

# EPRI NDE Research for Long Term Operations



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1/22/26

# Aging Status of Existing Nuclear Fleet

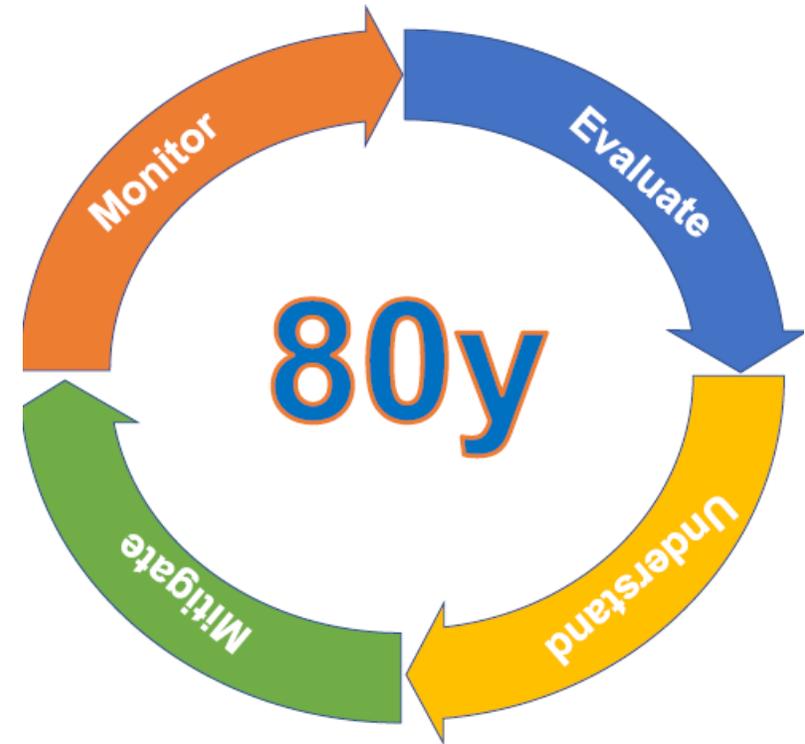


# Long-Term Operation (LTO) of Existing Fleet

- Long Term Operation (LTO): operating existing nuclear power plants reliably and safely for longer than the original operating license term (e.g., beyond 30 to 40 years in most countries).
- >90% of existing nuclear fleet expects to operate at least 80 years.

Requires Aging Management of:

- Reactor Vessel & Core Internals
- Steam Generator (Heat Exchanger)
- Primary Components (Piping, Valves, Pumps)
- Balance of Plant Components & Piping
- Spent Fuel Pools & Storage Casks
- Concrete and Civil Structures
- Electrical Cables



# EPRI Research on NDE for LTO

- License Renewal and LTO often lead to increased scope of inspections for BOP Components and Civil Infrastructure.
- EPRI's NDE and Plant Engineering Programs collaborate to provide guidance on implementation of AMPs with NDE Inspections.
  - Buried Piping, Structures and Components
  - Service Water Piping
  - BOP Heat Exchangers
  - Structures Monitoring Program
  - Selective Leaching
  - Tank Inspections
  - One-time inspections



# GALL SLR Mechanical AMPs with NDE

- M1. ASME Section XI Inservice Inspection IWB, IWC, IWD
- M3. Reactor Head Closure Stud Bolting
- M4. BWR Vessel ID Attachment Welds
- M5. BWR Feedwater Nozzle
- M7. BWR Stress Corrosion Cracking
- M8. BWR Penetrations
- M9. BWR Vessel Internals
- M10. Boric Acid Corrosion
- M11B. Cracking of Nickel-Alloy Components and Loss of Material due to Boric Acid-Induced Corrosion in Reactor Coolant Pressure Boundary Components (PWRs Only)
- M12. Thermal Aging Embrittlement of Cast Austenitic Stainless Steel
- M16. PWR Vessel Internals
- M17. Flow-Accelerated Corrosion
- M18. Bolting Integrity
- M19. Steam Generators
- M20. Open Cycle Cooling Water Systems
- M21A. Closed Treated Water Systems
- M23. Inspection of Overhead Heavy Load and Light Load (Related to Refueling) Handling Systems
- M25. BWR Reactor Water Cleanup System
- M27. Fire Water System
- M29. Aboveground Metallic Tanks
- M30. Fuel Oil Chemistry
- M32. One-Time Inspection
- M33. Selective Leaching
- M35. ASME Code Class 1 Small-Bore Piping
- M36. External Surfaces Monitoring of Mechanical Components
- M37. Flux Thimble Tube Inspection
- M38. Inspection of Internal Surfaces in Miscellaneous Piping and Ducting Components
- M41. Buried and Underground Piping and Tanks
- M42. Internal Coatings/linings for in Scope Piping, Piping Components, Heat Exchangers, and Tanks
- M43. High-Density Polyethylene (HDPE) Piping and Carbon Fiber-Reinforced Polymer (CFRP) Repaired Piping



# Selective Leaching

# Selective Leaching Challenges

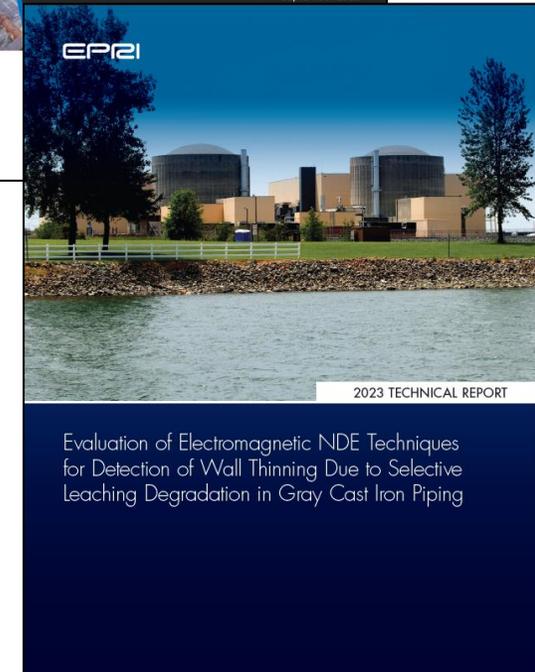
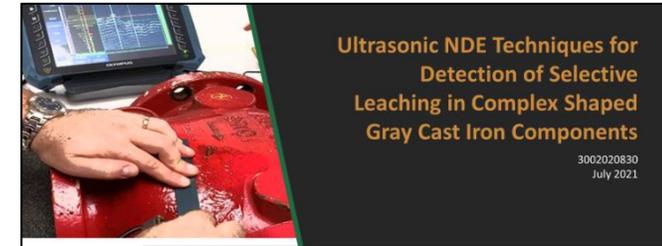
- Impact on power reactors licensed to operate beyond 40 years (and even more so for those licensed beyond 60 years)
  - NRC Information Notice 2020-04, Operating Experience Related to Failure of Buried Fire Protection Main Yard Piping
- Industry incurs significant expenses to meet aging management commitments for long term operations
  - Large inspection population sample sizes
  - Development of periodic inspection programs
- Inspection Challenges
  - Lack of previously demonstrated NDE techniques
  - Susceptible components can be difficult to inspect (e.g., valve & pump casing)



# Selective Leaching NDE Reports

## “Inspection Techniques” Research

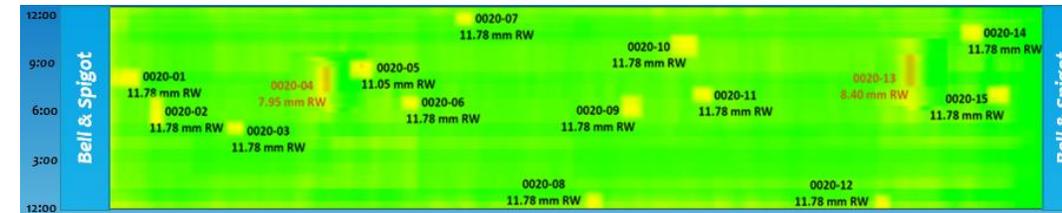
- Technical Brief: [3002020830](#) “Ultrasonic Techniques for Selective Leaching in Gray Cast Iron Components”
  - Scope: detection of internal selective leaching from outside surface examination (opposite surface)
  - 3 techniques successful demonstrated on field removed components for detection and characterization of opposite surface SL
- Technical Brief: [3002020832](#) “Electromagnetic NDE Techniques for Gray Cast Iron Piping”
  - Four (4) different techniques evaluated on field removed piping components
  - Includes both internal and external techniques
- Technical Report: [3002023785](#) “Evaluation of Electromagnetic NDE Techniques for Detection of Wall Thinning Due to Selective Leaching Degradation in Gray Cast Iron Piping”
  - More details and analysis of results from EM techniques
  - Includes results for two (2) additional techniques evaluated in 2022



**Reports Provide Techniques and Quantitative Results of Demonstration**

# Bruce Power's Application of RFT Technique

- In 2021, Bruce Power utilized the Remote Field Testing (RFT) technique to internally inspect >200 linear feet of cast iron fire water piping
- ~200 pitting indications were found across 20 pipe segments
- Pipes were abrasively blasted to reveal selective leaching degradation on both internal & external surfaces
- Successful use and application of RFT to identify extent of degradation led to proactive plans to begin replacements of susceptible portions of fire water ring header



# Future Research Needs for Selective Leaching NDE

- Field trials of NDE for selective leaching needed
- NDE techniques to detect and measure selective leaching
- UT to detect selective leaching on the exam side of the component



# Socket Welds

# EPRI-SW-PA-1 (R3)

- Procedure for Encoded Phased Array Ultrasonic Examination of Small-Bore Socket Fillet Welds
- Applicability
  - SW OD (19 mm, 25 mm, 32 mm, 38 mm, 51 mm)
  - Pipe Schedule (40, 80 and 160)
  - Stainless Steel, Carbon Steel
  - Fillet weld taper 1:1 and 2:1
- Download on [www.epri.com](http://www.epri.com)
  - ID: **3002023888**

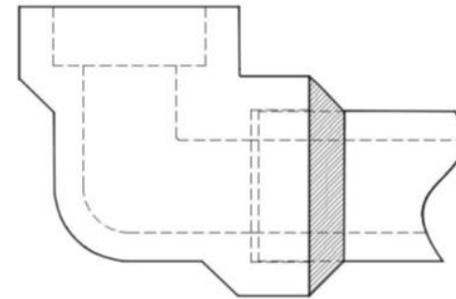


Illustration of 0.75-inch, 1-inch and 2-inch Sch.40, 80 and 160 Carbon Steel Pipe Elbow with 1:1 taper

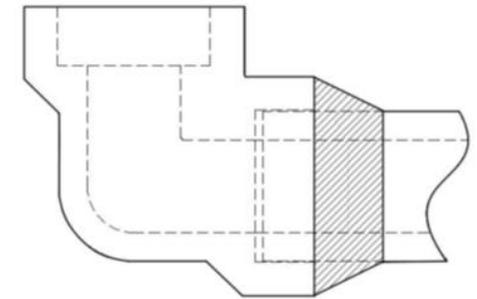
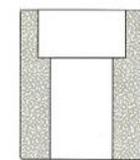
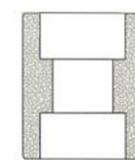


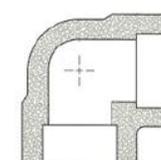
Illustration of 0.75-inch, 1-inch and 2-inch Sch.40, 80 and 160 Carbon Steel Pipe Elbow with 2:1 taper



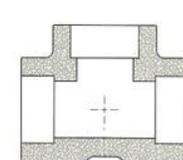
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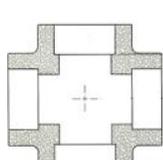
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[90° Elbow]



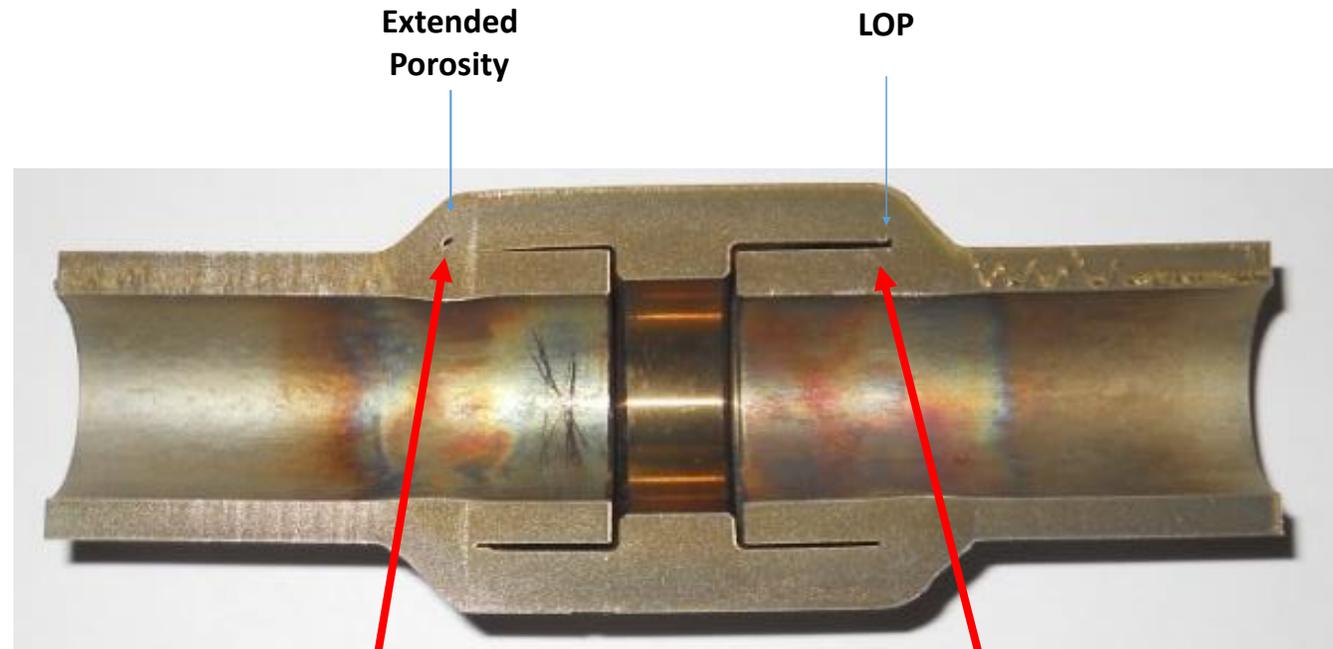
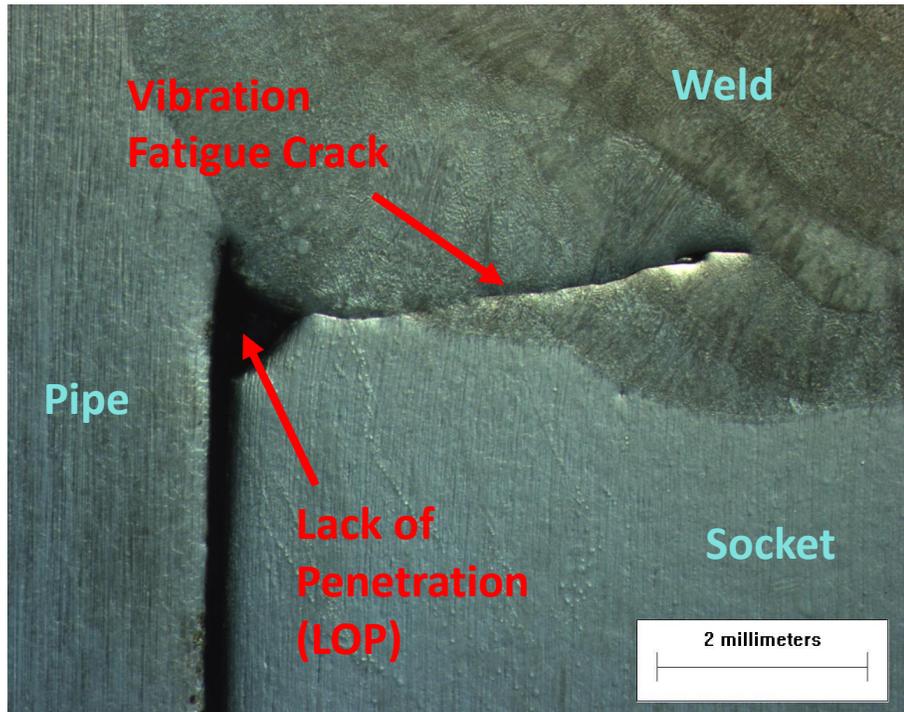
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# Vibration Fatigue

- Service induced flaws due to welding/manufacturing defects



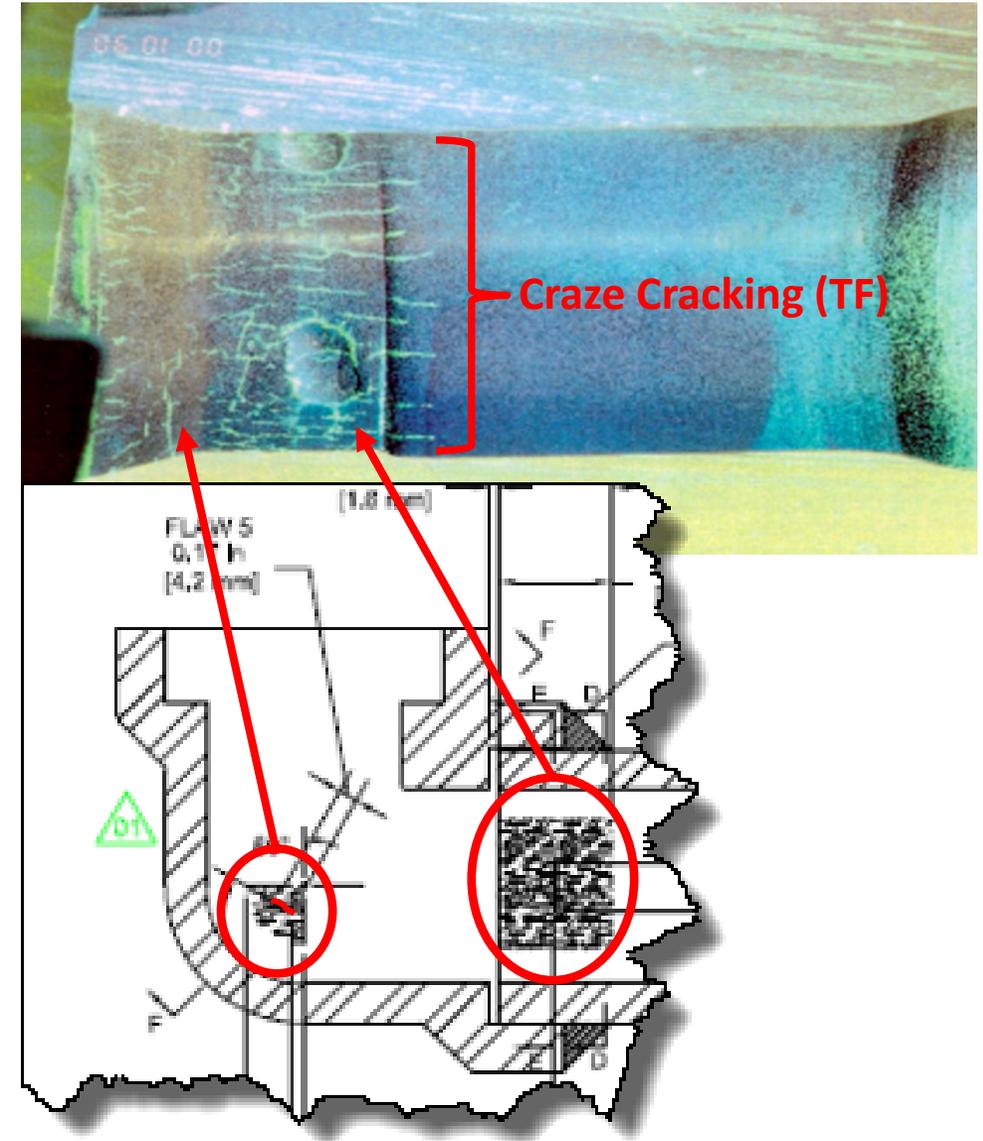
Extended Porosity



Lack of Penetration

# Thermal Fatigue

- Service induced type flaws
- May or may not involve a socket weld configuration
- Caused by concentrated stress due to large thermal “spikes”
- Only ID initiated
- Base metal flaws
- Tends to form craze cracking
- Can have singular, deeper flaw



# Procedure Evaluation

- For the vibration fatigue application, the ultrasonic phased array technique was found to perform the following:
  - Properly characterize the relevant weld toe cracks and **most root** cracks that were implanted
  - Exhibit mixed results detecting and characterizing the relevant and non-relevant lack-of-fusion defects that were implanted
- For the thermal fatigue application, the ultrasonic phased array technique developed was found to perform the following:
  - Properly characterize the pipe base material crazing and crack defects implanted
  - Properly characterize the defect implanted in the pipe's heat affected zone
  - Exhibit mixed results detecting the implanted defects in the pipe area under the weld

# MRP-350 Overview (1/2)

- **Product ID:** [3002023883](#)
- Presents the ultrasonic phased array technique development results for the examination of small bore, socket-welded piping connections that are susceptible to vibration or thermal fatigue

# MRP-350 Overview (2/2)

- EPRI originally published procedure [EPRI-SW-PA-1](#) in 2012, addressing 1- and 2-in. (25.4- and 50.8-mm) diameter socket weld fittings with Schedules 40, 80, and 160, and with 1:1 and 2:1 weld tapers
  - This inspection procedure was published as a part of MRP-350
- Revised (1) in 2015 to add ¾” diameter socket weld investigation and results
- Revised (2) in 2021 to include Carbon Steel socket welds and 1.25-inch socket welds
- Revised (3) in 2022 to include the use of the TOPAZ 32 inspection system and included the results from a high temperature study. The inspection procedure EPRI-SW-PA-1 has been removed from MRP-350 and is available for an independent download on [www.epri.com](http://www.epri.com)



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