BWRVIP Approach for Managing EAF of Internals

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NRC Public Meeting on Environmentally Assisted Fatigue (EAF) Research and Related ASME Activities
September 25, 2018
NRC Headquarters - Rockville, MD

Background

- There are questions associated with evaluation of environmentally assisted fatigue (EAF) for boiling water reactor (BWR) internals
  - Cumulative usage factor (CUF) values generally not available
    - Exceptions are:
      - Internals for newer (BWR/6) plants, where internals were evaluated to the requirements of ASME Section III Subsection NG, *Core Support Structures*
      - Internals repairs or replacements
      - Other internals where updated analyses were performed
- To address these questions, the BWR Vessel and Internals Project (BWRVIP) has developed a basis for how the existing guidance provided by the BWRVIP inspection-based reactor internals program addresses EAF
  - The basis describes how the BWRVIP program adequately fulfills the guidance currently defined in NUREG-2191, *Generic Aging Lessons Learned for Subsequent License Renewal (GALL-SLR) Report*, for managing EAF
  - As a result, EAF CUF (CUF_{en}) calculations to disposition fatigue time limited aging analyses (TLAAs) are not necessary

Objective of the EAF Internals Technical Basis

- The primary basis for this approach is that intergranular stress corrosion cracking (IGSCC) and irradiation-assisted stress corrosion cracking (IASCC) are significantly more limiting for reactor pressure vessel (RPV) internals than cracking caused by EAF
- The BWRVIP guidance assumes the potential for SCC occurrence and subsequent growth
  - In a number of cases, there are significant structural redundancies (e.g., top guide, core plate)
  - In all cases, evaluation methods are provided to disposition crack growth due to SCC
- Monitoring CUF values for components known (or presumed) to contain cracking has limited value
- The BWRVIP performed sample crack growth rate calculations to document that any fatigue crack growth (FCG) occurring in BWR reactor internals is accommodated by the conservatisms contained within existing BWRVIP IGSCC and IASCC crack growth correlations

Background of the EAF Internals Technical Basis

- Table B1, Item IV.B1.R-53 of the GALL-SLR Report identifies that one applicable aging effect and mechanism for BWR RPV internal components fabricated from stainless steel and nickel alloys is cumulative fatigue damage and cracking due to fatigue cyclical loading
  - This effect/mechanism may be adequately managed as a time-limited aging analysis (TLAA) under NUREG-2192, *Standard Review Plan for SLR (SRP-SLR)*, Section 4.3, "Metal Fatigue"
- Disposition can be addressed by:
  - Demonstrating the analysis remains valid for the period of extended operation (10 CFR 54.21(c)(1)(i))
  - Projecting the analysis to the end of the period of extended operation (10 CFR 54.21(c)(ii))
    OR
  - **Demonstrating that the effects of aging will be adequately managed for the period of extended operation (10 CFR 54.21(c)(1)(iii))**
- **The BWRVIP Program is adequate to manage cracking of reactor internals due to either SCC or fatigue, with SCC being by far the more limiting mechanism**

Six Elements of the EAF Internals Technical Basis (1/2)

1. BWRVIP Inspection Requirements
   - The BWRVIP I&E guidelines address management of BWR reactor internal components and are designed to provide confidence in continued structural integrity and reasonable assurance that BWR RPV internals will continue to perform their intended function(s)
2. BWRVIP Inspection Methods
   - BWRVIP inspections are performed in accordance with BWRVIP-03
   - The techniques described within BWRVIP 03 are primarily for the detection and characterization of service-induced, surface-connected planar discontinuities, such as IGSCC and IASCC, in welds and in adjacent base material
   - Volumetric methods applied to perform BWRVIP program inspections must be performed using techniques that have been demonstrated to be adequate to detect SCC in the component / geometry to which the technique will be applied
3. Application of BWRVIP Inspections to Detect and Characterize Fatigue Cracking
   - The methods applied by the BWRVIP reactor internals AMP to detect cracking have been shown capable of detecting all but very small cracks
   - The techniques implemented by the BWRVIP reactor internals AMP to detect tight IGSCC cracks are suitable for detecting fatigue cracks

Six Elements of the EAF Internals Technical Basis (2/2)

4. Significance of Crack Growth
   - The BWRVIP program defines inspection intervals unique to each component based on the component's importance to safety and its flaw tolerance
   - Generally, the controlling cracking mechanism evaluated in the determination of BWR RPV internal component inspection intervals is controlled by SCC
     - Effective EAF crack growth rates for BWR reactor internals are significantly less than SCC growth rates (assessment and figure to be included in report)
     - In all cases (for all materials and for both NWC and HWC environments), the SCC CGR correlations contained within BWRVIP guidance are at least two orders of magnitude larger than FCG rates at similar K / ΔK values
5. Potential for Flaw Initiation
   - The BWRVIP program for reactor internals includes the presumption that cracking may occur in any internals component
   - The fixed, upper bound CGRs are considered appropriate to address SCC growth and the potential for new initiations
   - These conservatisms encompass the potential for cracking due to EAF
6. Operating Experience
   - The BWRVIP program monitors plant-specific and industry aging issues, evaluates them, and, as necessary, enhances program requirements or develops new program requirements to manage the effects of aging
   - The combination of BWRVIP activities and licensee OE program procedures provides a basis for concluding that any unexpected cracking will be reviewed and aging management requirements will be enhanced as appropriate to the observed degradation

Conclusions of the EAF Internals Technical Basis

- Inspection intervals methods established by the BWRVIP for management of IGSCC are limiting and provide adequate assurance that cracking due to EAF in BWR reactor internals will be managed
- Additional margin against failure exists within the BWRVIP flaw evaluation procedures since the generic fracture mechanics evaluations apply safety factors against failure and use appropriately conservative SCC crack growth correlations
- Consideration of possible initiation of cracks due to EAF or growth of cracks due to FCG is accommodated by the conservatisms built into the BWRVIP reactor internals AMP related to management of SCC

Future Plans

- EPRI is publishing this topic in Appendix D to a new report for BWR internals for extended plant operation
  - EPRI Report 3002012535, *BWRVIP-315: BWR Vessel and Internals Project - Reactor Internals Aging Management Evaluation for Extended Operations*, Fall 2018
  - The objective of this report is to provide a technical basis demonstrating the adequacy of the BWRVIP reactor internals Aging Management Program (AMP) to adequately manage age-related degradation of BWR reactor internals for operation beyond 60 years
  - This report will be available to BWRVIP members only
  - The report will be submitted to the NRC for review and approval
- There is a public meeting on BWRVIP activities tomorrow (September 26th); this topic will be discussed at that meeting

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