

PWROG

PWR Owners Group



Global Expertise • One Voice

Tyler Whaley (MSC Chair) – Auxiliary Piping Stress Corrosion Cracking Operating Experience Focus Group and Industry Coordination – Presentation #14



Agenda

- **EDF SS SCC and Thermal Fatigue OE Update**
- **Auxiliary Piping SCC OE Focus Group Update**



EDF SS SCC and Thermal Fatigue OE Update

ASN Feedback on EDF OE at 2/21/24 NRC Public Meeting^(1/5)

- ASN, the French regulator, provided several observations on the EDF OE and actions taken and planned (ML24051A082)
 - Overall summary
 - Cracks located in the thermally affected areas (heat affected zones) of the welds on stainless steel pipes, in the non-isolable part of the main primary circuit (to the first isolation valve)
 - Affected systems: safety injection system and reactor heat removal system
 - Affected piping: 10 to 12 inches piping, piping wall ~1inch thick, 304L and 316L
 - 972 weld inspections conducted since 2021 (mainly using advanced UT methods)
 - 54 cracks with depth greater than 2mm found, however most cracks were below 6mm in depth (25% of pipe thickness)
 - The exception to this is in welds repaired at construction, where flaws \geq 6mm up to 23mm deep were found

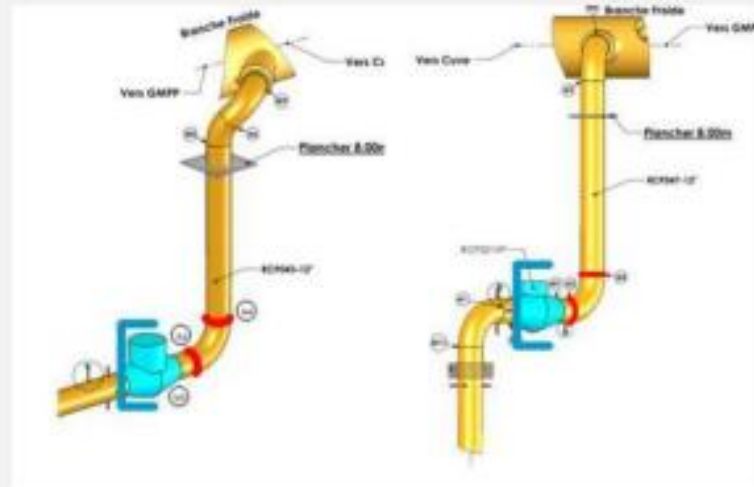
ASN Feedback on EDF OE at 2/21/24 NRC Public Meeting^(2/5)

- Susceptibility Factors – Thermal Stratification

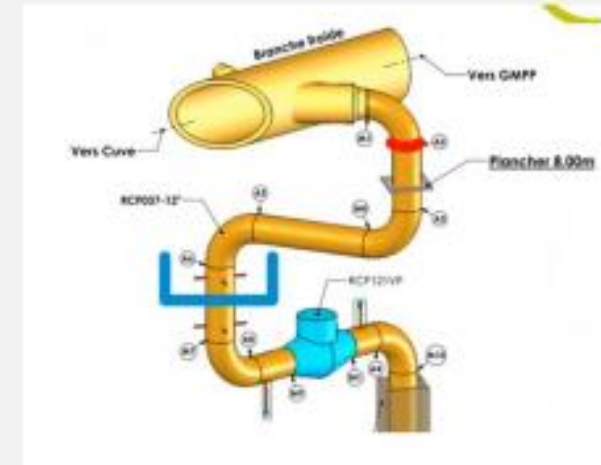
- Some specific designs of auxiliary piping appear to be more susceptible to SCC than others, i.e. N4 > P'4 > P4 > CPO/CPY

- These lines are subject to thermal stratification

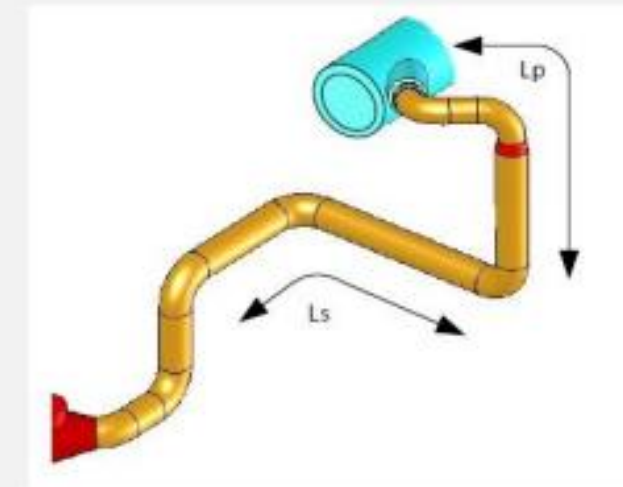
- However, there are other susceptibility factors; some cracks were found on pipes that are not susceptible to thermal stratification (typically, lines that are short in length that are entirely at the main coolant line temperature). These cracks were mostly detected on welds repaired at the manufacturing, but there are some occurrences concerning welds that were not repaired.



Low risk of stratification (?)



Limited risk of stratification (?)



High risk of stratification

- Knowledge of the thermohydraulic effects within these lines still not precise enough according to ASN – assessment to be confirmed

- **Susceptibility Factors – Weld Repairs**
 - There is undeniable evidence that some weld repairs are increasing the risk of SCC initiation and propagation
 - However, a lot of repaired welds have also been inspected and show no sign of SCC
 - The type of repairs that are presenting a risk is still under investigation (extension and depth of the area that is repaired is probably a factor)

- **Susceptibility Factors – Environmental Factors (temperature and chemistry)**
 - Laboratory tests and international experience show that high temperature and high oxygen content increase the risk of SCC
 - The role of oxygen and temperature in the development of cracks in France is not completely understood yet
 - Investigations conducted since 2021 show that the temperature distribution within auxiliary lines is not well known (and subject to variation between plants with the same design), and there are questions raised by some experts regarding the oxygen concentration in areas with no regular water circulation



ASN Feedback on EDF OE at 2/21/24 NRC Public Meeting^(4/5)

- EDF Inspection Program; 2023 – 2025
 - ALL reactors, SI and RHR piping non-isolable from the main primary circuit
 - All welds repaired during the construction on these systems
 - Due to higher risk of developing deep SCC
 - Other welds – inspect a sample
 - Higher sampling rate on lines considered susceptible to SCC according to current understanding
 - Minimal sampling rate on other lines to confirm understanding
 - 300 welds still to be inspected under this program
 - Some instrumentation programs about the temperature distribution, and a closer monitoring of oxygen levels in main coolant lines, has also been requested by the ASN



ASN Feedback on EDF OE at 2/21/24 NRC Public Meeting^(5/5)

- Additional 2024-2026 examination program on other auxiliary piping systems
 - ASN now considers that the risk of SCC on 304L/316L welds under nominal PWR conditions cannot be entirely excluded
 - Preliminary investigations, conducted on the pressurizer surge line and some parts of the main coolant lines: no SCC detected
 - Inspections on some components of the main coolant lines replaced after 40 years of operation
 - Advanced UT inspections on welds of the pressurizer surge line and other stainless steel lines below 8 inches in diameter, targeting a sample of welds

Recent Operating Experience

- Recently reported findings of cracking at the following EDF plants in late 2023 into 2024
 - Blayais 2 (CP1, 3-Loop 910 MW plant)
 - 2 indications 5mm deep have been reported in the “Primary Circuit”
 - Thermal fatigue is reported cause of cracking
 - Blayais 4 (CP1, 3-Loop 910 MW plant)
 - 2 indications 5mm deep have been reported in the news, one in Safety Injection system, one in Auxiliary Cooling Circuit
 - *EDF confirmed discovering an SCC flaw on a RHR pipe. The depth measure was around 4 mm and has been confirmed by lab analysis.*
 - Paluel 2 (P4, 4-loop 1300 MW plant)
 - Limited details other than the indication was found in a weld repair



Auxiliary Piping SCC OE Focus Group Update



Purpose of the Auxiliary Piping SCC OE Focus Group

- Coordinates efforts between the PWR Owners Group and EPRI-MRP in evaluating this OE
- 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

Auxiliary Piping SCC OE Focus Group Roadmap

	2021	2022	2023	2024	2025
Utilities	Provide Research Guidance				
				ASME Code Guidance for CGR	
EPRI		SCC White Paper	Complete (MRP 2022-018)		
	PWR SS SCC CGR (MRP-458)		Complete		
		WRTC Type 316LN Strain-Hardening Research			In progress
		MRP-236-R2 Pressure Boundary SS SCC OE			In progress
PWROG		Industry Inspection Survey		Complete (however additional data being collected)	
		Safety Assessment PWROG-23007-NP		Complete	
			Applicability Assessment		In progress (PWROG-24002)
ASME			CGR Curves, RI-ISI Review - In progress		
NRC					Endorse CGR Curves
		Safety Assessment (ML23236A079)			



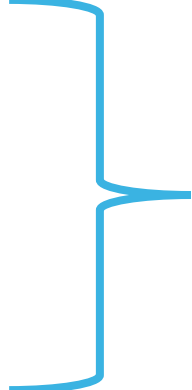
Status of PWROG Program Tasks^(1/3)

- Task 1: Focus Group
 - Meetings
 - Presentation at NRC Public Meeting 2/21/2024
 - Virtual Focus Group meetings 3/21/2024
 - In person 5/8/2024
 - Ongoing into 2025
- Task 2 Part 1: Safety Assessment (PWROG-23007-NP)
 - Completed April 2023
 - Transmitted to NRC for information May 2023
 - PWROG letter OG-23-82 issued; defines the NEI 03-08 Needed Guidance regarding IGSCC specific examination methods

Status of PWROG Program Tasks^(2/3)

- Task 2 Part 2: Applicability Assessment (PWROG-24002)
 - Expert Panel meeting regarding welding/WRS held 7/12/2023, 12/13/2023
 - Tasks 4 (PWROG-23036-P) and 5 (PWROG-23040-P) (completed – inputs to Applicability Assessment)
 - Draft report (Rev 0.A) June 2024 (delayed due to EDF OE requests)

Status of PWROG Program Tasks^(3/3)

- Task 3: Data Collection
 - Data incorporated into Safety Assessment (Task 2 Part 1), Complete
 - Task 4: B&W Core Flood Line Sample Case
 - Final report published and transmitted (PWROG-23036-P)
 - Task 5: WEC SI Line Sample Case
 - Final report published and transmitted (PWROG-23040-P)
 - PWROG-24011-P, “Applicability of Stress Corrosion Cracking of Stainless Steel Observed in EDF Plants to other Designs,” issued
 - Reviewed vintage US plant material hardness and sulfur content to compare to EDF OE
 - Estimated 30x to >200x slower SCCGR for vintage US SS pipe (due to effects of lower hardness and higher sulfur content)
 - Assumes same stress level (material difference only)
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- Tasks 4 and 5 support the Applicability Assessment (Task 2 Part 2)

Summary of Activities Since the Last Meeting^(1/4)

EPRI • IGSCC Survey Results up until April 25, 2024

- No indications reported to date

Line type		Spring 2023		Fall 2023		Spring 2024				Fall 2024			
		Completed	Plant	Completed	Plant	Scheduled	Plant	Completed	Plant	Scheduled	Plant	Completed	Plant
Safety Injection	Accumulator (10" Sch 140)			4	W4					2	W4		
	Accumulator (12")					1	W3						
	Safety Injection (6")					2	W4	2	W3				
	Core Flood (14")					1	B&W	2	B&W				
RHR	RHR (12" Sch 140)							1	W4	1	W4		
	RHR (12" Sch 140)									2	W4		
	Decay heat removal (12" Sch 140)			2	B&W	2	B&W	2	B&W				
	RHR - (14")			2	W4			1	W3				
Spray	PZR spray									6	W4		
	PZR Spray (4" Sch 160)			2	W4			4	W4				
	PZR Spray (4" Sch 160)					2	W3	1	B&W				
		25	International W3 (inspections of ASIS, SI, RHR, EBS systems)					38	International W2				
						20	International W3			30	International W3		
	Welds (TBD)					3	W4			TBD	CE		

Summary of Activities Since the Last Meeting^(2/4)

- Focus group discussion held 3/21/24. Topics included:
 - Future Inspections
 - Focus Group currently plans to continue the examinations for at least the next 5 to 10 years
 - Identification of flaw type
 - How to ascertain if an indication is a thermal fatigue crack vs IGSCC (if the flaw depth is small <10-20% of the wall thickness)
 - If IGSCC flaw is identified, then:
 - Extent of conditions (other welds), i.e. scope expansion?
 - Develop standard template for data submission and tracking

Summary of Activities Since the Last Meeting^(3/4)

- Focus group discussion held 5/8/24. Topics included:
 - Recent EDF OE
 - Blayais Units 2 and 4, Paluel 2
 - Interim Guidance
 - NEI 03-08 “Needed” Guidance (Issued April 2023)
 - FAQs raised by sites
 - Clarification being developed and will be shared with sites Q3 2024

Summary of Activities Since the Last Meeting^(4/4)

- Literature search
 - Literature search and report on AISI 316LN published in Framatome – will be incorporated into Applicability Assessment
- EPRI Projects Status
 - MRP-236, Revision 2 is in progress
 - Draft is prepared and is currently being reviewed within Framatome
 - WRTC Gleeble testing and mockups
 - Test fixture issue has been resolved and 7 simulations have been performed-hardness mapping in progress
 - Chiller response time issue found which may affect test results
- Reached out to EDF numerous occasions for status update considering observations of SCC on the “non-susceptible” lines
- Krsko observation of leakage from 4” type 304 SI line
 - Not SCC; Trans-granular with fatigue striations in some areas

Next Actions

- Continue focus group meetings and activities into 2025
- Support other meetings as needed; NRC Tech Exchange (June 2024)
- Continue to obtain and consider EdF OE, where possible and as applicable
- Continue to monitor and collect inspection OE from domestic and international utilities
- Issue draft Applicability Assessment (Rev 0.A) for member review (June 2024)
- Issue draft MRP-236 Revision 2 for member review 3rd quarter 2024

Questions?

The Materials Committee is established to provide a forum for the identification and resolution of materials issues including their development, modification and implementation to enhance the safe, efficient operation of PWR plants.