U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

ATF Fuel Fragmentation, Relocation, and Dispersal Consequences Workshop 3

September 18, 2025

September 19, 2025

Meeting Logistics

- Meeting visuals and audio are through MS Teams.
- Participants are in listen-only mode until the discussion and public feedback period. During which, we will first allow in-person attendees to participate, then allow remote attendees to un-mute.
  - Remote attendees should utilize the hand raised feature in MS Teams, if possible.
- This is an Observation Meeting. Public participation and comments are sought during specific points during the meeting.
  - NRC will consider the input received but will not prepare written responses.
  - No regulatory decisions will be made during this meeting.
- This meeting is being recorded.

Meeting Purpose

- Discuss the NRC's and industry's positions on topics related to performance monitoring, inspections, and seismic risk.
- Provide feedback on NEI and EPRI's proposed white paper on "Materials Degradation Research and NEI 03-08 Materials Initiative."
- Provide an opportunity for members of the public to ask questions of the NRC staff.
- The NRC is not looking for feedback on the Increased Enrichment (IE) Rulemaking.

Proposed Workshop Schedule

- Workshop 1 (May 20-21)
  – Fuel Fragmentation, Relocation, and Dispersal
  – Recriticality
- Workshop 2 (July 30-31)
  – Exemptions
  – Coolability
  – Reporting
- Workshop 3 (Today)
  – Materials
  – Inspections
- Workshop 4
  – Transition Break Size
  – Graded Approach

Agenda – Day 1

Time	Topic	Speaker
9:00 am	Welcome	NRC
9:05 am	Opening Remarks	NRC, NEI
9:10 am	Performance Monitoring Through Inspections and Demonstrating Acceptable Seismic Failure Risk	NRC
10:00 am	Discussion	
10:30 am	Break	
10:40 am	Demonstration of the Proven Effectiveness of Existing Materials Management and Inspection Programs	NEI, EPRI
11:20 am	NRC Efficiency Improvements	NEI
11:30 am	Discussion	
12:00 pm	Adjourn	NRC

Topic times are estimated based on the participation level and presentation length.

Agenda – Day 2

Time	Topic	Speaker
9:00 am	Welcome	NRC
9:05 am	Discussion	
10:30 am	Break	
10:40 am	Discussion	
11:45 am	Public Comment Period	
11:55 am	Closing Remarks	NRC, NEI
12:00 pm	Adjourn	NRC

Topic times are estimated based on the participation level and presentation length.

Opening Remarks

Performance Monitoring Through Inspections and Demonstrating Acceptable Seismic Failure Risk

Nuclear Regulatory Commission

ATF Fuel Fragmentation, Relocation, and Dispersal Consequences Workshop #3

NRC Headquarters

September 18 – 19, 2025

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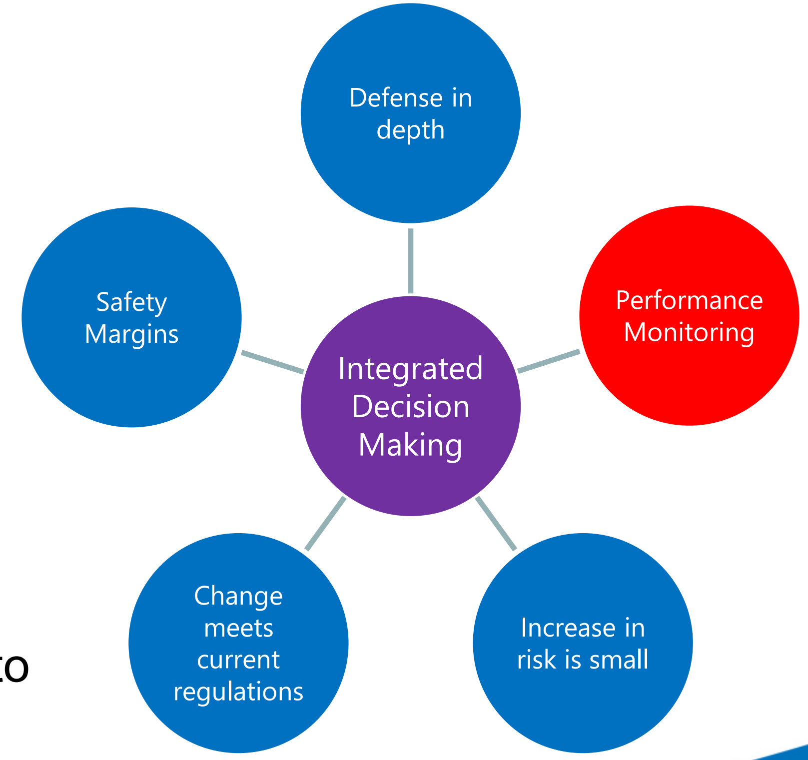
Performance Monitoring

- Performance Monitoring (PM) is one of the 5 fundamental considerations in a risk-informed licensing change under 1.174
- PM options are limited for reactor coolant pressure boundary (RCPB) passive components (i.e., piping)
  - Pressure/hydrostatic testing to evaluate structural integrity beyond leak-tightness is not required nor is it practical
  - Leakage monitoring not considered PM as it is inconsistent with GDC-14
    - Provides effective defense in depth (DID) in systems exhibiting leak-before-break (LBB)
  - Chemistry control provides assurance that global conditions exist to limit degradation but does not address localized variability or degradation within acceptable limits
  - ***Inspections are the most valuable PM tool that can provide both generic and plant-specific assurance that degradation rates are acceptable***



RCPB Piping Weld Inspections: History

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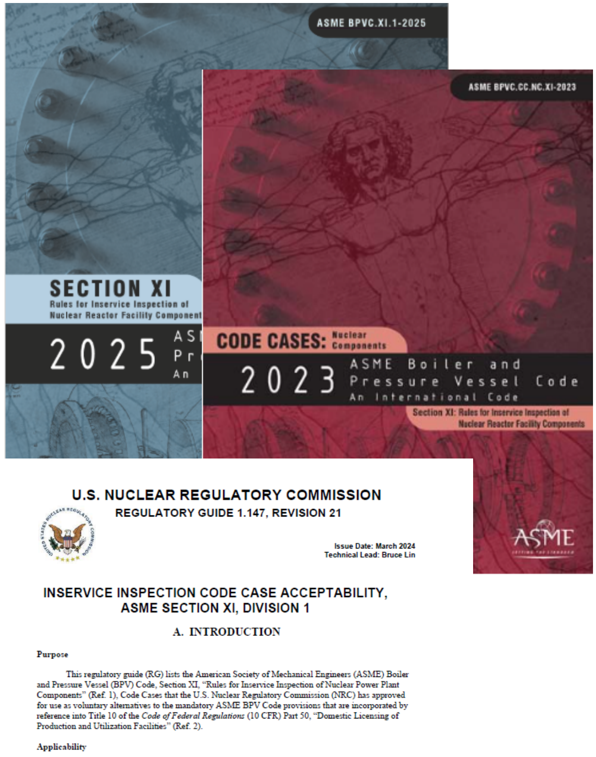
- ASME Section XI (IWB-2500) specifies conventional in-service inspection (ISI) requirements for NPS > 4” B-J welds
  - Requires a 25% inspection sample
    - Terminal ends connected to vessels
    - Terminal ends connected to other components with high applied stress or cumulative usage factor (CUF) associated with operation and seismic
    - Non B-F dissimilar metal welds
  - Can include additional hot leg and cold leg welds to reach 25%
- Plants have been implementing alternative risk-informed ISI (RI-ISI) for approximately the last 30 years
  - Approved plant-specific requests to use ASME CC N-560, N-578
  - Approved generic RI-ISI topicals: WCAP-14572, Rev 1; EPRI TR-112657
  - **Approved ASME Section XI, Appendix R, Supplement 2 (EPRI TR-112657) in 10 CFR 50.55a**
  - **Approved ASME CC N-716-3 in RG 1.147, Revision 21**
- *RI-ISI provides smaller, less prescriptive inspection sample*



RCPB Piping Weld Inspections: Section XI, Appendix R, Supplement 2

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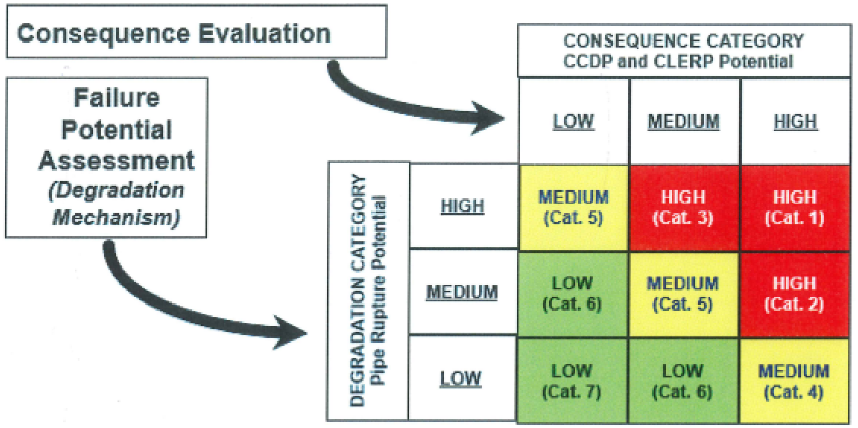
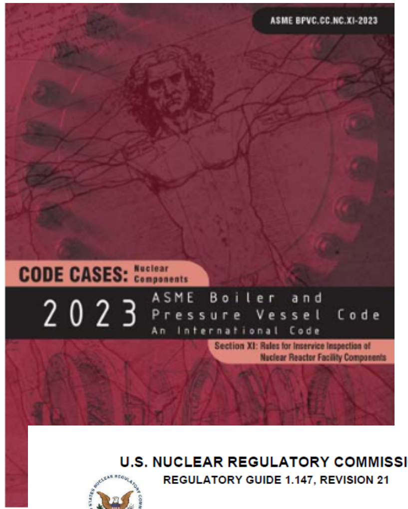
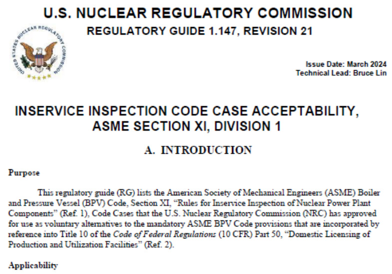
- Define risk categories from high consequence, high failure potential (1) to low consequence, low failure potential (7)
- Inspection for segments (consequence + DM) susceptible to FAC, IGSCC, and PWSCC are defined through owner's programs
  - Users can count these inspections as part of their sample
- Sampling requirements
  - Risk categories 1 – 3: 25% inspection sample
  - **Risk categories 4 – 5: 10% inspection sample**
  - Risk categories 6 – 7: exempt from inspection requirements
- **If application scope only applies to B-J welds, excluding socket welds**
  - Elements selected starting with high-risk group and working toward the low-risk group until 10% sample obtained
  - No more than 50% of owner's program examinations credited toward the 10% inspection sample
- When selecting welds, following shall be considered
  - Elements susceptible to DMs
  - Plant-specific cracking experience
  - Availability of previous examination results
  - Inspections for each DM and combination of DMs
  - **Risk Category 4 inspections based on stress concentration, terminal ends, or geometric discontinuities**
  - Accessibility
  - Minimization of worker exposure
  - Minimization of support services (e.g., scaffolding, insulation, and rigging)
- Inspection reductions from existing program justified by change-in-risk evaluation



RCPB Piping Weld Inspections: CC N-716-3

- Owner's programs for components susceptible to erosion-cavitation, IGSCC, PWSCC, and MIC
- Other requirements based on degradation mechanism (DM) and safety significance
- Inspections only required for high safety significance (HSS) components
- LSS exempt from Section XI inspection requirements, except VT2
- *Global 10% sample of piping welds, prorated among butt and socket welds*
- Can credit IGSCC welds toward global requirement
- Remaining welds selected as follows
  1. 25% of welds susceptible to an identified DM
  2. **10% of RCPB welds including at least 2/3rd of these between RPV and first isolation valve (or 25% between RPV and first isolation valve)**
  3. 10% of RCPB welds outside containment
  4. 10% of welds within break exclusion region
- If more than 10%, prorate categories 1 – 4 to reach 10%
- When selecting welds, following shall be considered
  - Plant-specific cracking experience
  - Weld repairs
  - Random selection
  - Minimization of worker exposure
- Inspection reductions from existing program justified by change-in-risk evaluation





U.S. NUCLEAR REGULATORY COMMISSION
REGULATORY GUIDE 1.147, REVISION 21

Issue Date: March 2024
Technical Lead: Bruce Lin

INSERVICE INSPECTION CODE CASE ACCEPTABILITY, ASME SECTION XI, DIVISION 1

A. INTRODUCTION

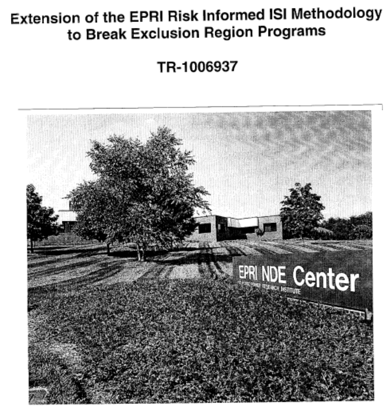
Purpose

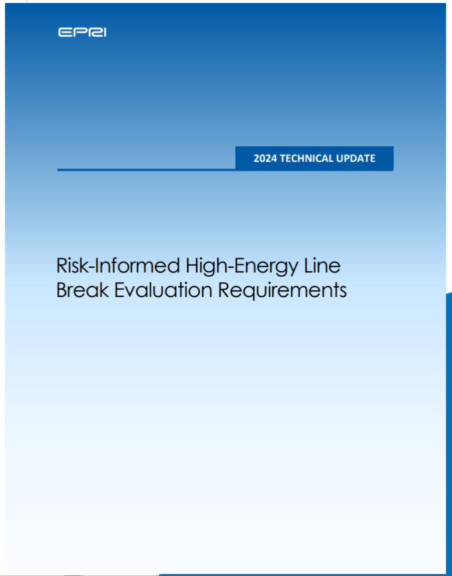
This regulatory guide (RG) lists the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel (BPV) Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components" (Ref. 1), Code Cases that the U.S. Nuclear Regulatory Commission (NRC) has approved for use as voluntary alternatives to the mandatory ASME BPV Code provisions that are incorporated by reference into Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 2).

Applicability

Extension of RI-ISI Concepts

- RI break exclusion region (BER)
  - Piping passing through containment penetrations to first outside isolation valve
  - Branch Technical Position MEB 3-1: 100% volumetric inspection or postulate breaks/leaks
  - EPRI TR-1006937 (NRC approved in 2002)
  - Extended TR-112657 methodology to BER
    - More focus on direct and indirect failure consequence assessment, consistent with SRP 3.6.2
    - **Sampling requirements:** high risk (25%) and medium risk (10%) elements for the RI-ISI and BER-only populations
    - **The number of BER inspections should not be significantly less than 10% of the BER scope unless plant design features justify otherwise.**
  - BER requirements are included in CC N-716-3
- High Energy Line Break (HELB)
  - Break postulation and mitigation for higher stress and cumulative usage factor locations
  - EPRI 3002028939 (NRC approved in 2025)
  - Extended TR-112657 methodology to HELB
    - Develops HELB response strategies instead of optimizing inspections
    - Categories 1, 3: Validate FAC program
    - Category 2: Reduce consequences and/or 10% inspections based on DM, or follow existing HELB requirements
    - **Category 4: Modify plant to reduce consequences or follow existing HELB requirements**
    - Category 5: Validate FAC, modify plant to reduce consequences, or 10% inspections based on DM





Steam Generator and Pressurizer Inspections

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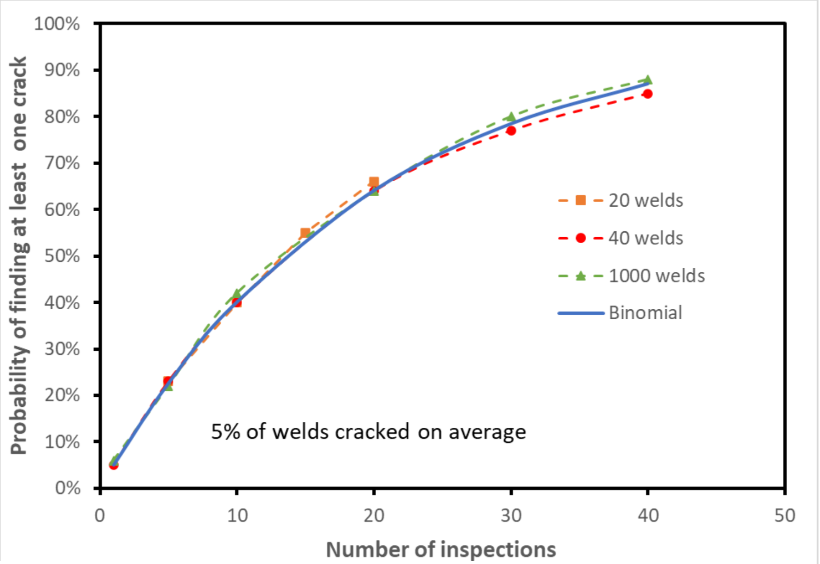
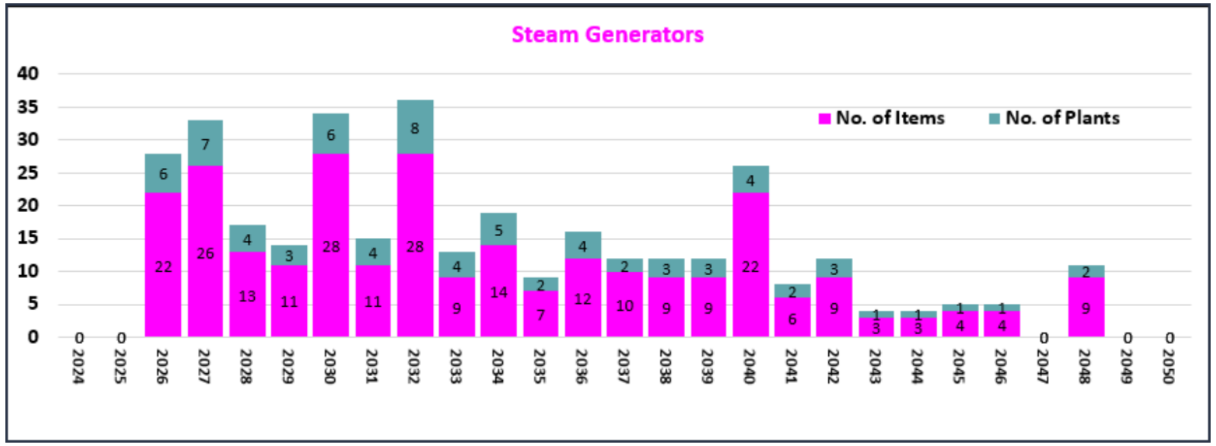
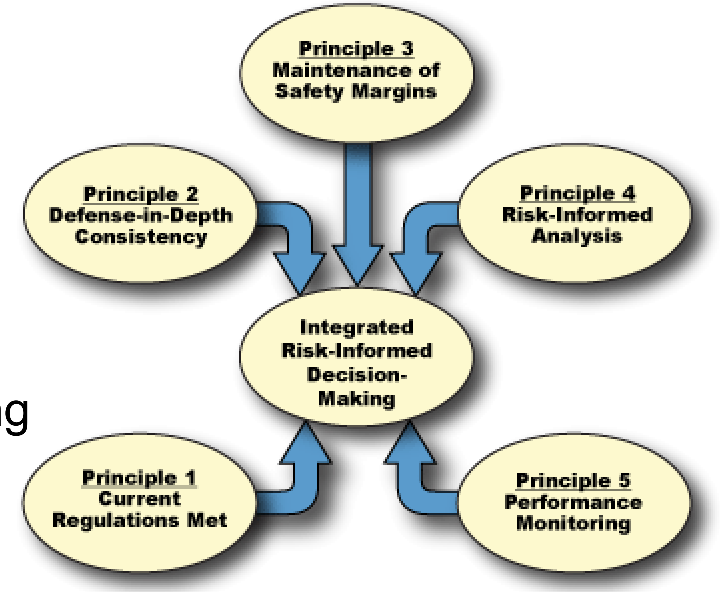
- ASME Section XI: inspections of 10 steam generator (SG) and 5 pressurizer (PZR) items every interval
- No evidence of degradation found to date
- Potentially high consequences of rupture at inspection locations
- PFM analyses concluded that failure risk is less than $1x10^{-6}$/yr
- EPRI 3002032184 submitted for NRC review in June 2025
  - Developed fleet-wide optimized inspection plan
  - Provides PM using 25% sampling criterion from binomial distribution model
    - Assumed 5% defect rate and 90% probability of detecting one occurrence
    - Sample population: Code-required PZR inspections over next 30 years
  - Plan recognizes units with existing PM commitments obtained through "Request for Alternative" submittals
  - Inspection plan provides continual generic data and will be updated on a regular basis





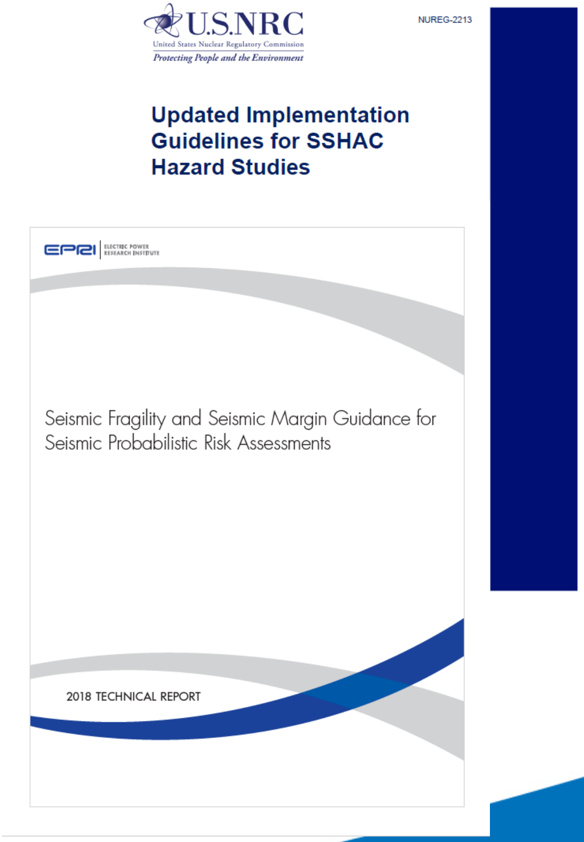
Performance Monitoring Considerations

- Performance monitoring required for potentially high failure consequence components to provide assurance that plant risk remains acceptable
- Volumetric inspections can provide reliable generic and plant-specific performance monitoring
- Inspection sample should include components with potentially high failure consequences
  - 10% to 25% of subject population are common targets
- Inspections should be risk-informed and focus scope on highest failure likelihood locations under both normal operational and upset/seismic loading
- Current inspections can be credited toward achieving an appropriate inspection sample
- Inspections should occur on a consistent basis and findings with potential generic implications should be widely shared in a timely manner
- Fleet-wide inspection may be appropriate to satisfy these objectives but plant-specific performance monitoring should be performed consistent with RG 1.174 principles



Seismic Risk Considerations

- Seismic risk not explicitly considered when determining LOCA frequencies in NUREG-1829
- Objective is to ensure that the seismic risk is less than the normal operational risk
- Seismic risk is an inherently plant specific convolution of seismic hazard and component fragility
  - Site location
  - Site characteristics
  - Plant configuration
- Direct and indirect seismic risk can be addressed by existing evaluations (e.g., seismic PRA, seismic margin assessment) ***as long as component fragilities appropriately address potential effects of plant aging***
  - Demonstrate that seismic risk is less than failure risk due to normal operation
  - Demonstrate that risk of failure of large piping components is a minor risk contributor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NUREG-2213
Updated Implementation Guidelines for SSHAC Hazard Studies

EPRI
Seismic Fragility and Seismic Margin Guidance for Seismic Probabilistic Risk Assessments
2018 TECHNICAL REPORT

Direct Seismic Risk Considerations

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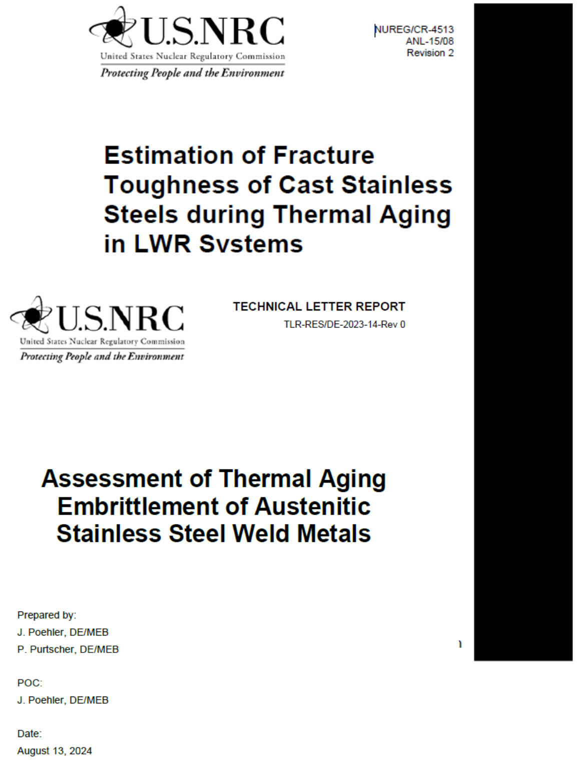
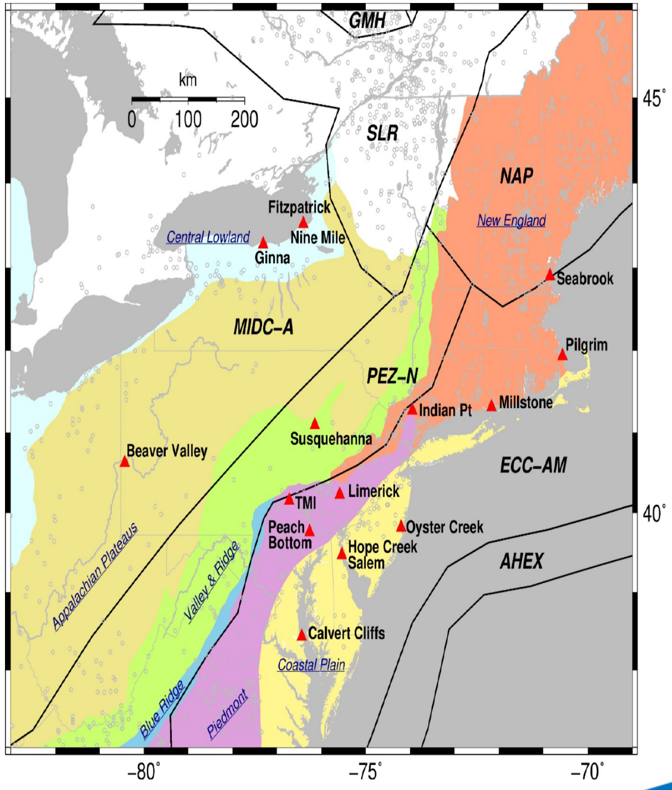
- Addressing potential effects of plant aging
  - Gross material loss through corrosion or flow accelerated corrosion not expected to be applicable in RCPB piping
  - Loss of material fracture toughness in combination with the existence of flaws is one possible scenario
- Loss of fracture toughness due to thermal aging
  - No significant effects expected in carbon steel or nickel-based alloy material systems
  - Affects cast austenitic steel (CASS) materials with certain chemistries (i.e., high delta ferrite and high Mo)
  - Affects stainless steel welds, more so for flux welds (i.e., SAW and SMAW) than GTAWs
- Potential cracking mechanisms in susceptible materials
  - Thermal or mechanical fatigue
  - SCC has only been experienced in U.S. plants in off-normal, or crevice-type conditions



Possible Screening Approach for Evaluating Seismic Risk

1. Qualitatively identify systems and weld locations with the highest potential failure risk due to seismic events
2. Evaluate materials at those locations to determine potential for loss of fracture toughness
3. Leverage results of existing or planned inspections at those locations to demonstrate that no unacceptable flaws exist
4. If ***either*** 2 or 3 can be demonstrated, ***no further evaluation*** is required
5. If neither 2 or 3 can be demonstrated, further evaluation may be needed
6. Utilize existing current seismic evaluations to demonstrate indirect seismic risk is acceptable
   - Leverage existing PRA requirements
   - Leverage existing plant walkdown and maintenance requirements to address non-piping failure potential (e.g. supports, snubbers) and associated risk



Northeastern U.S. Seismotectonic Source Zones (from NUREG/KM-0017)

Discussion Period

Break

Demonstration of the Proven Effectiveness of Existing Materials Management and Inspection Programs

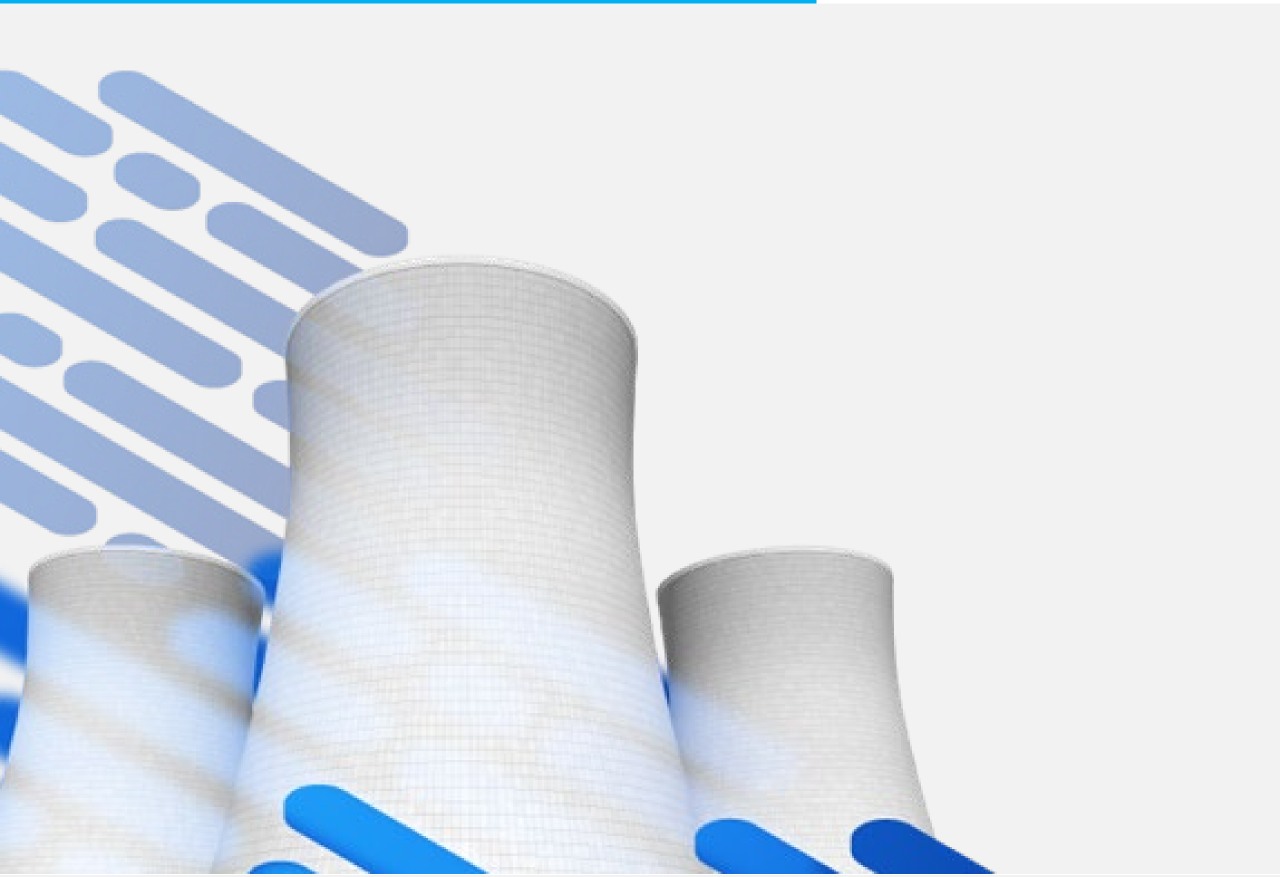
EPRI Nuclear Materials

Materials and Inspection Workshop
Rockville, MD
September 18, 2025

Date: 08/18/2025

Executive Summary

- The industry's current materials management and inspection infrastructure is sufficient to ensure continued safe operation of nuclear power plants without the need for additional piping fabrication searches and weld inspection requirements.
- The conclusions of NUREG-1829 remain valid and applicable to the operating fleet, supporting the use of TBS without the need for plant-specific justification.



Validation of NUREG-1829

- Updated analyses using the Extremely Low Probability of Rupture (xLPR) probabilistic fracture mechanics tool confirm that the original LOCA frequency estimates remain applicable, even when accounting for extended plant lifetimes and new data.

Inspection Program Effectiveness

- The industry remains committed to maintaining robust inspection programs including the RI-ISI programs, which ensure that high-risk piping segments are inspected with appropriate frequency and rigor, including similar metal stainless steel welds.

Proactive Industry Initiatives

- The NEI 03-08 framework, supported by Industry Materials Programs, has enabled the industry to anticipate and address degradation mechanisms before they impact safety.

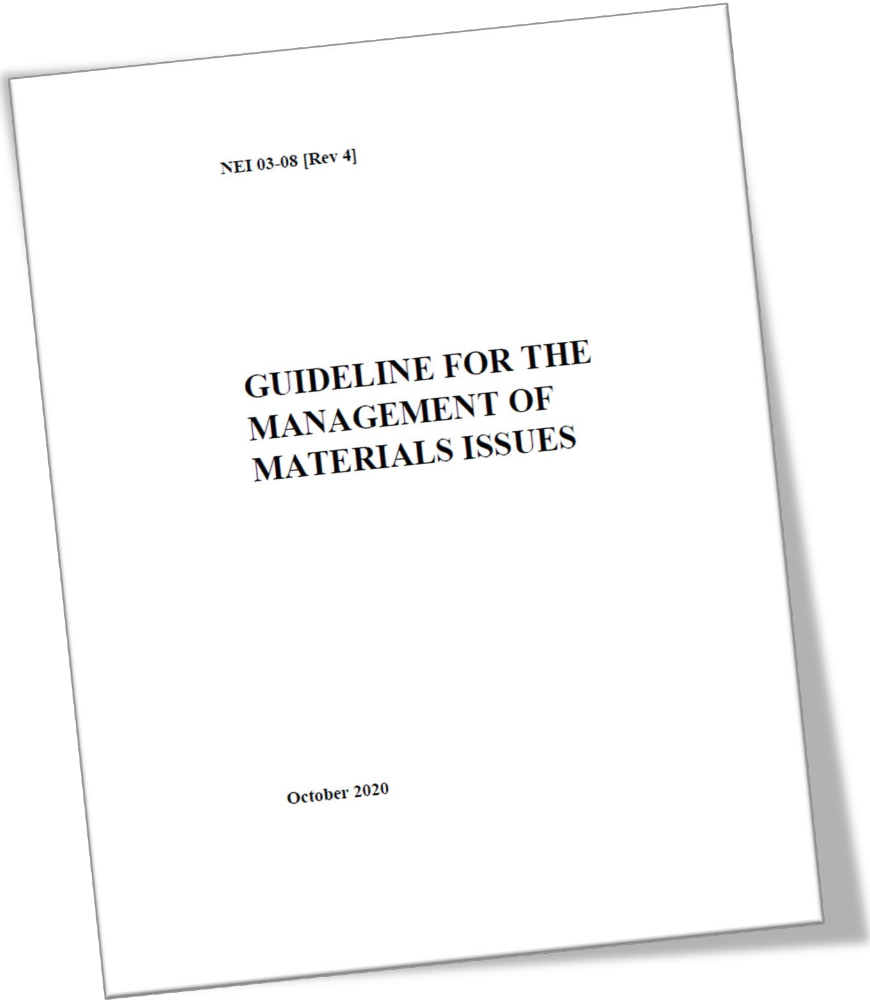
Contents

- NEI 03-08 Materials Initiative & Industry Materials Programs
- Current Inspection Programs
- Validation of NUREG-1829
- Summary and Conclusions

Overview of NEI 03-08 Materials Initiative & Industry Materials Programs

NEI 03-08, Guideline for the Management of Materials Issues

- Documents the Materials Initiative and defines the scope
- Establishes policy - ***Each licensee will endorse, support and meet the intent of NEI 03-08***
- Defines roles, and responsibilities
  - Executive / Management oversight
  - Issue Programs (IPs)
  - Utilities
- Approved unanimously by NSIAC in May 2003
- Initiative was effective January 2, 2004



Current version is Revision 4, effective October 2020

NEI 03-08 Materials Initiative Objective and Purpose

- The objective is to assure safe, reliable and efficient operation of the U.S. nuclear power plants in the management of materials issues.
- The purpose of this Initiative is to:
  - Provide a consistent management process
  - Provide for **prioritization of materials issues**
  - Provide for **proactive approaches**
  - Provide for integrated and coordinated approaches to materials issues
- Utility actions required by this Initiative include:
  - Commitment of executive leadership and technical personnel
  - Commitment of funds for materials issues within the scope of this Initiative
    - High priority, emergent, and long-term issues
  - Commitment to implement applicable guidance documents
  - Provide for oversight of implementation

NEI 03-08 Benefit to U.S. and International Members

- Assures the Materials Programs are **well integrated**
- **Consistent** technical **quality and rigor** built into the work and products of the IPs
- Confidence that senior **management perspectives are included**, and programs will be **living programs**
- NEI 03-08 programs have effectively resolved / **manage generic issues** and gained **USNRC acceptance**
- Documents are **recognized world-wide** as **aging management tools**
  - Referenced in USNRC Generic Aging Lessons Learned (**GALL**)
  - Also recognized IAEA's International Generic Aging Lessons Learned report (**IGALL**)
- Shows the Materials Programs are an **excellent platform** from which to develop **plant** and **country specific aging management programs**

NEI 03-08 Materials Initiative Accomplishments

- Integrated industry strategic plan for materials
- Achieved a high level of industry integration, coordination, alignment, and communication on material issues
- Established a process for prioritizing projects, budgets, and planning
- Predictable funding for materials R&D
- Engaged INPO as an active participant
- Defined expectations and protocols for industry actions upon discovery of an emergent issue
- Established consistent process for deviations and communication with NRC
- Executive level interactions between industry and senior NRC management
- Successful at closing materials issues and gaps
- Fewer unexpected materials related transients

EPRI

US NRC Feedback on the NEI 03-08 Materials Initiative

- NEI 03-08 Revision 3 was transmitted to US NRC in March 2017
  - US NRC issued a "thank you" letter to NEI in April 2017
    - *NRC quote: "We find that the NEI 03-08 program is a valuable component in achieving **safe operation** of nuclear power plants." -John Lubinski*

- In 2023, NRC evaluated two options for action in their LIC-504 Risk Informed Safety Assessment of the French stainless steel piping stress corrosion cracking issue:
  - Option 1: **Establish targeted inspections** and revision of inspection requirements for these piping locations
  - Option 2: **Take No Action** but continue to monitor industry action
    - NRC chose Option 2 noting in a 2/21/2024 presentation:
      - "With the implementation of the [industry] NEI 03-08 "needed" recommendation, the locations most susceptible in the non-isolable piping will be inspected with a SCC qualified technique
        - Safety margins and performance monitoring will be maintained"

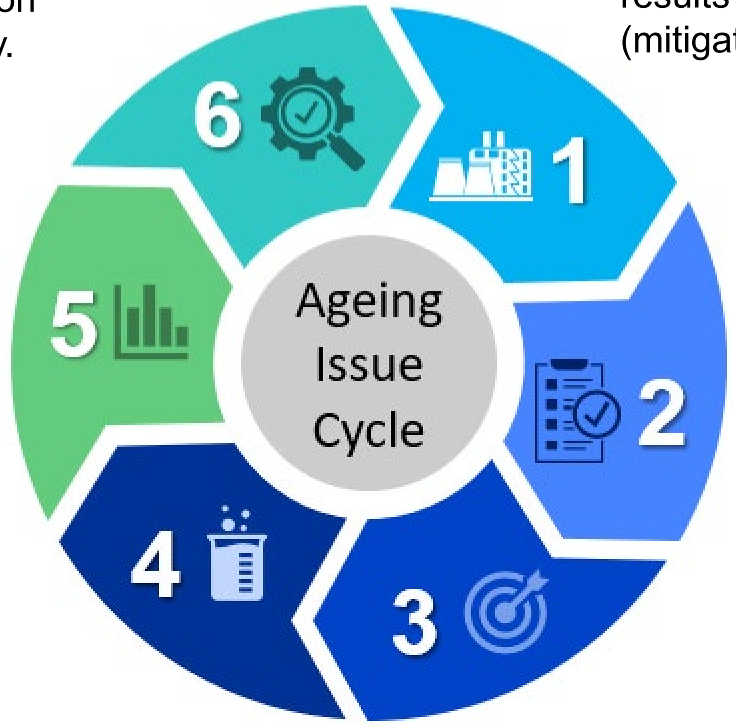
EPRI Materials Aging Management Cycle

6. Optimize Inspections

Increased confidence in ageing management strategies leads to optimized inspection requirements with respect to scope and frequency.

1. Collect Operating Experience

EPRI SMEs collect data from field reports and inspection results and assess the efficacy of corrective actions (mitigation, repair, replacement).



5. Calibrate Models

Improve accuracy and technical robustness of databases that provide inputs to materials models; calibrate conservatism applied to ageing management strategies.

2. Review Research Results

Updated research results from EPRI programs, technical literature, and conferences are reviewed by EPRI SMEs.

Materials Degradation Matrix (MDM) Revision 5 (3002030559; Nov 2024)

4. Address High-Priority Gaps

Conduct research on representative materials, perform simulations, develop new models to address high-priority assessment and degradation mechanism gaps.

3. Evaluate Technical Gaps

Review gaps from previous IMT (close, keep open, re-rank); define new gaps based on OE; prioritize gaps with utility members.

BWR Issue Management Tables BWRVIP-167 Rev. 4 (3002018319; June 2020)
PWR Issue Management Tables MRP-205 Rev. 4 (3002018255; September 2020)
*Both being revised based on MDM, Rev 5

Systematic Approach to Prioritizing Industry Issues

Materials Degradation Matrix

MDM

Every material, every potential degradation mechanism, and status of knowledge

- Mapped to 80 years of operation
- Covers BWR, PWR, CANDU, & VVER

Revision 5: 3002030559

Issue Management Tables

IMT

Every component/material, failure modes, mitigation, repair/ replacement, I&E Guidance → Knowledge Gaps identified and prioritized

- Covers BWR, PWR, CANDU, & VVER

PWR: 3002018255 (MRP-205, R4)

BWR: 3002018319 (BWRVIP-167, R4)

VVER: 3002021033 (MRP-471)

CANDU: 3002031002 (IMR-101)

MDM Revision 5: PWR Example – Primary Pressure Boundary Piping

Rev 4

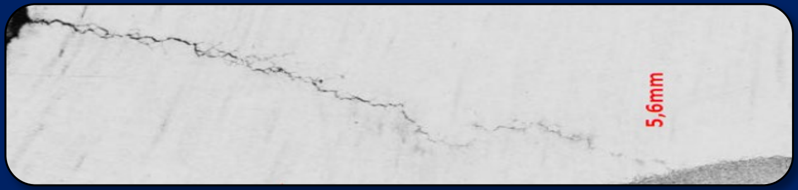
MATERIAL	DEGRADATION MODE: Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties	
	Wstg.	Pitting	FAC	Foul	Wear	IG / TG	IA	HCF	EAF	Th	Env
C&LAS: Base Metal & HAZ	Y p1-1a	N	N	N	N	Y p1-6a	Y p1-7a	N	Y p1-9a	? p1-10a	Y p1-11a
C&LAS: Welds	Y p1-1b	N	N	N	N	Y p1-6b	Y p1-7b	N	Y p1-9b	? p1-10b	Y p1-11b
SS: 300 Series SS Base Metal & HAZ	N	Y p1-2c	N	N	N	Y p1-6c	N	Y p1-8c	Y p1-9c	N	Y p1-11c
SS: 300 Series SS Welds & Clad	N	Y p1-2d	N	N	N	Y p1-6d	N	Y p1-8d	Y p1-9d	Y p1-10d	Y p1-11d
Cast Austenitic Stainless Steel	N	N	N	N	N	Y p1-6e	N	Y p1-8e	Y p1-9e	Y p1-10e	Y p1-11e

Rev 5

MATERIAL	DEGRADATION MODE: Corrosion				Wear	SCC		Fatigue		Reduction in Fract Properties	
	Wstg.	Pitting	FAC	Foul		IG / TG	IA	HCF	EAF	Th	Env
C&LAS: Base Metal & HAZ	Y p1-1a	N	N	N	N	Y p1-6a	Y p1-7a	N	Y p1-9a	Y p1-10a	Y p1-11a
C&LAS: Welds	Y p1-1b	N	N	N	N	Y p1-6b	Y p1-7b	N	Y p1-9b	Y p1-10b	Y p1-11b
SS: 300 Series SS Base Metal & HAZ	N	Y p1-2c	N	N	N	Y p1-6c	N	Y p1-8c	Y p1-9c	N	Y p1-11c
SS: 300 Series SS Welds & Clad	N	Y p1-2d	N	N	N	Y p1-6d	N	Y p1-8d	Y p1-9d	Y p1-10d	Y p1-11d
Cast Austenitic Stainless Steel	N	N	N	N	N	Y p1-6e	N	Y p1-8e	Y p1-9e	Y p1-10e	Y p1-11e

Aux. Piping IGSCC

- Ohi-3 (2020), KEPCO
  - Pressurizer spray line, weld HAZ 4.4 mm depth, circum. crack.
  - Suspected cause: high surface hardness.
- Several EDF N4/P4 Plants (2021-2023)
  - Cold leg SI & RHR suction lines.
  - Shallow but long circum. cracks.
  - Suspected cause: high stress thermal stratification + weld residual.



"The status was conservatively set to yellow to reflect potential gaps in knowledge with respect to the identification of susceptible components based on the recent OE with SCC of non-isolable branch piping in the safety injection system of some plants."

Overview of Existing Inspection Programs

Overview of Existing Inspection Programs

Risk Informed Inservice Inspection

- Focuses inspections on high-risk piping segments using probabilistic and deterministic methods
- NRC-approved methodologies (Traditional & Streamlined) implemented across 100% of U.S. fleet
- Enhances safety while reducing unnecessary inspections and regulatory burden

Augmented Inspection Programs

➢ Targeted inspections for known degradation mechanisms (e.g., SCC, thermal fatigue)
➢ Supports early detection and Industry-wide commitment to proactive materials management

Performance Demonstration Initiative

✓ Standardized qualification of ultrasonic NDE systems (personnel, procedures, equipment)
✓ Ensures high reliability in flaw detection and sizing, aligned with ASME and NRC standards

RI-ISI Overview and Methodologies

- Structured processes for identifying risk-significant components:
  - Traditional (EPRI TR-112657): Uses consequence and failure potential evaluations to classify piping segments
  - Streamlined (ASME Code Case N-716): Predefines high safety significant (HSS) piping and supplements with plant-specific outlier search
- Inspection Focus:
  - High-risk segments: 25% inspection population.
  - Medium-risk segments: 10% inspection population
  - Low-risk segments: No periodic NDE required
- Similar Metal Welds:
  - RI-ISI programs include similar metal welds in primary loop piping (PLP)
    - Surveyed plants confirm these welds are being sampled under RI-ISI protocols

RI-ISI Benefits and Implementation

- Safety Enhancement: Focuses inspections on components with highest failure potential and safety impact
- Efficiency Gains: Reduces unnecessary inspections, minimizing worker exposure and operational costs
- Regulatory Alignment: Supports NRC PRA Policy Statement and RG 1.174 for risk-informed decision-making
- NUREG-1829 Relevance: RI-ISI programs cover LOCA-sensitive piping, validating continued applicability of Transition Break Size (TBS)
- Stainless Steel Weld Inclusion: Welds with elevated SCC risk are routinely examined

RI-ISI Methodologies are NRC Approved

RI-ISI implementation was available and in use during the development of NUREG-1829

Summary of Plant Survey Results

- 37 plants (25 PWRs and 12 BWRs) were surveyed to determine the number of PLP similar metal piping circumferential welds being examined under the RI-ISI program

Reactor Type	# of Units Surveyed	NSSS Design	# of PLP SMW Exams	Description of PLP Locations Selected for RI-ISI Examination
PWR	13	West 4-Loop and 2-Loop	48	Hot leg and cold leg SMW locations adjacent to RV nozzle-to-safe end DMWs
	5	B&W Lowered Loop	36	Hot leg, cold leg and crossover leg SMW locations
	7	CE 2-Loop	61	Hot leg, cold leg and crossover leg SMW locations
BWR	12	GE BWR-1, 2, 3, 4, 5 and 6	194	SMW locations with a NPS greater than the largest diameter FW or RHR piping
Totals	**37**		**339**	

Industry Augmented Inspection Programs

Like RI-ISI, Augmented Inspection Programs enhance the safety and reliability of nuclear power plants by focusing inspection efforts on the most critical components while considering the likelihood of degradation and defense in depth

- MRP-139
- MRP-146
- MRP-192
- BWRVIP-75-A
- BWRVIP-155
- BWRVIP-196

- The Inspection Programs differ in their focus, scope, and methodologies, however they share common goals of inspecting critical welds (e.g., leading indicators), both dissimilar and similar metals

MRP-146 and MRP-192

- Provide thermal fatigue monitoring and inspection guidelines for non-isolable branch lines in the RCS and mixing tees
  - These lines often experience more severe stress and environmental conditions than the main reactor coolant loop, making them <u>early indicators of potential degradation mechanisms</u> in similar metal welds
    - French SS SCC was discovered during similar thermal fatigue inspections
  - The industry proactively applied MRP-146 using NEI 03-08 guidance to ensure that any potential SS SCC in the U.S. fleet would be identified at an early stage, if present

MRP-139 and ASME Code Case N-770

- Addresses Primary Water Stress Corrosion Cracking (PWSCC) in Alloy 600/82/182 materials used in PWR reactor pressure vessel nozzles and dissimilar metal welds
  - **Regulatory Alignment**: Informed ASME Code Case N-770, mandated by 10 CFR 50.55a
- Analyses (MRP-480, xLPR) show Alloy 82/182 welds are more limiting than similar metal, which demonstrate high flaw tolerance

Fleet-wide inspections per 10 CFR 50.55a ensure effective oversight of the most limiting PLP components

BWRVIP-75-A

- In conjunction with Generic Letter (GL) 88-01, provides a comprehensive inspection framework for BWR austenitic stainless steel piping welds susceptible to Intergranular Stress Corrosion Cracking (IGSCC).
- **Risk-Based Optimization**: Revises inspection schedules from Generic Letter 88-01 to concentrate resources on welds with greater IGSCC risk, particularly non-resistant welds without stress improvement.
- **Industry Impact**: Aligns with NRC requirements and enhances understanding of material degradation, supporting the development of future optimized aging management programs.

BWRVIP-155 AND BWRVIP-196

- Provide thermal fatigue screening and inspection guidance for BWRs, analogous to MRP-146 and -192 for PWRs.
- **Proactive Screening**: BWRVIP-155 defines methods to evaluate stagnant branch connections for thermal fatigue susceptibility, even without prior operating experience in BWRs.
- **Limited Susceptibility**: BWRVIP-196 addresses mixing tee fatigue risks in two BWR systems, recommending inspections or operational checks despite minimal BWR operating experience.

EPRI PERFORMANCE DEMONSTRATION INITIATIVE (PDI)

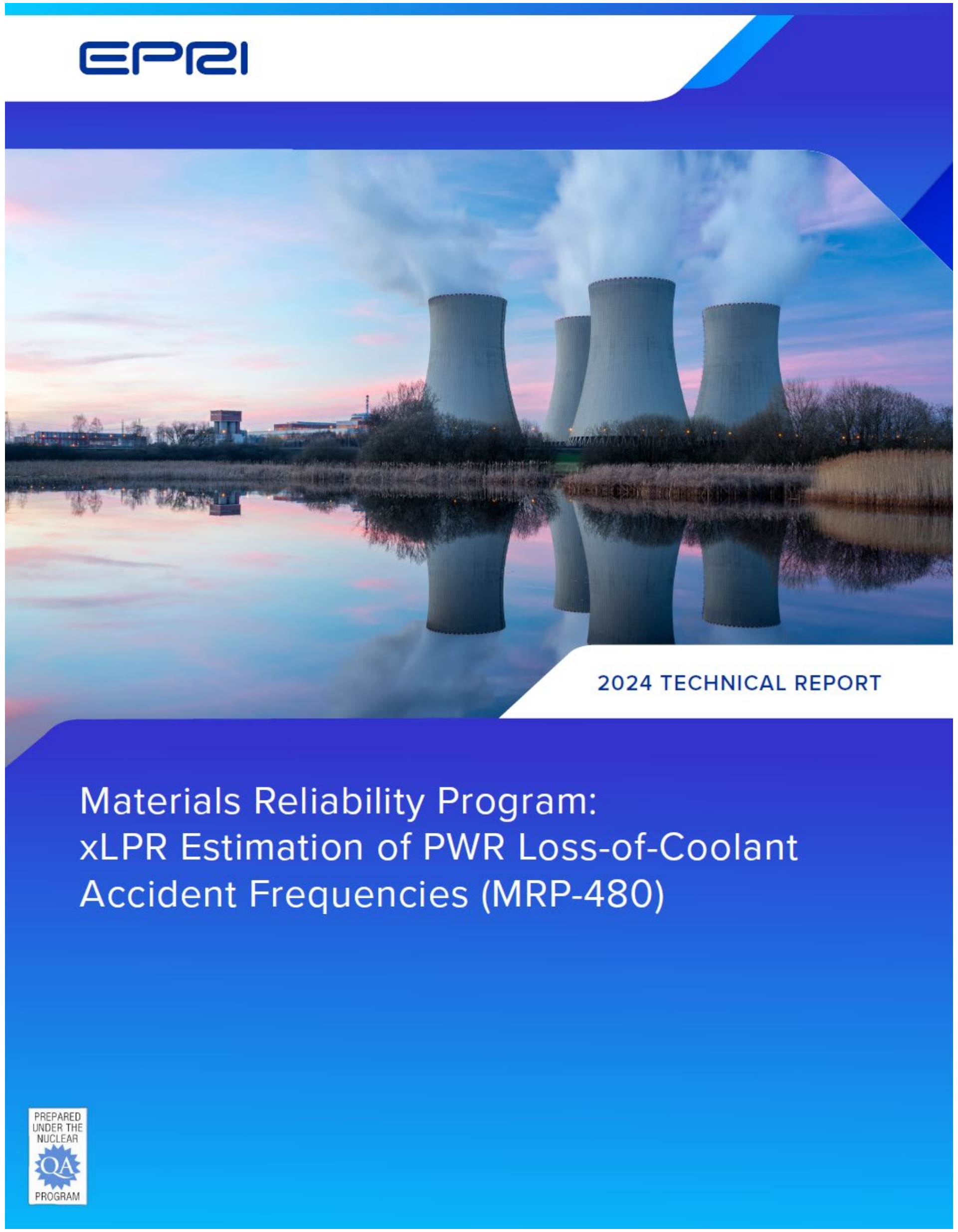
- **Purpose of PDI**: Provides a rigorous framework for qualifying ultrasonic examination systems used in nuclear piping inspections, including those within the scope of NUREG-1829.
- **Regulatory Compliance**: Ensures inspections meet ASME and NRC standards, enhancing reliability and safety across nuclear power plants.
- **Industry Value**: Participation in PDI supports continued safety, reliability, and efficiency for utilities, vendors, and regulators.

Since 1994, EPRI has led the PDI program, qualifying over 100 procedures, conducting hundreds of thousands of personnel tests, and supporting adoption in multiple countries.

NUREG-1829 Comparative Analyses
Leak Detection
Leak Before Break

NUREG-1829 Comparative Analyses

- MRP-480, *Materials Reliability Program: xLPR Estimation of PWR Loss-of-Coolant Accident Frequencies*, was used to evaluate PWR piping systems identified as LOCA-sensitive in NUREG-1829
  - Investigated dissimilar metal welds and stainless steel welds
    - EPRI has since investigated welds in carbon steel piping as well



NUREG-1829 Comparative Analyses

- Used xLPR, which is a state-of-the-art **probabilistic fracture mechanics code** jointly developed by the NRC's Office of Nuclear Regulatory Research and EPRI
- MRP-480 key outputs:
  - Rupture frequency outputs (which were compared against LOCA frequency estimates given in NUREG-1829)
  - Time between detectable leakage and LOCA
  - Time between detectable leakage and rupture
- Investigated 20 additional years of service experience since NUREG-1829 was published

NUREG-1829 Comparative Analyses

Alloy 82/182 dissimilar metal welds

- Most limiting in the PLP
  - Most cases showed zero rupture occurrence when inspection and leak rate detection were credited
    - Nonzero rupture cases were part of sensitivity analyses and do not reflect realistic operating conditions

Similar metal welds

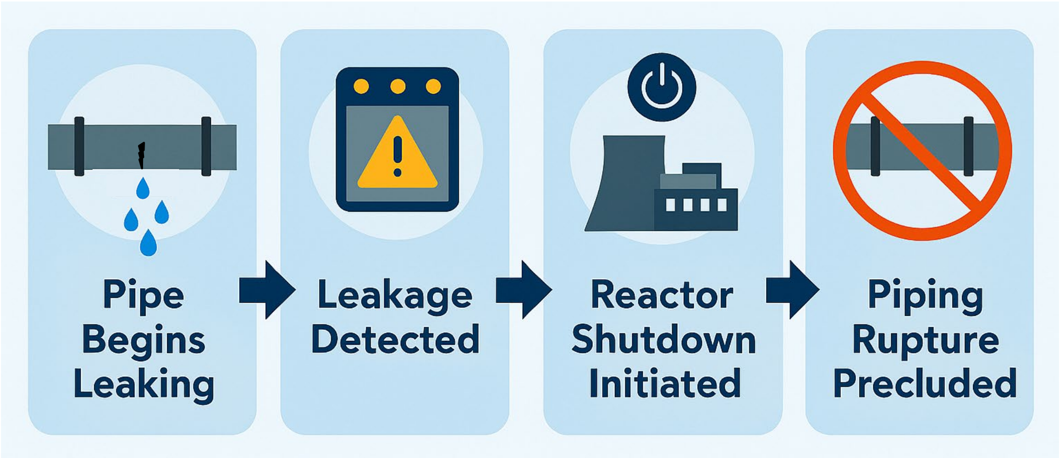
- Minimal flaw growth
  - No leaks or ruptures
  - Demonstrated high flaw tolerance, consistent with operating experience
  - Carbon steel welds had similar performance to stainless steel welds

- Evaluation of time between leakage and rupture showed that operators had sufficient time to identify leakage and shutdown reactor

- Results demonstrates that substantial margin between the target break frequency and the typical TBS used by Licensees sufficiently accounts for plant-to-plant variability, making plant-specific justification of NUREG-1829's applicability unnecessary

Leak Detection Capabilities

- Operating plant leakage action levels are grounded in a risk-informed approach, supported by PRA, operating experience, and engineering judgment, ensuring that the recommendations are both conservative and practical
- Enhanced safety through early detection is supported by xLPR demonstrating a significant window for intervention



Leak Detection Capabilities

- For example, WCAP-16465 provides standardized guidance for PWR licensees on establishing RCS leakage action levels and response guidelines
  - RCS leakage is classified into distinct levels based on severity and potential impact:
    - **Action Level 1:** One seven (7) day rolling average of daily Unidentified RCS leak rates > 0.1 gpm
    - **Action Level 2:** Two consecutive daily Unidentified RCS leak rates > 0.15 gpm
    - **Action Level 3:** One daily Unidentified RCS leak rate > 0.3 gpm

Leak–Before-Break

- All operating PWRs in the US have received Leak-Before-Break (LBB) approval for the PLP
  - One additional reactor that is restarting is pursuing LBB
- LBB approval demonstrates that leak detection systems are sufficient, making plant-specific leak detection evaluations redundant
- LBB evaluations are used to confirm that breaks larger than the TBS are extremely unlikely
  - Supports the continued use of generic TBS values without requiring plant-specific justification, as long as LBB conditions are met

SUMMARY

- Industry programs focused on leveraging operating experience, sound engineering principles, and advanced analytical tools to ensure that the reactor coolant pressure boundary is effectively managed

01	The fleet continues to implement a substantive ongoing inspection program for the reactor coolant pressure boundary inclusive of the PLP.
02	The likelihood of a break larger than the TBS continues to be extremely remote is applicable to the operating fleet without the need for plant-specific justification.
03	The substantial margin between the target break frequency and the typical TBS used by Licensees sufficiently accounts for plant-to-plant variability.

Conclusion

- The industry's current materials management and inspection infrastructure is sufficient to ensure the continued safe operation of nuclear power plants
  - Existing inspection programs appropriately prioritize the highest safety and risk significance welds
  - Decades of additional operating experience have not revealed new degradation mechanisms that would challenge the assumptions of NUREG-1829
- The conclusions of NUREG-1829 remain valid and applicable to the operating fleet, supporting the continued use of TBS without the need for plant-specific justification
  - The likelihood of a break larger than the TBS continues to be extremely remote

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NRC EFFICIENCY IMPROVEMENTS

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Director, Fuels

September 18, 2025

NUCLEAR ENERGY INSTITUTE

NRC Efficiency Improvements

Combined IE & 50.46a/c Rule

Increased Enrichment (IE)

- Remove 5 wt% U-235 limit
- Increase to policy limit of 20 wt% U-235
- Improved regulatory efficiency and durability:
  - ATF/LEU+/HBU and 24-month fuel cycle
  - Advanced reactor fuels

50.46a: Risk-Informed LOCA

- Proposed Final Rule Discontinued in 2016
- Voluntary, risk-informed alternative to 50.46
- Increased potential for larger power uprates
- Improved realism for advanced fuel licensing

50.46c: Acceptance Criteria for ECCS

- Proposed Final Rule withdrawn in 2024
- Accounts for fuel embrittlement mechanisms
- Excessive burden for little to no safety benefit
- Commission returned it to the staff and required combining 50.46a/c with the IE rulemaking

- Allows enrichments to LEU+/HAELU
- NUREG-2266 for up to 10 wt% U235 enrichments & 80 GWd/MTU burnup
- Existing UF6 packages <10 wt% U235
- Amended control room dose design criteria (5 to 25 Rem TEDE)
- Improved AST models in RG 1.183R2
- Reduced risk significance of LOCA/FFRD
- ATF/LEU+/HBU and uprates do not reasonably increase piping degradation
- Current programs addressing concerns
- Address degradation issues in AMPs, ASME Code, etc. but not in the IE rule

Questions

Discussion Period

Public Comment Period

Closing Remarks

Adjourn