

MRP-146 Revision 3

Overview of planned changes to inspection requirements and assessment guidance

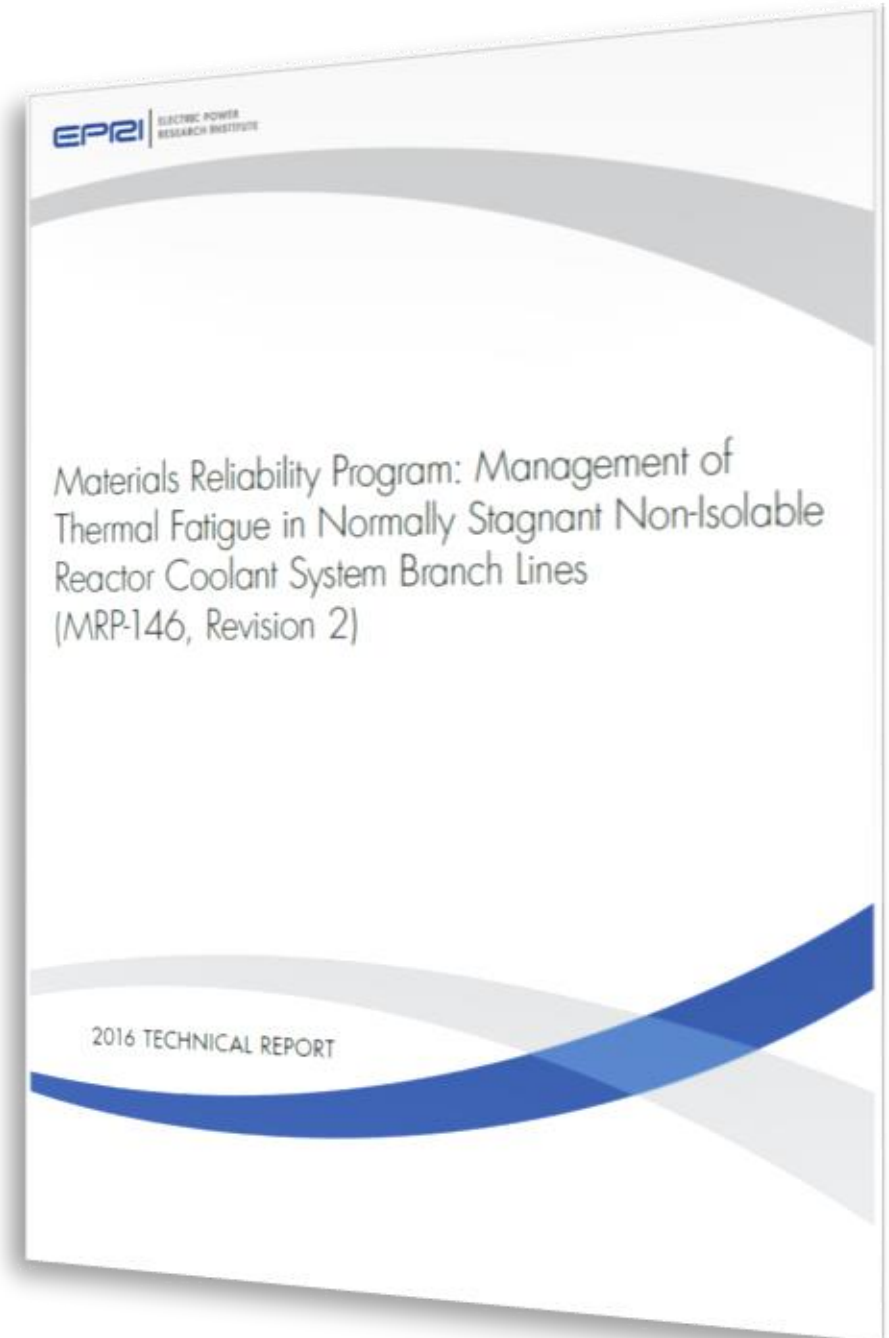


Tom Damiani
Sr. Principal Technical Leader, EPRI-MRP

Industry/U.S. NRC Materials Program Technical Information Exchange Meeting
June 16, 2026
Rockville, MD

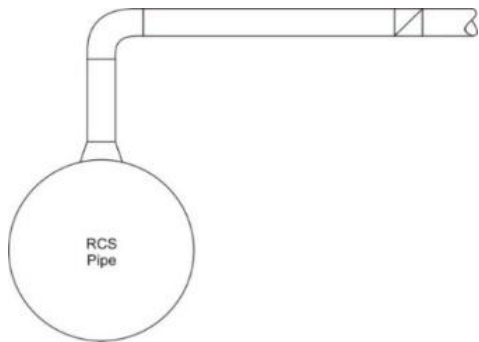
What is MRP-146?

- MRP-146 provides NEI-03-08 needed requirements and best practice guidance for managing thermal fatigue in normally stagnant, non-isolable branch lines attached to the reactor coolant system
- MRP-132 documents the screening and evaluation analytical model, which was implemented in the **MRP-170 software** (published in 2006)

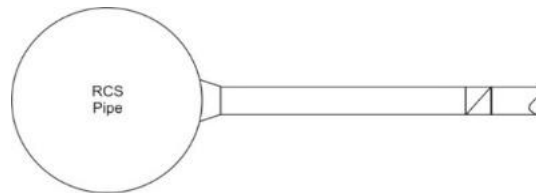


What's in MRP-146 Rev. 2

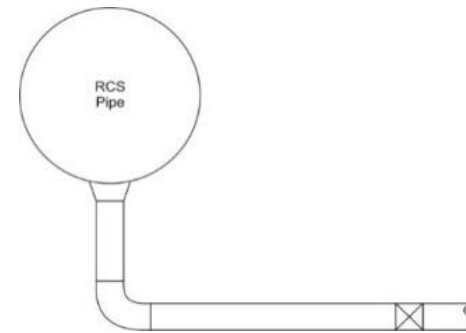
- Consolidates MRP-146 Rev 0/Rev 1, MRP-146S, and 2015 Interim Guidance into one document
- Addresses thermal fatigue in stagnant non-isolable RCS branch lines
- Branch line scope: SI, charging, drain, excess letdown, and RHR suction lines > 1-inch NPS
- Two configurations: Up-Horizontal/Horizontal (UH/H) and Down-Horizontal (DH)



“UH” Configurations

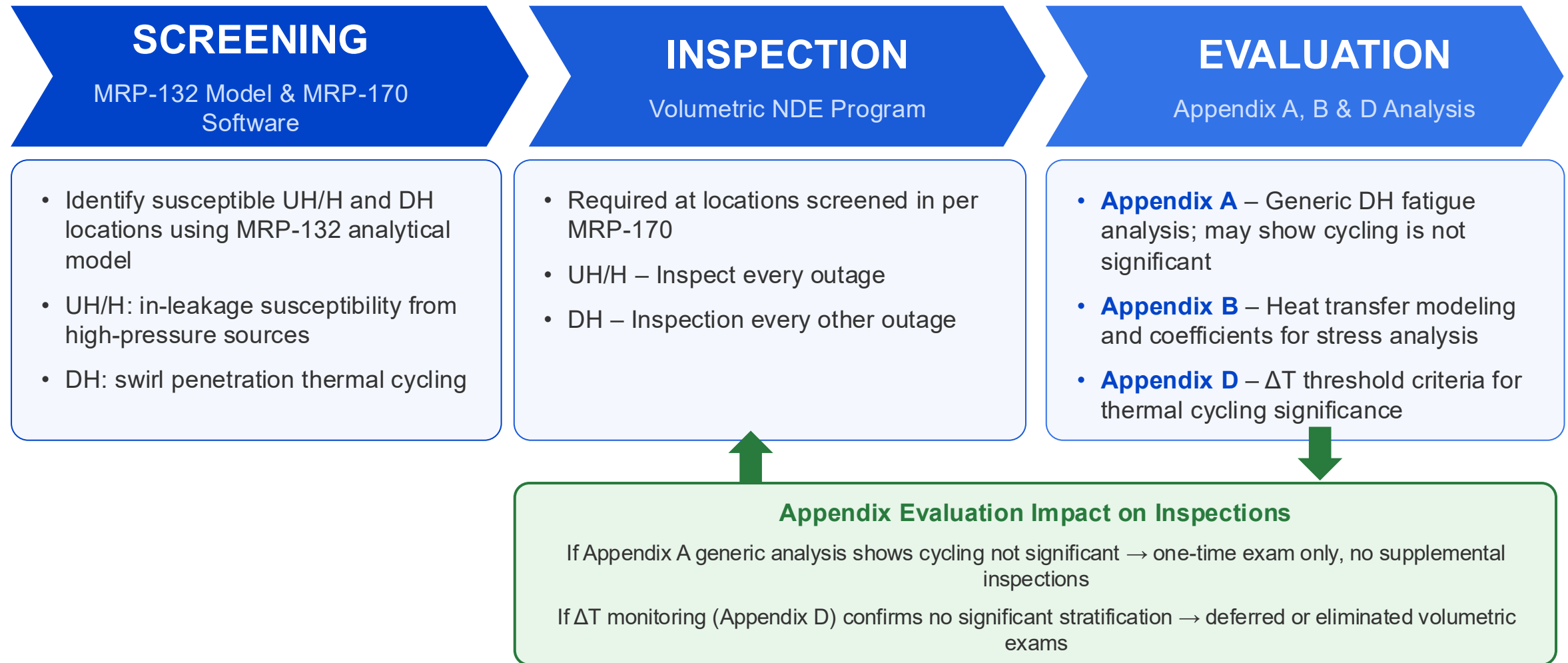


“H” Configurations



“DH” Configurations

MRP-146 Rev 2 — Assessment Approach



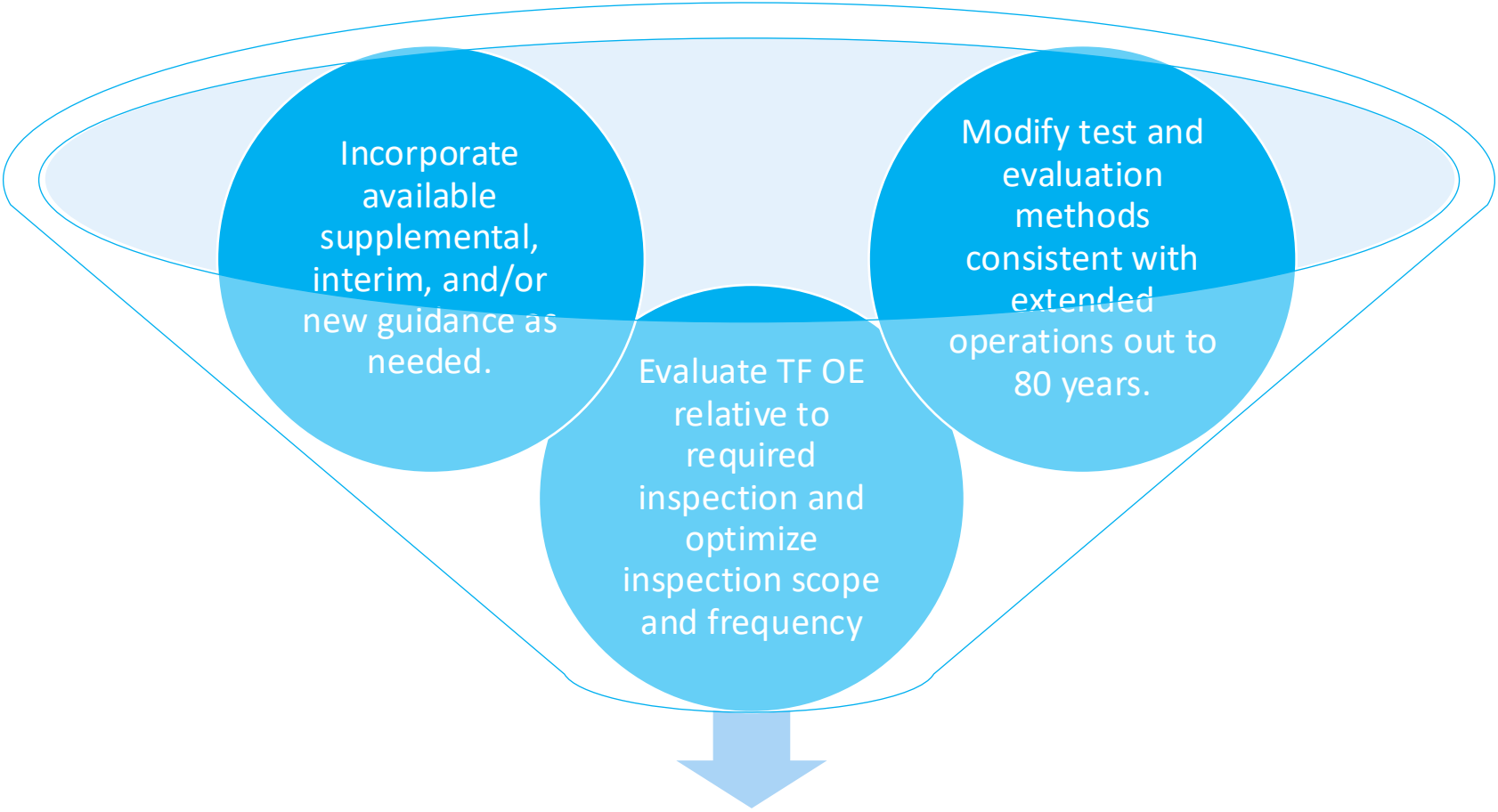
All screened in lines without further evaluation require inspections (NEI-03-08)

Status of Industry and MRP Efforts Since Rev. 2

- NEI-03-08 interim guidance **MRP 2019-008** issued to address McGuire Unit 2 cross-flow operating experience and incorporate lessons learned.
 - Included additional one-time inspections
- MRP conducted research to use **CFD analysis** to better characterize the thermal fatigue mechanisms and benchmark models against plant operating experience
 - Benchmarked CFD models performed well in certain cases
 - Evaluation against OE showed the limitations of the CFD capability
- Several plant operating cycles;
 - many inspections --> relatively few identified flaws in the US fleet (3)

In November 2024, MRP began scoping Rev. 3

Rev. 3 Objectives



MRP-146 Rev. 3

Predominant focus on inspection requirements

Reduced Inspection Scope: Justification by OE

Can we demonstrate...

... cracking is rare?

- Informal survey to characterize inspection programs: number of locations inspected and their interval
 - DH Drains ranging from 1.5" to 3.0"
 - DH RHR/SDC/DHR suction ranging from 8.0" to 16.0"
 - What is actual extent for H/UH systems?
 - **Do they screen-in because they cannot verify no valve in-leakage?**
- EPRI plans to separately send out a survey to formally capture scope of inspections in spring 2025

... cracking is not systemic?

- One-time inspections were performed in response to MRP 2019-008
 - Large bore piping screened out as run hot
 - Cross flow piping
- **Were any additional flaws identified during those exams?**
- **Any OE indicating sister plants or trains to be prioritized in a sample inspection regime?**

Reduced Inspection Scope: Additional Topics

- Can we demonstrate...
 - A generic LBB case exists for MRP-146 piping using conservative loads and the database of through-wall cracks in MRP-468?
- How many locations have inspections that are above the pain threshold to consider ...
 - ... performing optional analysis to justify reduced inspection?
 - ... performing monitoring to justify reduced inspection?

Survey of MRP membership

1. Summarize the scope of your current MRP-146 inspections (line name, quantity, brief description and orientation)?
 - a. Do you have H/UH lines that are screened-in by MRP-170? Are they inspected or demonstrated to not have valve in-leakage?
 - b. What locations are particularly onerous to inspect (e.g., pain points with scaffolding, high dose, and difficult to remove insulation)?
2. Did any of your plants find flaws as part of the one-time MRP 2019-008 inspections?
3. Are any of your plants using the fatigue evaluation in MRP-146 R2 Appendix A?
4. Are there any ambiguous or confusing requirements in MRP-146 R2 or R1S that should be clarified?

Inspection Scope Data Summary

- Broken down by NSSS type
 - W 2 loop – 4 units
 - W 3 loop – 14 units
 - W 4 loop – 6 units
 - B&W – 3 units
 - CE – 6 units
- Further broken down by system
 - Drain lines (2")
 - SI / Charging lines (3" – 6")
 - RHR lines (8" – 12"+)
- Summed up total inspections per 10 year ISI interval
 - Assumed 6 outages per interval

Inspection Scope Data Summary

- Drain lines total
 - W 2 loop (4 units): 3 inspections / 10 yr interval
 - W 3 loop (14 units): 93 inspections / 10 yr interval
 - W 4 loop (6 units): 16 inspections / 10 yr interval
 - B&W (3 units): 27 inspections / 10 yr interval
 - CE (6 units): 54 inspections / 10 yr interval
- SI / Charging lines total
 - W 3 loop (14 units): 304 inspections / 10 yr interval
 - W 4 loop (6 units): 90 inspections / 10 yr interval
 - CE (6 units): 72 inspections / 10 yr interval
- RHR lines total
 - W 2 loop (4 units): 8 inspections / 10 yr interval
 - W 3 loop (14 units): 26 inspections / 10 yr interval
 - W 4 loop (6 units): 2 inspections / 10 yr interval
 - CE (6 units): 6 inspections / 10 yr interval

Inspection Scope Data Summary

- Drain lines total
 - 6 inspections / unit / 10 yr interval
- SI / Charging lines total
 - 18 inspections / unit / 10 yr interval
- RHR lines total
 - 1 inspection / unit / 10 yr interval
- Each inspection is multiple welds/locations
 - Typically 3 examinations are performed for each inspection site
- Compare with “normal” Category B-J (or Category R-A) weld inspections
 - 25-100 welds / 10 yr interval depending on system and approach

MRP-146 Inspection Burden – “Average” Plant

- MRP-146 burden overall to the industry assessed by plant survey
 - Total number of inspections divided by total number of units responding
 - Each MRP-146 location includes multiple inspections – welds plus elbow
 - Normalized to ASME Section XI interval of 10-12 years (6 outages)
 - Repeat exams of a handful of locations
- MRP-146 overall burden by system
 - Drain lines: 18 exams / unit / interval
 - SI / Charging: 54 exams / unit / interval
 - RHR: 3 exams / unit / interval
- Compare with typical US plant Section XI PB weld inspections
 - 75-150 unique weld exams/ interval

MRP-146 by itself is comparable to full Section XI program

MRP-146 Inspection Burden – Specific Plants

- Plant A (W 4-loop)
 - 18-month cycle / 7 outages per interval
 - MRP-146: 63 exams per interval
 - Section XI PB Welds (volumetric): 100 exams per interval
 - N-770 (unmitigated DM welds): 32 exams per interval
- Plant B (B&W)
 - 24-month cycle / 6 outages per interval
 - MRP-146: 27 exams per interval
 - Section XI PB Welds (volumetric): 70 exams per interval
 - N-770 (unmitigated DM welds): 18 exams per interval

MRP-146 requires more examinations than N-770

MRP-146 Inspection Burden – Case for LBB

- Can we demonstrate...
 - A generic LBB case exists for MRP-146 piping using conservative loads and the database of through-wall cracks in MRP-468?
 - May come with the need to demonstrate loads at a plant meet evaluation parameters
- Inspection survey indicates greatest pain point may be SI/Charging lines
- Compare limiting flaw size to typical piping system loads provided by WEC to EPRI
 - Define structural margin for known leaking locations
- Potential implementation paths for revised inspection guidance

Limiting Circ TW Flaw Size Evaluation

- Representative loads obtained from Westinghouse for piping systems covered by MRP-146 inspections
 - RHR, SI, Charging, BIT, Drain
- Using SSE and LOCA loads (Level D), calculate limiting flaw size
 - Conservatively assume TW crack
 - ASME Section XI limit load maximum allowable flaw size (including SFs)
 - Bounding combination of max bending and max axial force
 - Also investigating EPFM calculation of failure size (xLPR approach)
- Compare to sizes of flaws found in service

Limiting Circ TW Length Comparison

System	Pipe Size (NPS, in)	Limit Load Max Length (inch)	Max Found TW Length (inch)
RHR	14	19.0	n/a
SI	6	8.5	4.3
Charging	3	6.3	n/a
BIT / SI	1.5	2.4	1.3
Drain	2	3.5	2.0

Limiting flaw sizes are larger than found TW flaws

Inspection Requirements Options – Interval

- Function of crack growth rate
 - How long for crack to grow from undetectable to limit
- Some examples:
 - MRP-146: every outage (UH/H) or every other outage (DH)
 - N-770 (unmitigated DM welds): every 5 yr (hot leg), every 7 yr (cold leg)
 - Section XI Class 1 PB welds (B-J): every interval (10-12 years)

Inspection Requirements Options – Sample Size

- Function of cracking extent and risk of limiting flaw size
- Some examples:
 - MRP-146: All screened-in welds
 - N-770 (unmitigated DM welds): All welds
 - Section XI Class 1 PB welds (B-J): 25% of welds
 - Expand inspection if relevant conditions identified
 - RI-ISI of HSS welds: 10% of welds, 25% of welds subject to deg. mech.

Current MRP-146 Inspection Requirements

Current Inspection Interval

1.5 years – UH/H

18 month cycle Every outage

3 years – DH

18 month cycle Every other outage

Current Inspection Sample (without analysis)

All screened-in lines

All susceptible welds and elbow Inspect according to MRP-146 for all screened in lines across the site

Baseline Higher inspection burden with uniform scope and no leveraging of fleet operating experience

Proposed Inspection Program

Proposed Inspection Interval

4 years

Time-based, all configurations (DH, H, UH)

18 / 24-month
cycle

Effectively every other outage

12-month cycle

International plants also benefit

Note Unknown crack growth rate currently limits ability to recommend longer intervals.

Proposed Sample Size

$\geq 50\%$

of sites from each similar system type

All susceptible
welds and elbow

Inspect according to MRP-146 for the sample size

- Rotate through sites across interval
- Expand to full set of sites if relevant conditions are found

Result Reduced inspection burden relative to PWSCC and general Section XI PB welds; More frequent than N-770 for SCC

Proposed Inspection Program – Example 1

- Plant A (W 4-loop, 7 outages per interval)
 - Current MRP-146 Program: 63 inspections / interval
 - 1: 4 similar UH systems, 7x per interval – 56 exams
 - 2: 2 similar UH systems (alternating operation) – 7 exams
 - Revised Program: 18 exams / interval
 - 1: 2 of 4 systems, 4x per interval – 16 exams
 - 2: 1 of 2 systems, 2x per interval – 2 exams
- Compare with
 - Current Section XI PB Welds (volumetric): 100 exams per interval
 - Current N-770 Program: 32 exams / interval

Recommended Inspection Program – Example 2

- Plant B (B&W, 6 outages per interval)
 - Current MRP-146 Program: 27 exams / interval
 - 3 similar DH systems, 3x per interval – 27 exams
 - Revised Program: 18 exams / interval
 - 2 of 3 systems, 3x per interval – 18 exams
- Compare with
 - Current Section XI PB Welds (volumetric): 70 exams per interval
 - Current N-770 Program: 18 exams / interval

Timeline

- Draft currently in process
- EPRI receives draft – End of June 2026
- EPRI review/comment and membership review – September 2026
- EPRI published final report – November 2026



TOGETHER...SHAPING THE FUTURE OF ENERGY®