Use of the xLPR Code for Developing LOCA Frequency Estimates

Overview and Key Analysis Results

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Outline

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- Summary of xLPR analysis cases
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  - Time between detectable leakage and rupture
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- Schedule

List of Acronyms

CE	Combustion Engineering
CL	Cold leg
COD	Crack opening displacement
DMW	Dissimilar metal weld
DN	Diametre nominal
FEA	Finite element analysis
FFRD	Fuel fragmentation, relocation and dispersal
HL	Hot leg
ID	Inner diameter
ISI	In-service inspection
LBB	Leak-before-break
LRD	Leak rate detection
LOCA	Loss-of-coolant accident
MSIP	Mechanical stress improvement process
NPS	Nominal pipe size
NRC TLR	US Nuclear Regulatory Commission Technical Letter Report
OD	Outer diameter
PWSCC	Primary water stress corrosion cracking
PZR	Pressurizer
RCP	Reactor coolant pump
RHR	Residual heat removal
RVIN	Reactor vessel inlet nozzle
RVON	Reactor vessel outlet nozzle
SGIN	Steam generator inlet nozzle
SGON	Steam generator outlet nozzle
SRP	Standard review plan
SSE	Safe shutdown earthquake
SQA	Software quality assurance
TIFFANY	Thermal Stress Intensity Factors for Any Coolant History
TW	Through-wall
TWC	Through-wall crack
WRS	Weld residual stress
xLPR	Extremely Low Probability of Rupture

Background and Scope

Background

- NUREG-1829, Vol. 1 estimates Loss-of-Coolant Accident (LOCA) frequencies
  - Evaluated the technical adequacy of redefining the design-basis break size (largest pipe break to which 10 CFR 50.46 applies) to a smaller size
  - Estimated LOCA frequencies through an expert elicitation process
- As part of research into an alternative fuel licensing strategy for fuel fragmentation, relocation, and dispersal (FFRD), it was suggested to apply xLPR to:
  - Evaluate probability of LOCAs as a function of line size
  - Validate NUREG-1829 frequency estimates for use in high burnup fuel licensing
    - Demonstrating LOCAs/ruptures are sufficiently low frequency
  - Evaluate if leakage would be detected in sufficient time prior to piping rupture
    - Demonstrating further defense in depth

Scope

- NUREG-1829 gives estimates of LOCA frequencies based on expert elicitation (Table 1)
- The expert elicitation considered LOCA-sensitive piping systems and associated degradation mechanisms (Table 3.5)
- The goal of the current study is to analyze:
  - Rupture probability and time between detectable leakage and rupture
  - Over the range of piping systems and line sizes from NUREG-1829
  - Initial focus on piping welds > NPS 6 (> DN 150)
  - Later refocus on piping welds > NPS 14 (> DN 350) in support of alternative licensing strategy (ALS) for FFRD
- xLPR analysis work:
  - Considered previous xLPR analysis cases where possible
  - Supplemented with additional xLPR analysis cases as needed

Table 1 Total BWR and PWR LOCA Frequencies (After Overconfidence Adjustment using Error-Factor Scheme)

Plant Type	LOCA Size (gpm)	Eff. Break Size (inch)	Current-day Estimate (per cal. yr) (25 yr fleet average operation)				End-of-Plant-License Estimate (per cal. yr) (40 yr fleet average operation)			
			5th Per.	Median	Mean	95th Per.	5th Per.	Median	Mean	95th Per.
BWR	>100	½	3.3E-05	3.0E-04	6.5E-04	2.3E-03	2.8E-05	2.6E-04	6.2E-04	2.2E-03
	>1,500	1 7/8	3.0E-06	5.0E-05	1.3E-04	4.8E-04	2.5E-06	4.5E-05	1.2E-04	4.8E-04
	>5,000	3 ¼	6.0E-07	9.7E-06	2.9E-05	1.1E-04	5.4E-07	9.8E-06	3.2E-05	1.3E-04
	>25K	7	8.6E-08	2.2E-06	7.3E-06	2.9E-05	7.8E-08	2.3E-06	9.4E-06	3.7E-05
	>100K	18	7.7E-09	2.9E-07	1.5E-06	5.9E-06	6.8E-09	3.1E-07	2.1E-06	7.9E-06
	>500K	41	6.3E-12	2.9E-10	6.3E-09	1.8E-08	7.5E-12	4.0E-10	1.0E-08	2.8E-08
PWR	>100	½	6.9E-04	3.9E-03	7.3E-03	2.3E-02	4.0E-04	2.6E-03	5.2E-03	1.8E-02
	>1,500	1 5/8	7.6E-06	1.4E-04	6.4E-04	2.4E-03	8.3E-06	1.6E-04	7.8E-04	2.9E-03
	>5,000	3	2.1E-07	3.4E-06	1.6E-05	6.1E-05	4.8E-07	7.6E-06	3.6E-05	1.4E-04
	>25K	7	1.4E-08	3.1E-07	1.6E-06	6.1E-06	2.8E-08	6.6E-07	3.6E-06	1.4E-05
	>100K	14	4.1E-10	1.2E-08	2.0E-07	5.8E-07	1.0E-09	2.8E-08	4.8E-07	1.4E-06
	>500K	31	3.5E-11	1.2E-09	2.9E-08	8.1E-08	8.7E-11	2.9E-09	7.5E-08	2.1E-07

Table 3.5 PWR LOCA-Sensitive Piping Systems

System	Piping Matls.	Piping Size (in)	Safe End Matls.	Welds	Sig. Degrad. Mechs.	Sig. Loads.	Mitigation/ Maint.
RCP: Hot Leg	304 SS, 316 SS, C-SS, SSC-CS CS – SW	30 - 44	A600, 304 SS, 316 SS, CS	A82 304 SS, 316 SS, CS	TF, SCC, MA, FDR, UA	P, S, T, RS, DW, O, SUP	ISI w TSL, REM
RCP: Cold Leg/Crossover Leg	304 SS, 316 SS, C- SS, SSC-CS, CS – SW	22 - 34	A600, 304 SS, 316 SS, CS	A82 304 SS, 316 SS, CS	TF, SCC, MA, FDR, UA	P, S, T, RS, DW, O, SUP	ISI w TSL, REM
Surge line	304 SS, 316 SS, C-SS	10 - 14	A600, 304 SS, 316 SS,	A82 304 SS, 316 SS	TF, SCC, MA, FDR, UA	P, S, T, RS, DW, O, TFL, TS	TSMIT, ISI w TSL, REM
SIS: ACCUM	304 SS, 316 SS, C-SS	10 - 12	A600, 304 SS, 316 SS,	A82 304 SS, 316 SS	TF, SCC, MA, FS, FDR, UA (FAC)	P, S, T, RS, DW, O	ISI w TSL, REM
SIS: DVI	304 SS, 316 SS	2 – 6	A600, 304 SS, 316 SS,	A82 304 SS, 316 SS	TF, SCC, MA, FS, FDR, UA (FAC)	P, S, T, RS, DW, O	ISI w TSL, REM
Drain line	304 SS, 316 SS, CS	< 2"			MF, TF, GC, LC, FDR, UA	P, S, T, RS, DW, O, V, TFL	ISI w TSL, REM
CVCS	304 SS, 316 SS	2 – 8	A600 (B&W and CE)	A82	SCC, TF, MF, FDR, UA	P, S, T, RS, DW, O, V	ISI w TSL, REM
RHR	304 SS, 316 SS	6 – 12			SCC, TF, MA, FDR, UA	P, S, T, RS, DW, O, TFL	ISI w TSL, REM
SRV lines	304 SS, 316 SS	1 – 6			TF, SCC, MF, FDR, UA	P, S, T, RS, DW, O, SRV	ISI w TSL, REM
PSL	304 SS, 316 SS	3 – 6		A82	TF, SCC, MA, FDR, UA	P, S, T, RS, DW, O, WH, TS	ISI w TSL, REM
CRDM	A600	4 – 6			SCC, TF, MF, LC, FDR, UA	P, S, T, RS, DW, O	HREPL, ISI w TSL, REM
RH	304 SS, 316 SS	< 2	A600		MF, SCC, TF, FDR, UA	P, S, T, RS, DW, O, V, TS	ISI w TSL, REM
ICI	304 SS, 316 SS	< 2	A600		MF, SCC, TF, FW, FDR, UA	P, S, T, RS, DW, O, V	ISI w TSL, REM
INST	304 SS, 316 SS	< 2			MF, SCC, TF, FDR, UA	P, S, T, RS, DW, O, V	ISI w TSL, REM

Summary of xLPR Analysis Cases

Previous xLPR Studies

- xLPR analyses have recently been published by the US NRC in the context of LBB analyses for A82/182 dissimilar metal butt welds in PWR piping systems:
  - **TLR-RES/DE/REB-2021-09 (ML21217A088)**
    - Referred to herein as “xLPR piping system analysis”
    - Documented xLPR analysis of representative reactor vessel outlet and inlet nozzle welds in a Westinghouse four-loop PWR
    - Includes extensive set of sensitivity studies
  - **TLR-RES/DE/REB-2021-14 R1 (ML22088A006)**
    - Referred to herein as “xLPR generalization study”
    - Documented xLPR analysis of other piping systems containing Alloy 82/182 dissimilar metal piping butt welds which had received prior LBB approvals from the NRC staff
    - Includes reduced set of sensitivity studies per analyzed component, as informed by “xLPR piping system analysis”

Additional xLPR Analysis Cases

- Previous xLPR studies were supplemented with additional analysis cases
  - Safety Injection System
  - Residual Heat Removal System
- Focus of welds selected for evaluation:
  - If an Alloy 82/182 weld is present in a line, that Alloy 82/182 location was modeled
    - Considered limiting based on PWSCC OE
  - If no Alloy 82/182 welds were present, modeled a genericized representative weld within the portion of the line exposed to reactor coolant system normal operating conditions (pressure, temperature)
- General results provided will consider full range of cases analyzed using xLPR
  - However, presentation will focus discussion on cases relevant to the ALS (i.e., main loop piping DMWs)

Focus of ALS; > NPS 14 (> DN 350)

Table 3.5 PWR LOCA-Sensitive Piping Systems

System	Piping Matls.	Piping Size (in)	Safe End Matls.	Welds	Sig. Degrad. Mechs.	Sig. Loads.	Mitigation/ Maint.
RCP: Hot Leg	304 SS, 316 SS, C-SS, SSC-CS CS – SW	30 - 44	A600, 304 SS, 316 SS, CS	A82 304 SS, 316 SS, CS	TF, SCC, MA, FDR, UA	P, S, T, RS, DW, O, SUP	ISI w TSL, REM
RCP: Cold Leg/Crossover Leg	304 SS, 316 SS, C- SS, SSC-CS, CS – SW	22 - 34	A600, 304 SS, 316 SS, CS	A82 304 SS, 316 SS, CS	TF, SCC, MA, FDR, UA	P, S, T, RS, DW, O, SUP	ISI w TSL, REM
Surge line	304 SS, 316 SS, C-SS	10 - 14	[illegible] 304 SS, 316 SS,	[illegible] 304 SS, 316 SS	[illegible] MA, FDR, UA	P, S, T, RS, DW, O, TFL, TS	TSMIT, ISI w TSL, REM
SIS: ACCUM	304 SS, 316 SS, C-SS	10 - 12	A600, 304 SS, 316 SS,	A82 304 SS, 316 SS	TF, SCC, MA, FS, FDR, UA (FAC)	P, S, T, RS, DW, O	ISI w TSL, REM
SIS: DVI	304 SS, 316 SS	2 – 6	A600, 304 SS, 316 SS,	A82 304 SS, 316 SS	TF, SCC, MA, FS, FDR, UA (FAC)	P, S, T, RS, DW, O	ISI w TSL, REM
Drain line	304 SS, 316 SS, CS	< 2"			MF, TF, GC, LC, FDR, UA	P, S, T, RS, DW, O, V, TFL	ISI w TSL, REM
CVCS	304 SS, 316 SS	2 – 8	A600 (B&W and CE)	A82	SCC, TF, MF, FDR, UA	P, S, T, RS, DW, O, V	ISI w TSL, REM
RHR	304 SS, 316 SS	6 – 12			SCC, TF, MA, FDR, UA	P, S, T, RS, DW, O, TFL	ISI w TSL, REM
SRV lines	304 SS, 316 SS	1 – 6			TF, SCC, MF, FDR, UA	P, S, T, RS, DW, O, SRV	ISI w TSL, REM
PSL	304 SS, 316 SS	3 – 6		A82	TF, SCC, MA, FDR, UA	P, S, T, RS, DW, O, WH, TS	ISI w TSL, REM
CRDM	A600	4 – 6			SCC, TF, MF, LC, FDR, UA	P, S, T, RS, DW, O	HREPL, ISI w TSL, REM
RH	304 SS, 316 SS	< 2	A600		MF, SCC, TF, FDR, UA	P, S, T, RS, DW, O, V, TS	ISI w TSL, REM
ICI	304 SS, 316 SS	< 2	A600		MF, SCC, TF, FW, FDR, UA	P, S, T, RS, DW, O, V	ISI w TSL, REM
INST	304 SS, 316 SS	< 2			MF, SCC, TF, FDR, UA	P, S, T, RS, DW, O, V	ISI w TSL, REM

Analyzed using xLPR (RCP: Hot Leg, RCP: Cold Leg/Crossover Leg, Surge line, SIS: ACCUM, SIS: DVI)

Analyzed using xLPR (RHR)

Summary of Base Cases

Study	Piping System Analysis		Generalization Study				New Analyses	
NUREG-1829 Line/System	Reactor Coolant Piping: Hot Leg	Reactor Coolant Piping: Cold Leg/Crossover Leg	Reactor Coolant Piping: Hot Leg	Reactor Coolant Piping: Cold Leg	Surge Line	Safety Injection (Accumulator)	Safety Injection (Accumulator)	Residual Heat Removal
Weld Analyzed	RVON	RVIN	RVON, SGIN	RCP Inlet/Outlet, SGON	PZR Surge, CE Hot Leg Branch Line DMW	CE Cold Leg Branch Line DMW	CE safety Injection/ Accumulator DMW	Genericized RHR Piping System Weld
Fatigue Crack Growth	No	No	No	No	No	No	No	Yes
PWSCC Crack Growth	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Initial Flaws	No	No	No	No	No	No	Yes	Yes
Axial/Circ Flaws	Circ	Circ	Both	Both	Both	Both	Both	Both
Seismic Occurrences	No	No	No	No	No	No	Yes	Yes
Mitigation	No	No	No (RVON); Yes (SGIN)	No	No	No	No	No
ISI/LRD	Optional in outputs	Optional in outputs	Optional in outputs	Optional in outputs	Optional in outputs	Optional in outputs	Optional in outputs	Optional in outputs

Focus of ALS

Summary of Sensitivity Cases

Legend	
■	Sensitivity case included

Study	Piping System Analysis		Generalization Study				New Analyses	
NUREG-1829 Line/System	Reactor Coolant Piping: Hot Leg	Reactor Coolant Piping: Cold Leg/Crossover Leg	Reactor Coolant Piping: Hot Leg	Reactor Coolant Piping: Cold Leg	Surge Line	Safety Injection (Accumulator)	Safety Injection (Accumulator)	Residual Heat Removal
Weld Analyzed	RVON	RVIN	RVON, SGIN	RCP Inlet/Outlet, SGON	PZR Surge, CE HL Branch Line DMW	CE CL Branch Line DMW	CE Safety Injection/ Accumulator DMW	Genericized RHR Piping System Weld
Initiation	■		■	■	■	■	■	■
WRS	■		■	■	■		■	■
Earthquake	■						■	
Normal Operating Thermal Loads	■						■	■
LRD/ISI	■							
Mitigation	■		■	■	■		■	
Fatigue	■	■			■		■	
Initial Flaw Size	■							■
Multiple Initial Flaws								■
Geometry	■							■
Other	axial cracks, hydrogen, temperature						WRS & initiation combined	Transients

Focus of ALS

Output Quantities of Interest

- Results Directly Output by xLPR
  - Probability of rupture
    - Used to calculate rupture frequencies
    - Option of conservatively not crediting in-service inspection (ISI) or leak rate detection (LRD)
    - Results utilizing initial flaw of engineering scale are conditional on crack initiation
  - Probability of crack initiation
  - Leak rate
- Post-Processed Results
  - Time between 1 gpm detectable leakage and rupture ("lapse time")
  - P(Rupture|Initiation) ≈ P(Rupture|Initial Flaw) × P(Initiation)
    - Approach for combining xLPR analyses with decoupled crack initiation and growth to work within xLPR memory limitations
    - Approach benchmarked versus direct calculation of probability of rupture
      - Decoupled approach within a factor of 2 of direct calculation
  - Average 80-year rupture (LOCA) frequency = P(Rupture) / 80 yrs

LOCA Frequency Compared to NUREG-1829

LOCA Frequency Compared to NUREG-1829 Table 1

Overview

- NUREG-1829 LOCA frequencies used for comparison are:
  - From Table 1
    - Median, 5th percentile, and 95th percentile
    - Total PWR LOCA frequencies after overconfidence adjustment using error-factor scheme
    - 40 yr fleet average values
    - Consider typical ISI with LRD resolution as required by tech spec limits
  - Results are presented on a per plant basis, for each distinct LOCA category
  - Consider piping and non-piping passive system contributions
    - For PWRs, ratio of non-piping to piping contribution for 7, 14, and 31 in. lines ranges from 0.5 to 1.4 *[Table 7.2, Figure 7.7 of NUREG-1829]*
      - Due to similarity in piping and non-piping contributions, NUREG-1829 Table 1 results are selected for comparison

Confidence Interval when no Failures are Observed

95% Upper Bound on Probability of Failure

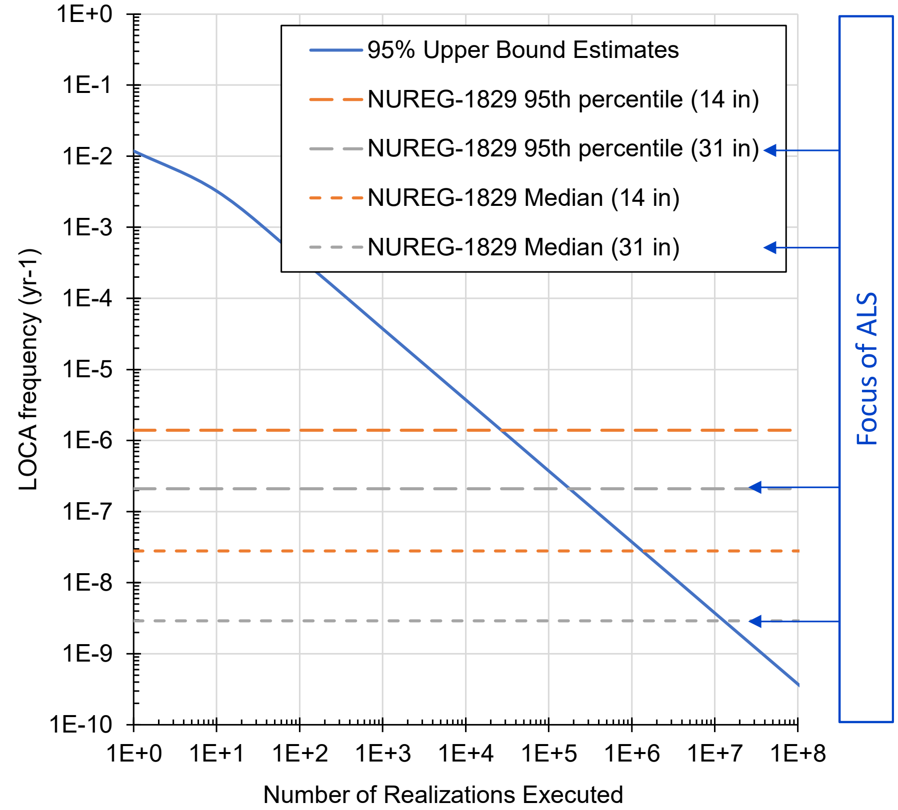
- NUREG/CR-7278, Section 4.3.6.4 states that:
  - "If [no] failures are observed in *n* realizations, then we can use the fact that [the number of failures] follows a binomial distribution to place a one-sided confidence interval on the probability of failure"
- The table below shows how the 95% upper bound one-sided confidence interval (estimated using a binomial distribution) is calculated for an average 80-year LOCA frequency
  - Different approaches for cases modeling crack initiation vs cases modeling initial flaws

Are Failures Observed?	If the case models…	Then the 95% upper bound, given n realizations run, is equal to
No	Crack Initiation	$(1 - 0.05^{1/n})/80$
	Initial Flaws	$P(crack) \times \left(1 - 0.05^{1/n}\right)/80$ where $P(crack)$ is based on an associated case modeling initiation
Yes	Not Applicable	

LOCA Frequency Compared to NUREG-1829 Table 1

95% Upper Bound Estimates Equal To NUREG-1829 LOCA Frequencies

- For cases with ruptures (occurrence of rupture ≠ 0) but no ruptures with LRD (occurrence of rupture w/ LRD = 0) ("zero" results), data are plotted with a 95% upper bound one-sided confidence interval
  - Accounts for probability of initiation
  - Considers number of realizations executed
  - Conveys level of confidence in "zero" results
- Executing this number of realizations for each case in xLPR is impractical, particularly for the larger line sizes

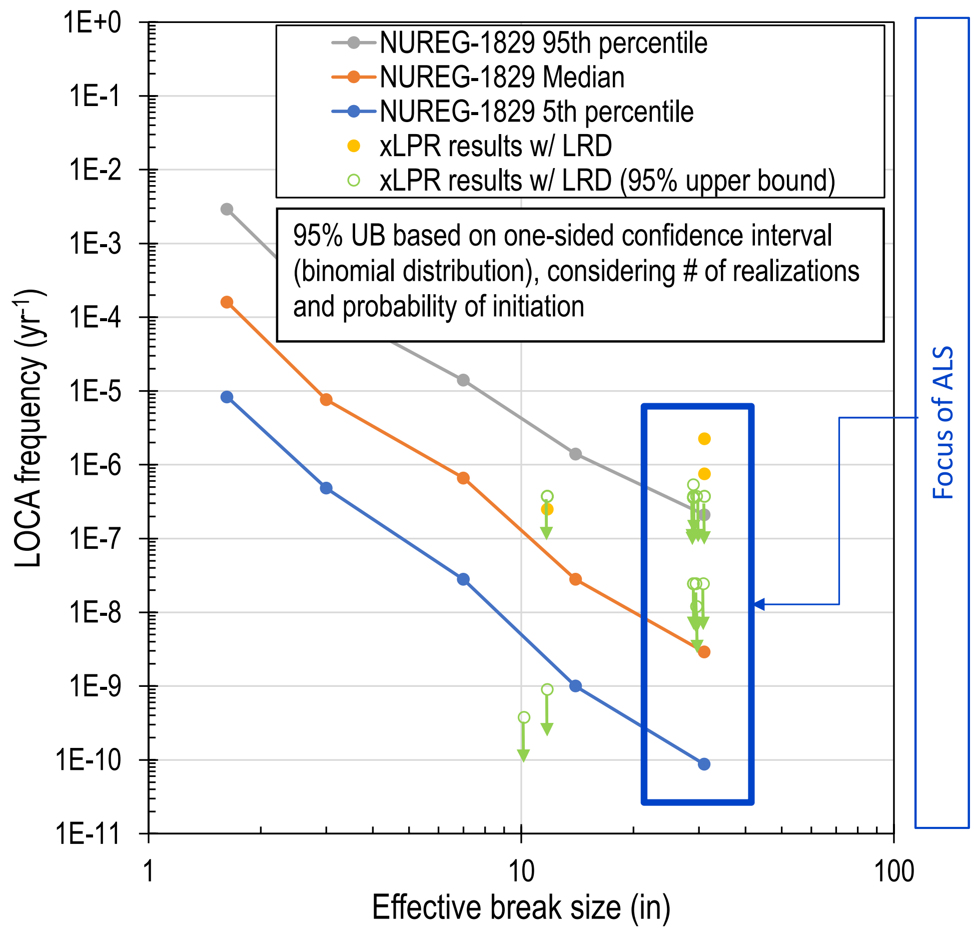


Number of realizations required to obtain 95% upper bound equal to NUREG-1829 LOCA frequency estimates

LOCA Frequency Compared to NUREG-1829 Table 1

Crediting LRD, Without Crediting ISI

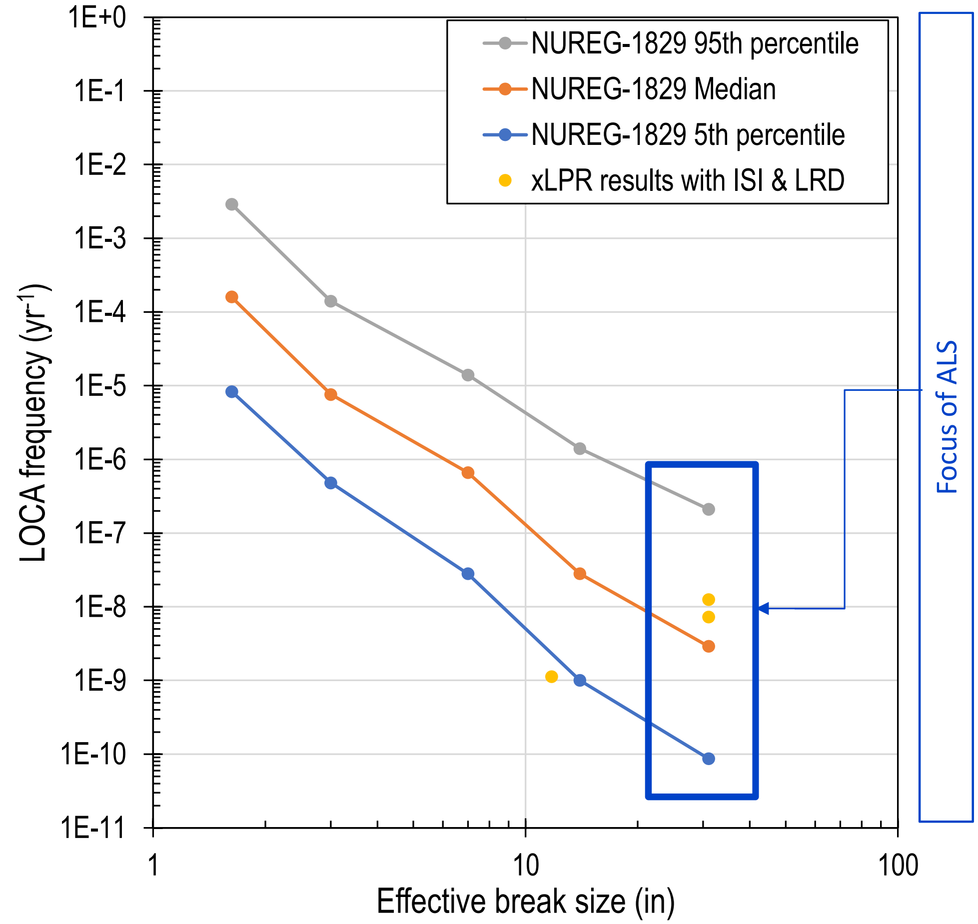
- NUREG-1829 compared with xLPR estimated LOCA Frequencies crediting 1 gpm LRD but not ISI
  - Calculated based on "occurrence of rupture with LRD" at 80 years
- Occurrence of rupture with LRD is 0 for most xLPR cases considered
  - Nonzero occurrence of rupture with LRD is shown explicitly
- Ruptures with LRD are due to modeling that is not representative of plant conditions and operations
  - (e.g., overlay application caused rupture, initial flaw deeper than inlay depth)
  - All such cases are sensitivity cases
  - These cases, as relevant to the ALS, are further investigated later in this presentation



LOCA Frequency Compared to NUREG-1829 Table 1

Crediting ISI and LRD

- NUREG-1829 compared with xLPR estimated LOCA Frequencies crediting ISI and 1 gpm LRD
  - Calculated based on "occurrence of rupture with ISI and LRD" at 80 years
- Occurrence of rupture with ISI and LRD is 0 for most xLPR cases considered
  - Nonzero occurrence of rupture with ISI and LRD is shown explicitly
- Ruptures with ISI and LRD are due to modeling that is not representative of plant conditions and operations
  - (e.g., overlay application caused rupture, initial flaw deeper than inlay depth)
  - All such cases are sensitivity cases
  - These cases, as relevant to the ALS, are further investigated later in this presentation



When considering ISI and LRD, LOCA frequencies estimated from xLPR are on a similar order of magnitude as median NUREG-1829 LOCA frequency estimates

LOCA Frequency Compared to NUREG-1829 Table 1

Executing Additional Realizations

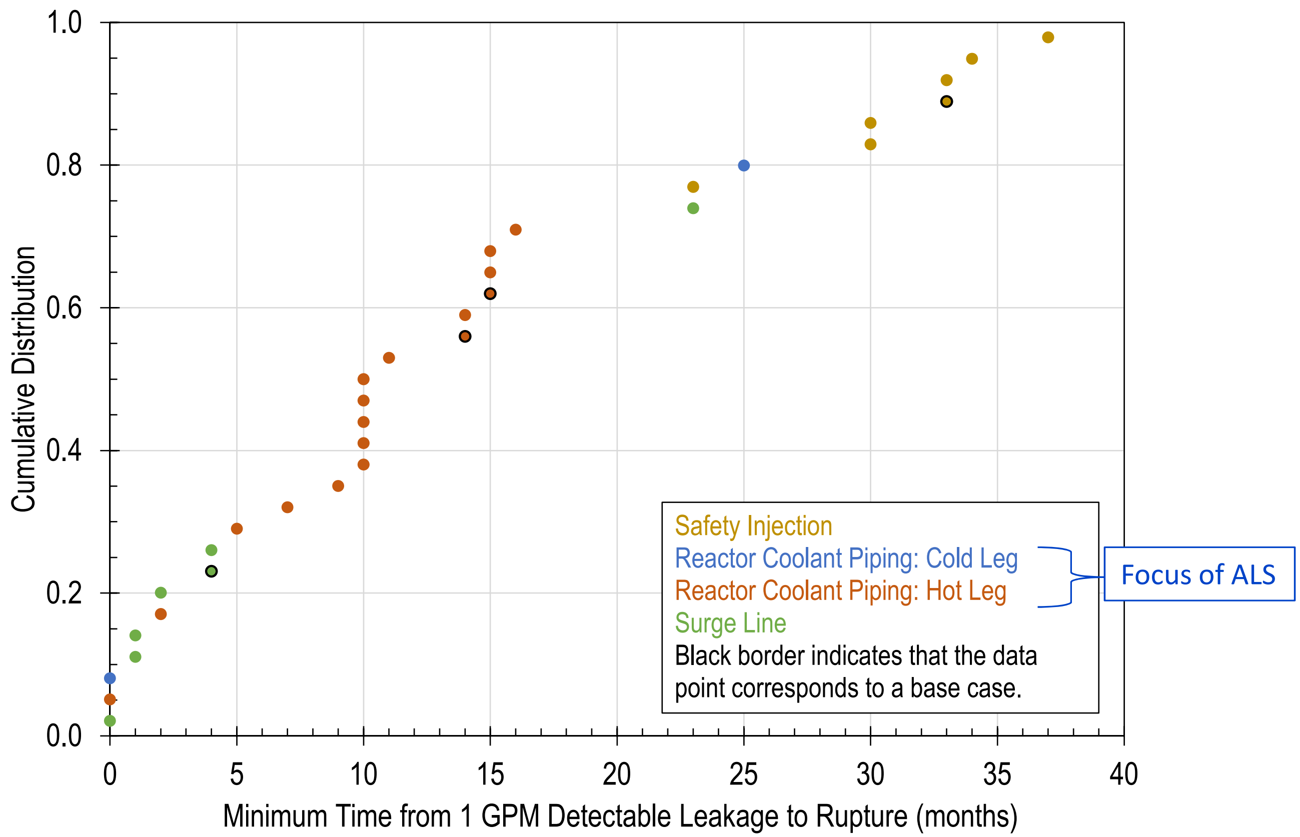
- One case was re-run with 1 million realizations
  - Case 1.1.6 from xLPR Piping System Analysis – RVON DMW with circumferential and axial flaws
- Key observations:
  - It is possible (but impractical) to execute a larger number of realizations in xLPR, if needed
  - For this case, the output quantities of interest appear to be converged
  - No ruptures with LRD occurred

Realization count	Mean Occurrence of Crack @80 yr	Mean Occurrence of Leak @80 yr	Mean Occurrence of Rupture @80 yr	Mean Occurrence of Rupture with LRD @80 yr	LOCA Frequency Based on 95% Upper Bound One-Sided Confidence Interval
70,000 (NRC TLR)	8.07E-3	4.03E-3	1.27E-3	0	5.3E-7 yr^{-1}
1,000,000 (Further Investigation)	8.17E-3	4.11E-3	1.34E-3	0	3.7E-8 yr^{-1}

Time Between Detectable Leakage and Rupture

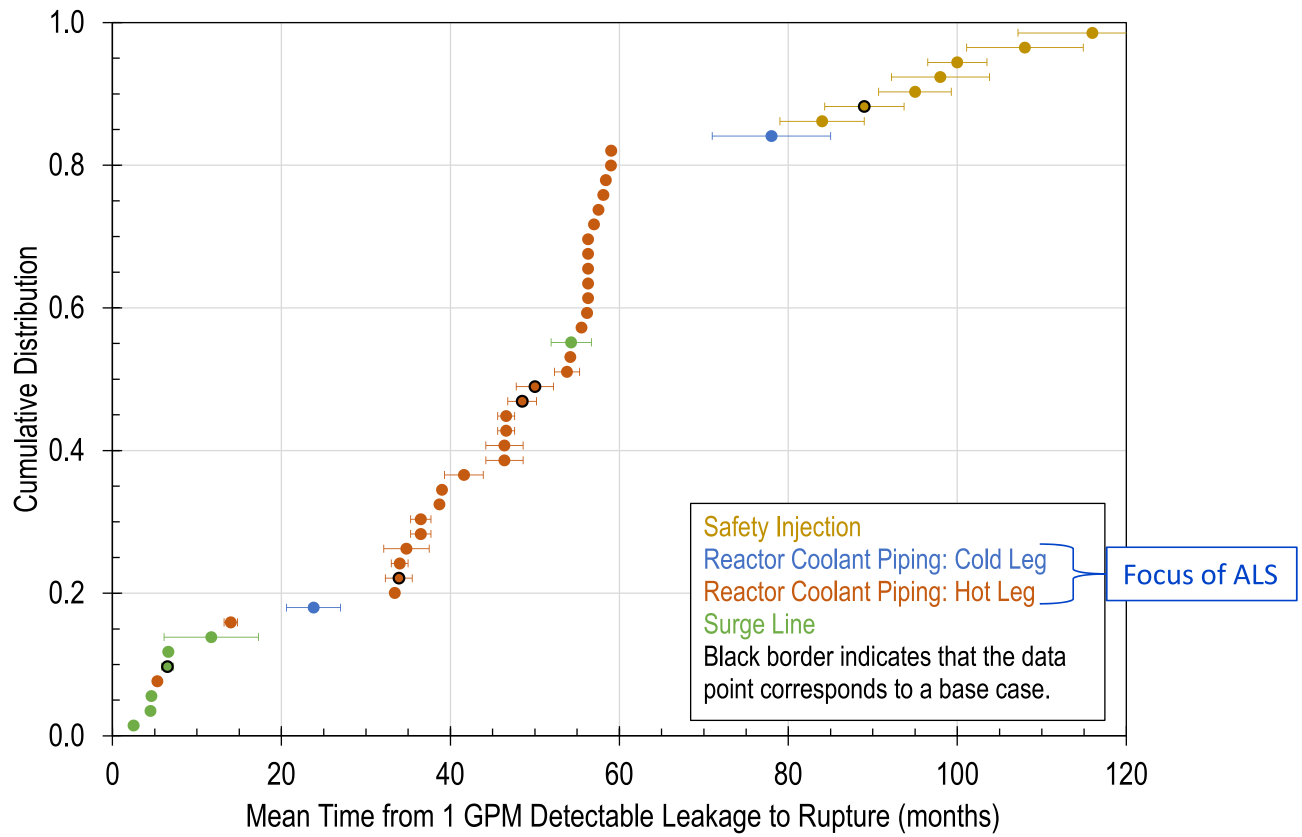
Minimum Time from Detectable Leakage to Rupture

- Minimum times from detectable leakage to rupture are reviewed as a screening exercise
  - Times from detectable leakage to rupture listed as N/A in the NRC TLRs are not shown
- Cases with minimum time from detectable leakage to rupture under 3 months are investigated in further detail
  - These cases
    - Considered unmitigated welds subject to PWSCC growth at hot leg or pressurizer temperatures or included modeling not representative of plant conditions and operations
    - Are all sensitivity cases



Mean Time from Detectable Leakage to Rupture

- Mean times from detectable leakage to rupture are also reviewed for additional context
  - Shown with error bars equal to standard error
  - Times from detectable leakage to rupture listed as N/A in the NRC TLRs are not shown



Investigating Limiting Cases

Time Between Detectable Leakage and Rupture

Sensitivity Cases with Limiting Times from Detectable Leakage to Rupture

Focus of ALS

NRC TLR Case	Description	Rupture Freq.	Rupture Freq. w/ LRD	Minimum Time from 1 gpm Detectable Leakage to Rupture	Comments
1.1.2	RVON severe WRS	1.54E-5 yr^{-1}	0 yr^{-1}	1 month	Case models unmitigated weld at HL temperature.
2.1.1	PZR surge initial flaw	1.30E-6 yr^{-1}	0 yr^{-1}	2 months	Case models unmitigated weld at PZR temperature.
2.1.2	PZR surge severe WRS	1.29E-5 yr^{-1}	0 yr^{-1}	1 month	Case models unmitigated weld at PZR temperature.
2.1.3	PZR surge w/ overlay	1.03E-6 yr^{-1}	2.5E-7 yr^{-1}	0 months	NRC TLR states the application of the overlay is the cause of these ruptures.
2.1.4	PZR surge w/ fatigue	1.25E-6 yr^{-1}	0 yr^{-1}	1 month	Case models unmitigated weld at PZR temperature.
4.1.1	SGIN initial flaw	1.00E-6 yr^{-1}	7.5E-7 yr^{-1}	Noted as N/A in NRC TLR	Associated w/ flaws initiating deeper than Alloy 52 inlay material. NRC TLR states that the nature of these ruptures makes the distribution of times from detectable leakage to rupture irrelevant.
4.1.2	SGIN severe WRS	2.63E-6 yr^{-1}	2.25E-6 yr^{-1}	Noted as N/A in NRC TLR	
4.1.3	SGIN overlay mitigation	4.16E-5 yr^{-1}	0 yr^{-1}	0 months (2 months w/ normal operating loads only)	Cases show 0-month time from detectable leakage to rupture but 0 rupture frequency w/ LRD. The minimum times are greater than zero when considering only normal operating loads (that is, non-probabilistically treated seismic loads are not included).
4.1.4	SGON no mitigation	6.75E-6 yr^{-1}	0 yr^{-1}	0 months (16 months w/ normal operating loads only)	

Time Between Detectable Leakage and Rupture

Summary of Investigation of Limiting Sensitivity Cases

NRC TLR Case	Description	Minimum Time Between Detectable Leakage and Rupture after Investigation	Relevance to Alternative Licensing Strategy
1.1.2	RVON severe WRS	1 month	Although minimum time from detectable leakage to rupture is low, it is still greater than 1 full month time step
4.1.1	SGIN initial flaw	N/A – No ruptures occur	No ruptures occurred when case was re-run with reduced initial flaw sizes shallower than the inlay depth
4.1.2	SGIN severe WRS		
4.1.3	SGIN overlay mitigation	N/A – No ruptures occur	No ruptures occurred after mitigation (no unmitigated SGINs remain in the fleet)
4.1.4	SGON no mitigation	2 months	When crediting axial flaw leakage and normal operating loads, the minimum time from detectable leakage to rupture is 2 months

Conclusions and Schedule

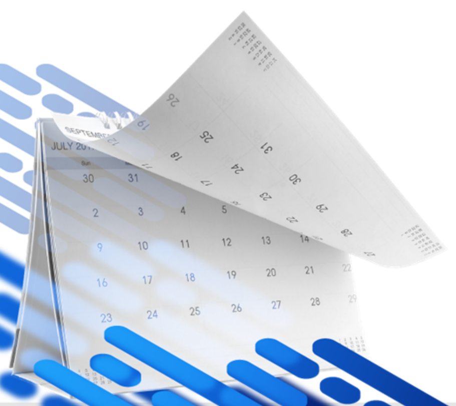
Conclusions

As Relevant to the ALS

- Main loop piping DMW cases are the focus of cases relevant to the ALS
- When crediting ISI and LRD, occurrence of rupture results are on a similar order of magnitude as NUREG-1829 LOCA frequency estimates
  - The only nonzero results were for cases including modeling not representative of plant conditions and operations
- Cases with limiting times from detectable leakage to rupture were further investigated and dispositioned
  - After dispositioning, minimum time from detectable leakage to rupture is at least
    - 14 months for all base cases evaluated
    - 1 month for all sensitivity cases evaluated

Schedule

- Publication of EPRI Technical Report focused on xLPR analyses
  - Spring 2023



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