

# Status of Previous EPRI EAF Efforts

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**NRC Public Meeting on Environmentally  
Assisted Fatigue (EAF) Research and Related  
ASME Activities**

September 25, 2018

NRC Headquarters - Rockville, MD

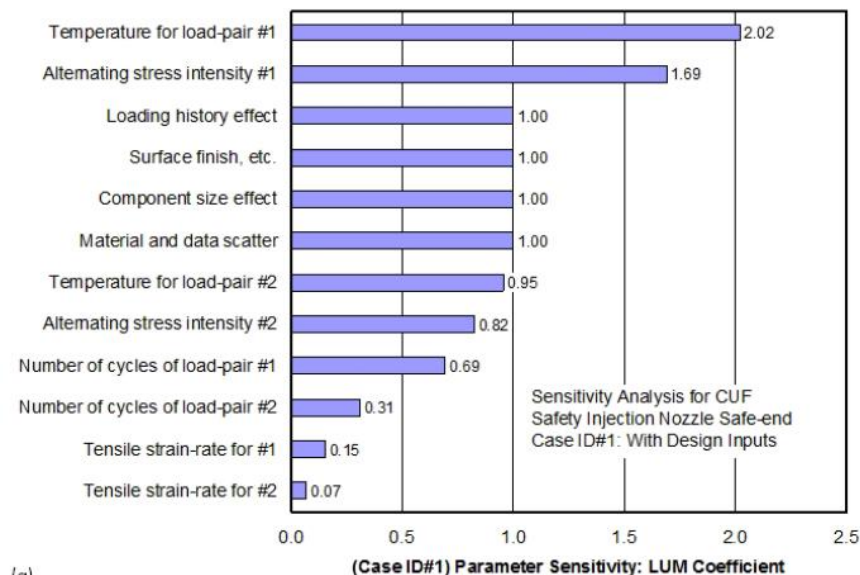


# EPRI's EAF Research Efforts

- Previous presentations at this meeting have provided updates of many of EPRI's EAF research projects
  - Fatigue Usage Gradient and Life Factor Concept (Gosselin)
  - Alternative Approaches for Simplified Elastic-Plastic Analysis (Raganath)
  - Fatigue Limit of Stainless Steel for Use in Vibration Evaluation (Raganath)
  - Corrosion Fatigue Crack Growth of Low Alloy Steel in BWRs (Raganath)
  - Non-Isothermal EAF Testing for 316 Stainless Steel in Simulated PWR Environment (Asada)
  - Hold Time and Water Chemistry Effects Testing (Smith)
  - EAF Short Crack Growth Testing (Smith)
  - EPRI EAF Component Testing (Smith)
- This presentation provides the status of EPRI's remaining ongoing EAF research:
  1. Probabilistic Determination of Margins in ASME Code Section III CUF Calculations
  2. Fatigue Crack Growth Rates for Austenitic Stainless Steels in BWR Environments
  3. BWR Subsequent License Renewal EAF Database
  4. International Collaboration Group

# Probabilistic Determination of CUF Margins

- This project develops a simplified engineering approach (based on probabilistic methods) that quantifies the uncertainties of inputs in CUF and  $CUF_{en}$  calculations
- This approach may be used in CUF and  $CUF_{en}$  sensitivity analyses to identify and rank those inputs and their uncertainties that control component CUF and  $CUF_{en}$  and their uncertainties
- Detailed knowledge of the CUF and  $CUF_{en}$  uncertainties in the underlying deterministic framework can help to:
  - Focus and direct efforts to eliminate unnecessary conservatism
  - Reduce associated costs of (re)design, (re)analysis, inspections, and mitigation efforts to meet the unspecified margins associated with acceptance limits
- EPRI Report No. 3002012326, *Basis and Method for Assessing Adequacy and Margins for Fatigue Under the Effects of Water Environment and Sources of Uncertainty* May 2018 (publicly available at [www.epri.com](http://www.epri.com))
  - The technical report was provided to the ASME Code Section III Fatigue Steering Committee for their use to potentially refine Section III CUF calculation methods as a part of their Fatigue Action Plan



# BWR FCG Rates for Stainless Steels

- In the wake of the publication of ASME Code Section XI Appendix L (Flaw Tolerance) in 2008, a need arose for updated fatigue crack growth (FCG) rates in water environments for most Class 1 nuclear component materials
- ASME Code Case N-809, *Reference Fatigue Crack Growth Rate Curves for Austenitic Stainless Steels in Pressurized Water Reactor Environments*, was approved in 2015, and has been successfully used in at least two NRC-approved flaw tolerance submittals to-date
- Code Case N-809 has also been used applications supporting calculations for weld overlay repairs conducted using Code Cases N-504 and N-740-2
- EPRI funded completion of the technical basis document and sample calculations for N-809
- Additional efforts are needed to develop other FCG rate curves for other materials and other environments
- This project is developing FCG rates for austenitic stainless steels in BWR environments
- This project will revise Code Case N-809 to extend its application to BWR environments
- This project began earlier this year; data collection is in process
- Project outputs will be an ASME Code Section XI Code Case and a Technical Report
- Anticipated completion: 2019

# BWR EAF Database for 80 Years

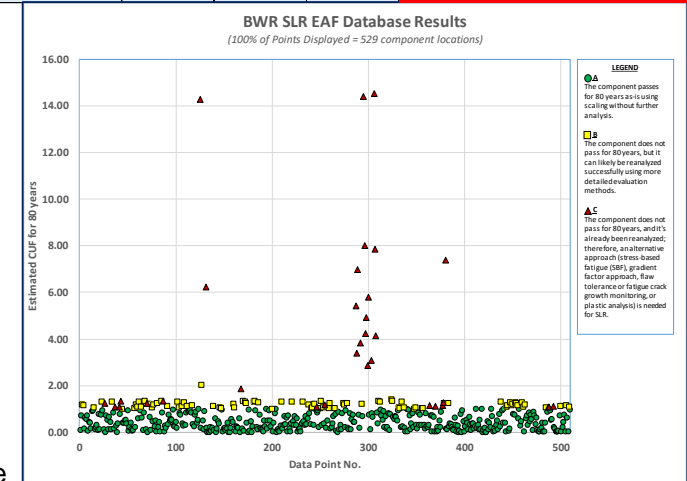
- As part of the revision to BWRVIP RPV Inspection and Evaluation Guidelines for life extension, EAF results were compiled for all BWRs that submitted 60-year LRAs and performed EAF evaluations
- The resulting database provides an overall snapshot of the work needed to address EAF for the BWR fleet for SLR

- Extensive database (over 500 components!)
- Majority (76.7%) are acceptable for 80 years
- An additional 16.4% can use refined analysis to demonstrate acceptability (same as those used for 60 years)
- Remaining 6.8% require other methods for acceptability
  - Other methods that already exist or are under development will likely produce satisfactory results
    - e.g., flaw tolerance, LF/GF approach, revised  $K_e$
  - Therefore, completion of ongoing analytical projects is important to address BWR fleet needs for SLR

Last Updated: 10/05/2016

SUMMARY OF RESULTS	No. of Nuclear Sites:	22	No. of Locations per Suggested Approach		
	No. of Nuclear Units:	33	A	B	C
	No. of Locations:	529	406	87	36
			76.7%	16.4%	6.8%

All Data Shown



- This project is complete and the results will be documented in an Appendix to BWRVIP-316, Reactor Pressure Vessel Inspection and Evaluation Guidelines for Long Term Operation (to be published in December 2018)

# International Collaboration Group (1/2)

- EPRI hosts an EAF International Collaboration Group
- Original motivations for forming this group:
  - During an EPRI Conference in Summer of 2013 (San Francisco), several observations were identified on differences between European EAF work and the U.S. situation
  - A subsequent meeting was held in January 2014 (France) between EDF, Rolls-Royce and AMEC to discuss exchanges on future test programs and ways of working together on alternative environmental fatigue and propagation methods
  - The subsequent discussions recognized that there are mutual benefits to have a common approach
    - e.g., data exchange, testing to fill gaps, avoiding duplication, analytical round robin studies, benchmarking of methods, mechanistic understanding, and joint lobbying of industry
- The purpose of this collaboration is to:
  - Periodically meet to exchange EAF information and data
  - Coordinate research efforts to the extent practical
  - Review on-going research and provide constructive input and direction
  - Provide insight and ideas for new research projects (e.g., EPRI's EAF Component Test)

# International Collaboration Group (2/2)

- There are currently 7 participating organizations:
  - EPRI
  - Rolls-Royce
  - Wood Group (formerly AMEC Foster Wheeler)
  - Framatome
  - Électricité de France SA (EDF)
  - Bechtel Marine Propulsion Corporation – Naval Nuclear Laboratory (Bettis site)
  - Mitsubishi Heavy Industries (MHI)
- All 7 organizations have signed a Non-Disclosure Agreement (NDA) to facilitate exchange of information and data
- This group meets approximately once each year

- The last meeting was in December 14, 2017 (Paris, France)
- The next meeting is September 26-27, 2018 (Washington, DC)

DAY #1: Wednesday, September 26, 2018

Topic	Time	Presenter
Greetings and Introductions	08:00	All
Member Reports:	08:15	G. Stevens (EPRI)
Organizational EAF Status Updates	08:45	S. Cuvilliez (EdF)
	09:15	T. Sumon (R-R)
	09:45	D. Tise (Wood) – via dial-in
<b>Break</b>	<b>10:15</b>	
Member Reports:	10:30	L. De Baglion (AREVA)
Organizational EAF Status Updates (continued)	11:00	T. Damiani (NNL)
	11:30	S. Asada (MHI)
<b>Lunch</b>	<b>12:00</b>	
Review of Actions from December 14, 2017 Meeting in Paris:		
1. International Consensus on the F <sub>inc</sub> -Incorporated Approach	13:00	A. Morley (R-R)
2. Hollow vs. Solid Specimen Data	13:30	P. Gill (Wood)
3a. Update on R-R's Life Assessment Approach	13:45	D. Leary (R-R)
3b. Update on EPRI's Life and Gradient Factor Work	14:15	G. Stevens (EPRI)
4. Fatigue Database	14:45	G. Stevens (EPRI)
<b>Break</b>	<b>15:00</b>	
Review of Actions from December 14, 2017 Meeting in Paris (continued):		
5. Data Exchange Rules	15:30	M. Tuttle (R-R)
Further Validation of F <sub>incorporated</sub> and SNW	16:00	A. Morley (R-R)
Update on INCEFA+ Program	16:30	K. Mottershead (Wood)
Open Discussion/Summary of Actions	17:00	All/G. Stevens (EPRI)
<b>Adjourn</b>	<b>17:30</b>	

DAY #2: Thursday, September 27, 2018

Topic	Time	Presenter
Greetings/Introductions/Recap of Day #1	08:00	G. Stevens (EPRI)
Update on EAF Component Test Project	08:15	J. Smith (EPRI)
EAF Short Crack Testing	09:00	P. Gill (Wood)
Update on Fatigue Crack Growth Testing (Temperature-cycling FCG Tests)	09:30	D. Leary (R-R)
<b>Break</b>	<b>10:00</b>	
Hardening/Softening Behaviour in Air/PWR Environments	10:30	S. Asada (MHI)
EDF's Position Regarding EAF and CS/LAS Components without Cladding (Secondary Cooling System Components)	11:00	S. Cuvilliez (EdF)
Summary of Sep. 25 <sup>th</sup> NRC EAF Public Meeting	11:30	G. Stevens (EPRI)
Meeting Recap, Actions, and Next Meeting	11:45	G. Stevens (EPRI)



