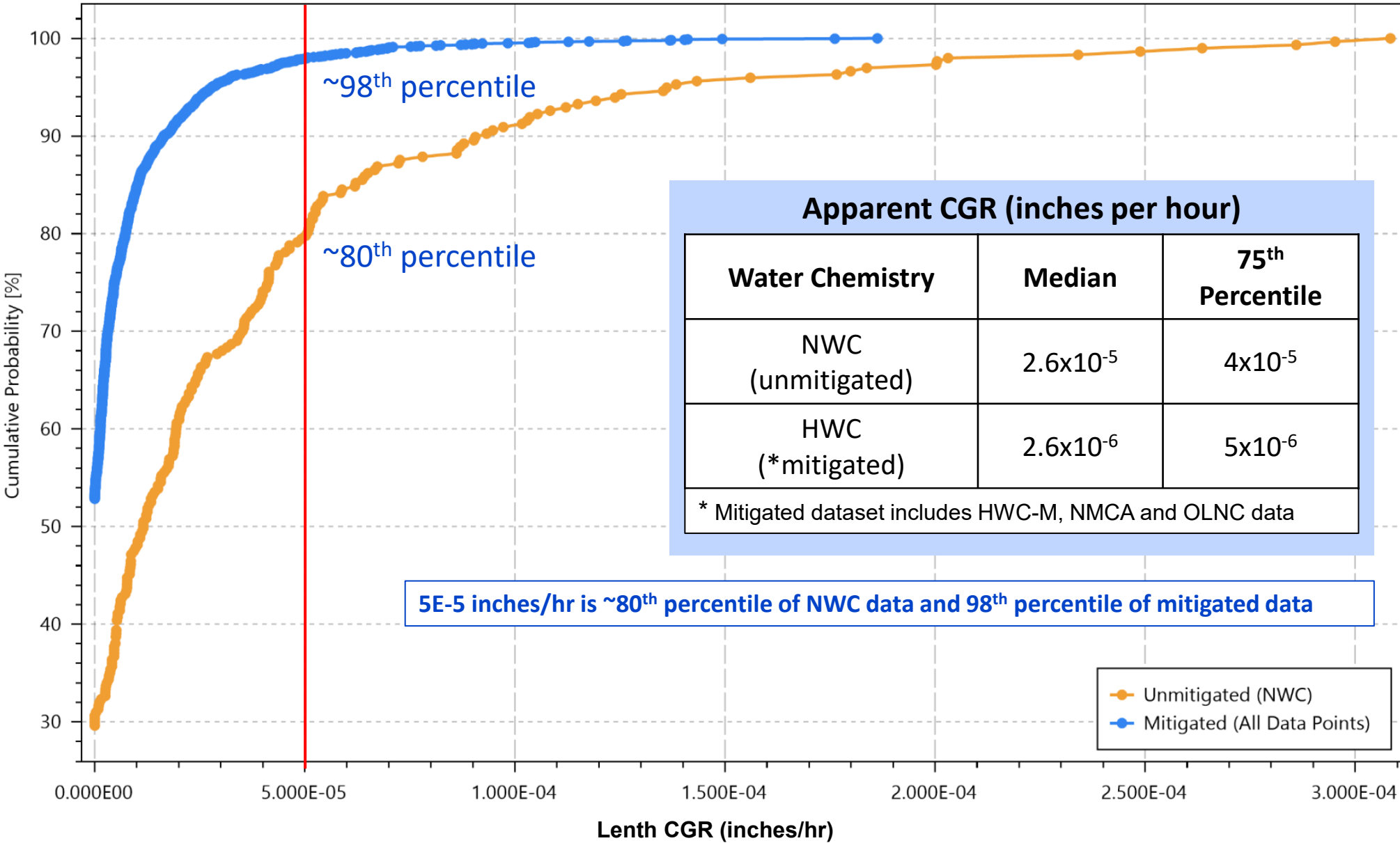
- The BWRVIP has been collecting and analyzing the results of field inspections to assess CGRs for many years now
- For core shrouds, BWRVIP-174 Rev. 3 represents the most detailed evaluation of core shroud inspection data ever performed
 - Data from 33 BWR core shrouds
 - Over 8,000 indication records associated with approximately 5,000 indications
 - Results in over 3,500 CGR estimates being calculated for both length and depth directions
- BWRVIP-339 documents a similar evaluation of SCC CGRs for core spray piping and jet pump riser welds

BWRVIP-339: BWR Vessel and Internals Project
BWR Jet Pump and Core Spray Piping Linear Flaw Occurrence and Growth

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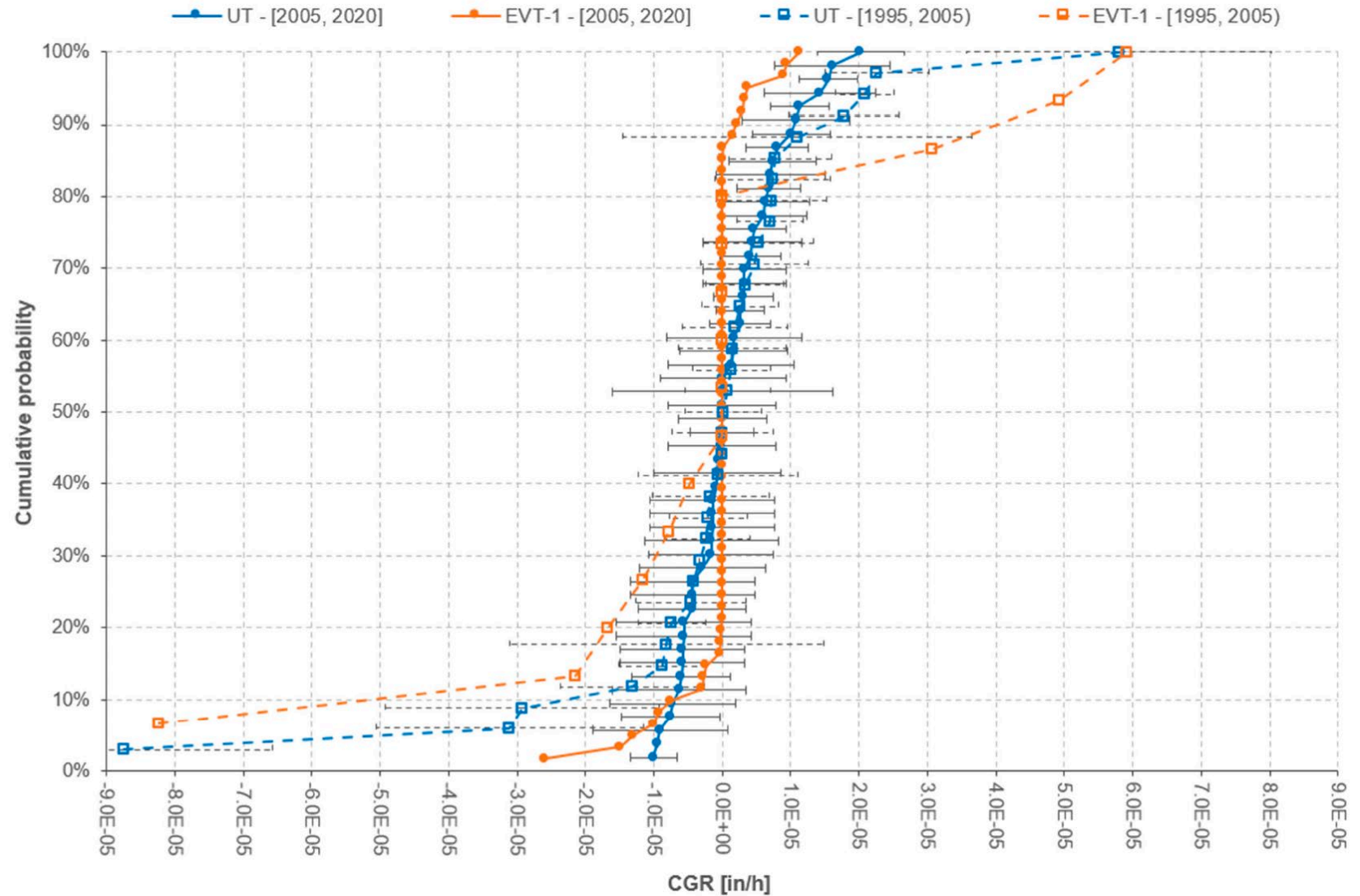


Example: Core Shroud Length SCC CGRs

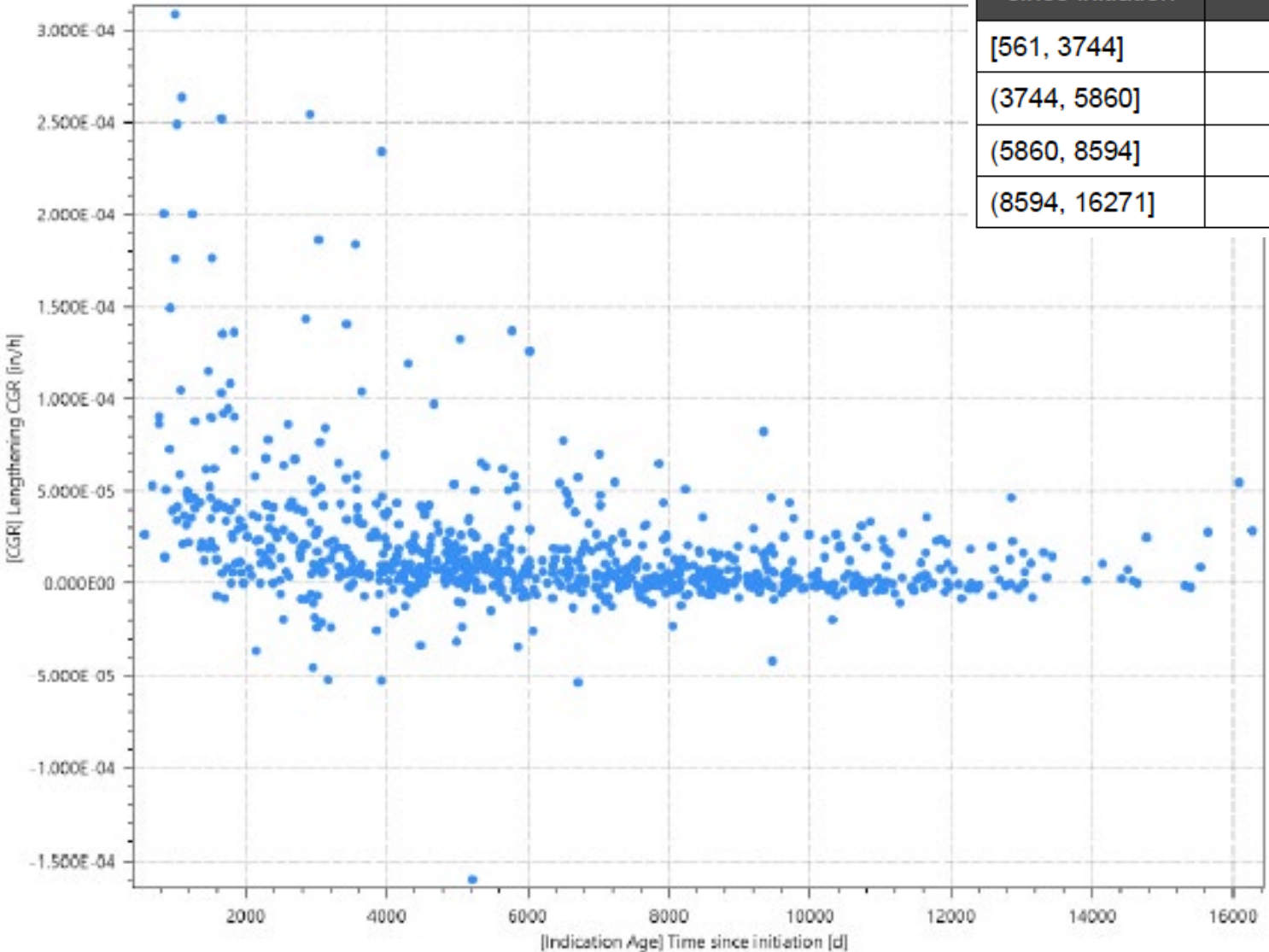


Example: Core Spray Piping SCC CGRs

- Results indicate CGRs well below $5E-5$ inch/hr, particularly for more recent exams
- In the majority of cases, flaws appear dormant



Example: Core Shroud Time-Based SCC CGR Evaluation (All Data - NWC and HWC)



Number of days since initiation	Number of data points	Average CGR [in/hr]	Median CGR [in/hr]	75 th Percentile CGR [in/hr]
[561, 3744]	202	4.2×10^{-5}	2.6×10^{-5}	5.1×10^{-5}
(3744, 5860]	202	1.5×10^{-5}	9.3×10^{-6}	2.0×10^{-5}
(5860, 8594]	201	9.2×10^{-6}	4.7×10^{-6}	1.3×10^{-5}
(8594, 16271]	202	6.5×10^{-6}	2.3×10^{-6}	1.2×10^{-5}

As with the core spray piping CGR data, shroud CGRs appear to be trending toward zero as operating time increases, likely due to crack fronts reaching lower stress regions where crack growth slows and crack arrest may occur

BWRVIP Perspective & Plans

- CGRs used in structural evaluations of BWR reactor internals have historically been based on correlations derived from laboratory test results
- It is appropriate to reconsider existing laboratory-based CGR correlations and guidance given the significant amount of new data that have been generated since initial model development and improvements in the methods used to screen and evaluate these data
- However, it is also appropriate to use information from field inspections to inform CGR guidance, particularly given the abundance of data as compared to laboratory measurements
- Since this topic was initially introduced at the 2024 Materials Tech Exchange meeting, the BWRVIP has continued to evaluate options for application of field-based SCC CGRs
- Planned future submittals will likely include refined SCC CGRs based on both updated CGR models based on modern data and evaluation methods as well as on analysis of field-inspection data



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