PWR Owners Group

EPRI

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Chris Koehler – Auxiliary Piping SCC OE Focus Group Update

Industry/NRC Materials Technical Exchange Meeting 6/14/23

Agenda

Industry actions to consider EDF OE

- PWROG Auxiliary Piping SCC OE Focus Group
  - Safety Assessment (complete)
  - Applicability Assessment (in progress)
- EPRI white paper (complete)
- Revision to MRP-236R1 (in progress)

Roadmap

Purpose of the Auxiliary Piping SCC OE Focus Group

- Coordinating efforts between PWROG and EPRI
- Focus:
  - Understanding causal factors associated with recent auxiliary piping SCC operating experience and the potential relevance to the rest of the industry
  - Development of industry positions and/or guidance as needed
  - Regulatory interactions
- PWROG MSC Current Work
  - Safety Assessment
    - Purpose: Assess potential safety impact of EDF OE on the industry
  - Applicability Assessment
    - Purpose: Assess applicability of EDF OE to the industry

Safety Assessment (1/4)

Approach

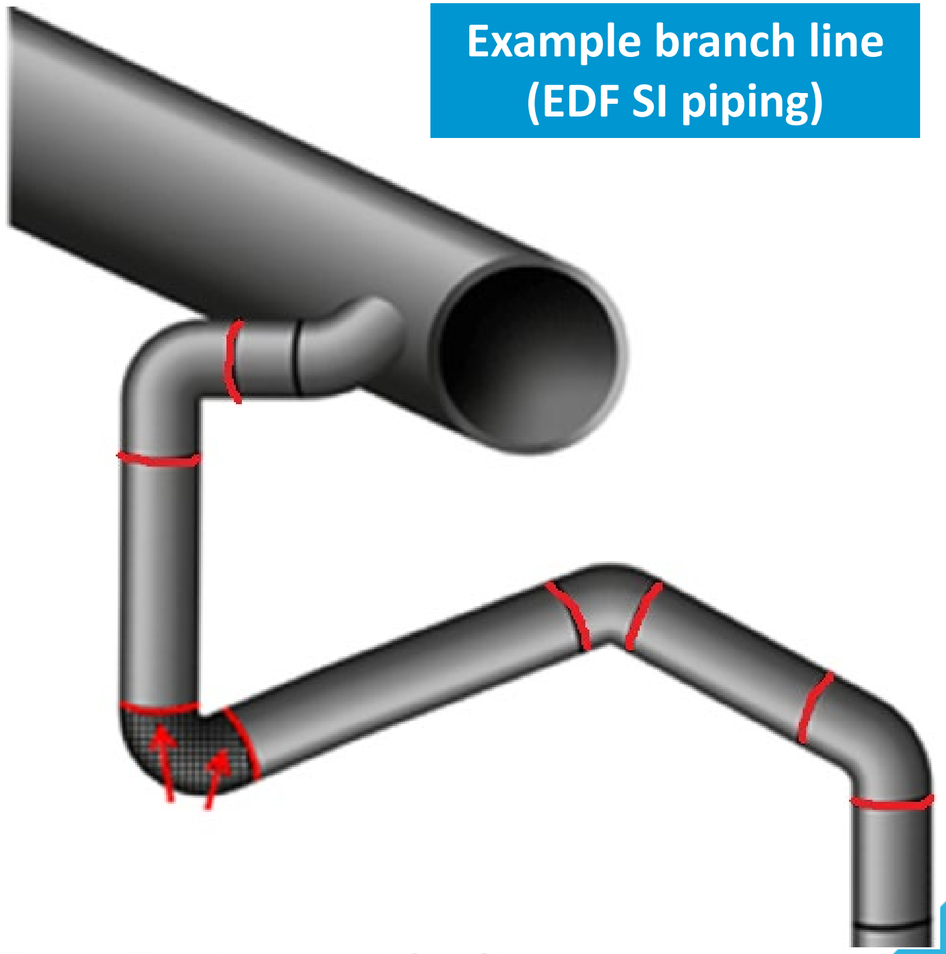
- Safety is based on risk, which is a function of likelihood and consequence
  - Likelihood of SCC
    - Review inspection data to determine if applicable locations are being inspected
    - Review UT method to determine if EDF-type flaws would be identified
    - Review SCC OE database to determine if EDF-type SCC has occurred elsewhere
  - Consequence of SCC
    - Review available flaw evaluations to determine if a flaw could reach critical flaw size
    - Compare design basis analysis breaks to branch line breaks

Issue Recommendations (as appropriate)

Safety Assessment (2/4)

Areas of interest per EDF/Japan SCC OE

- Red highlighted welds indicate weld HAZ locations of interest (i.e., elbow welds)



Example branch line (EDF SI piping)

Safety Assessment (3/4)

Conclusions

- Existing inspection programs include the locations of interest
- Industry survey results indicate that the locations of interest are being inspected
- The volumetric inspection methods used provide reasonable assurance that significant flaws would be detected; however, an IGSCC-specific inspection method is recommended
- Review of industry OE found no cases of confirmed atypical SCC beyond EDF and the one flaw at Ohi-3; there were three cases with similar characteristics to atypical SCC, but confirmatory destructive examinations have not been performed because either a WOL was performed or a flaw evaluation
- A break in a branch line is bounded by breaks considered by design basis analyses
- Given the paucity of this type of OE and the extent of inspection coverage, simultaneous breaks in multiple branch lines is highly unlikely

The observed atypical SCC OE at EDF and Ohi-3 does not represent a significant safety concern for the US fleet.

Safety Assessment (4/4)

NEI 03-08 Guidance

- Intergranular stress corrosion cracking (IGSCC) specific ultrasonic testing (UT) examination techniques and personnel qualifications shall be implemented when performing the planned (next and future) volumetric inspections of the locations of interest: elbow weld heat-affected zone (HAZ) (both sides) for the non-isolable portions of passive safety injection (SI) piping (i.e., Westinghouse (W) SI piping, Combustion Engineering (CE) SI piping, and Babcock and Wilcox (B&W) core flood piping), residual heat removal (RHR) suction piping (i.e., W RHR piping, CE shutdown cooling piping, and B&W decay heat piping), and pressurizer spray line piping (i.e., W, CE, and B&W). This recommendation does not require new inspections, but instead only recommends that the IGSCC specific examination methods be used for the volumetric inspections that are already planned (next and future). If inspections are scheduled for less than a year from the time of issuance of this recommendation, then the recommendation can instead be implemented at the subsequent inspection. Intervals

The above was approved by the PWROG Executive Committee

Applicability Assessment (1/4)

Approach

- Consider potential root causes for atypical SCC
- Assess whether these conditions are present in the industry

Applicability Assessment (2/4)

Potential root causes for atypical SCC

- Nitrogen content of Type 316LN resulting in higher hardness in the HAZ ID due to strain-hardening behavior (relative to typical US fleet grades: 303, 304L, 316, 316L)
  - The affected EDF locations are in the newer designs (N4 and P4/P'4), which use Type 316LN
  - However, the older EDF units (CPY design) also use Type 316LN and they have not been affected by this atypical SCC. Also, Type 316NG (which contains nitrogen) has been widely used in BWRs without atypical SCC.
  - If not the sole cause, this may be a contributing factor, so a literature search and OE review will be performed
- Elevated stresses in the elbow weld regions due branch piping configurations with thermal stratification resulting in bending from differential thermal expansion
  - EDF has attributed the atypical SCC to the down-horizontal (DH) branch piping configuration (specifically when the H portion is long)
- Possible Atypical Weld Residual Stress (WRS) profile
  - This profile would have exceptionally high tensile WRS at the ID and highly compressive subsurface
  - This is possible given indirect indicators: 1) the EDF OE being early onset, 2) the observed flaws are long and shallow, and 3) this profile is consistent with through thickness balance of stresses

Applicability Assessment (3/4)

Assess whether these conditions are present in the industry

- Type 316LN
  - Survey of PWROG fleet (55 units) found no cases of LN grades being used
- Thermal stratification in industry branch piping
  - Reviewed PWROG fleet branch piping configurations and identify those that meet the EDF criteria (i.e., DH with a long H portion)
    - DH configuration is rare for SI piping, but common for RHR suction piping
  - Note that, as discussed in the Safety Assessment, these locations are the primary focus for existing thermal fatigue inspection requirements (MRP-146R2) and there are no confirmed cases of atypical SCC

Applicability Assessment (4/4)

Assess whether these conditions are present in the industry (cont.)

- Atypical WRS profile
  - It is not practical to perform direct WRS measurements of the EDF and the US fleet to perform a direct comparison of the WRS profiles
  - Alternatively, available information will be used to perform sample case analyses for the US fleet considering:
    - Typical WRS profile based on extensive WRS measurement performed for similar BWR piping
    - Atypical WRS profile based on the characteristics of the observed EDF flaws (early onset, long, and shallow)
  - In addition, an expert panel will be convened to consider the welding process that could result in the postulated WRS profile

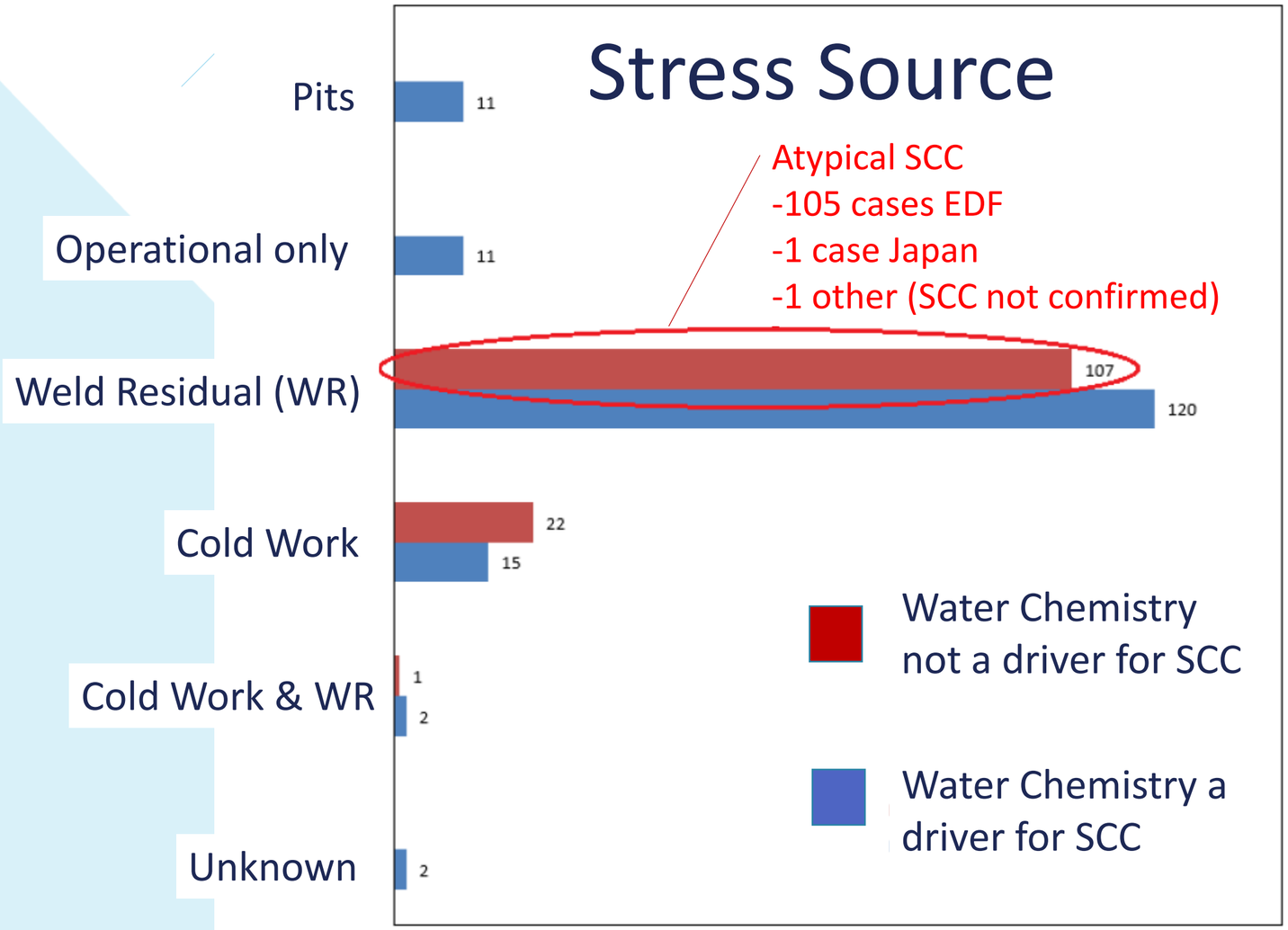
EPRI White Paper (MRP Letter 2022-018)

- Developed by experts in the field of SCC in LWRs
- Conclusions:
  - The most important factors that accelerate SCC to higher levels than expected in PWR primary water are residual deformation (from cold work or welding), stress (from welding, pressurization, fit up, etc.) and environment (oxidants and contaminants in creviced areas)
  - There is a newly developed empirically-based SCC CGR equation (MRP-458)
  - SCC in stainless steel components exposed to flowing PWR primary water will continue to occur, but there is no evidence of aging that accelerates SCC in wrought stainless steels, and no sudden increase in SCC initiation and growth is expected after decades of operation

Revision to MRP-236R1 (1/2)

- MRP-236 contains information concerning SCC of primary circuit pressure boundary stainless steel, including an OE database
- Last revision was completed in 2017, which found no cases of SCC in the non-isolable portions of branch piping
- New revision (in progress) is reviewing OE since 2017
  - Only confirmed cases of SCC in non-isolable portions of branch piping have occurred in the EDF fleet and one case at a Japanese unit
  - Revision will also include a review of the thermal fatigue OE database (MRP-85R2/MRP-468) for cases that have the potential to be EDF-like SCC
    - Focused on flaws with large aspect ratios and where a destructive exam to confirm mechanism was not performed
      - Three units have presumed thermal fatigue with these characteristics

Revision to MRP-236R1 (2/2)



EDF/Japan OE is atypical because

- given well-controlled water chemistry, WRS alone is sufficient for SCC
- Located in non-isolable portion of branch piping
  - Previous OE indicated that only thermal fatigue occurred in this piping (MRP-85R2/MRP-468), which is addressed by an inspection program (MRP-146R2)

Roadmap

	2020	2021	2022	2023	2024
Utilities	Provide Research Guidance				
				ASME Code Guidance for CGR	
EPRI			SCC White Paper		
		PWR SCC SS CGR (MRP-458)			
			WRC Type 316LN Strain-Hardening Research		
			Revision to MRP-236-R1: Press. Bound. SS SCC OE		
PWROG			Industry Inspection Survey		
			Safety Assessment		
				Applicability Assessment	
ASME				CGR Curves	
NRC				Endorse CGR Curves	
			Safety Assessment		

Questions?