



Cast Austenitic Stainless Steel Performance Demonstration Development



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2026 NRC-Industry NDE Technical Information Exchange
January 21st – 22nd

Topics

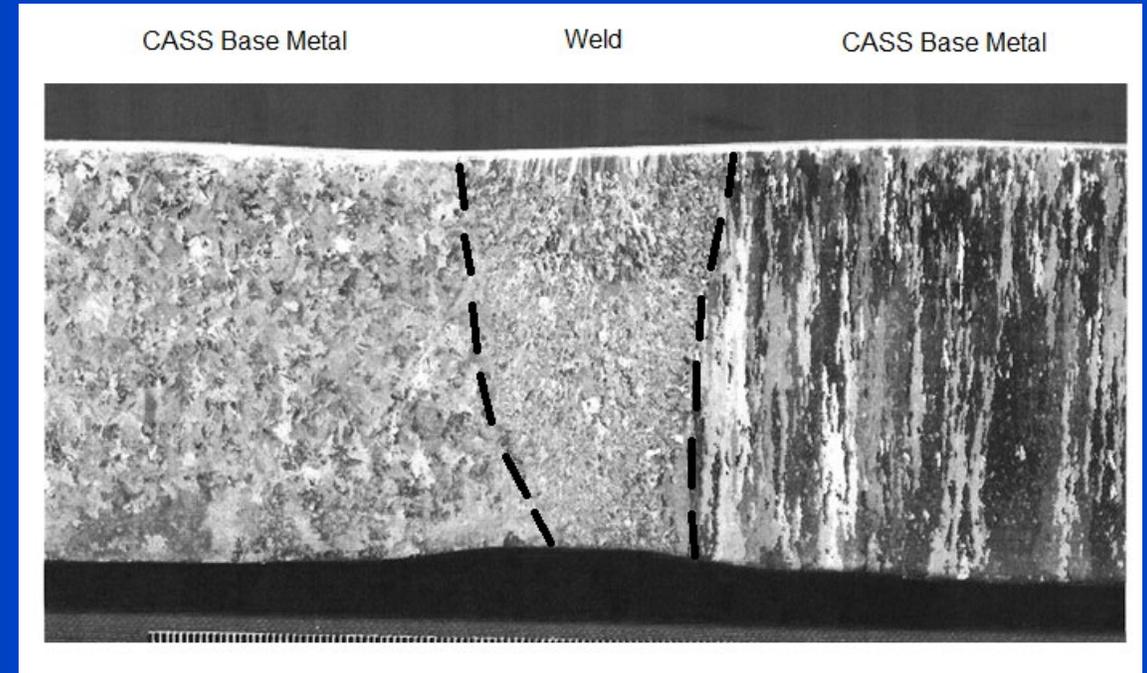
- Background
- CASS Flaw Tolerance Evaluation and Probabilistic Fracture Mechanics (PFM) Analytical Approach and Current ASME Code Status for CASS
- Advancements in Flaw Making Technology



Background

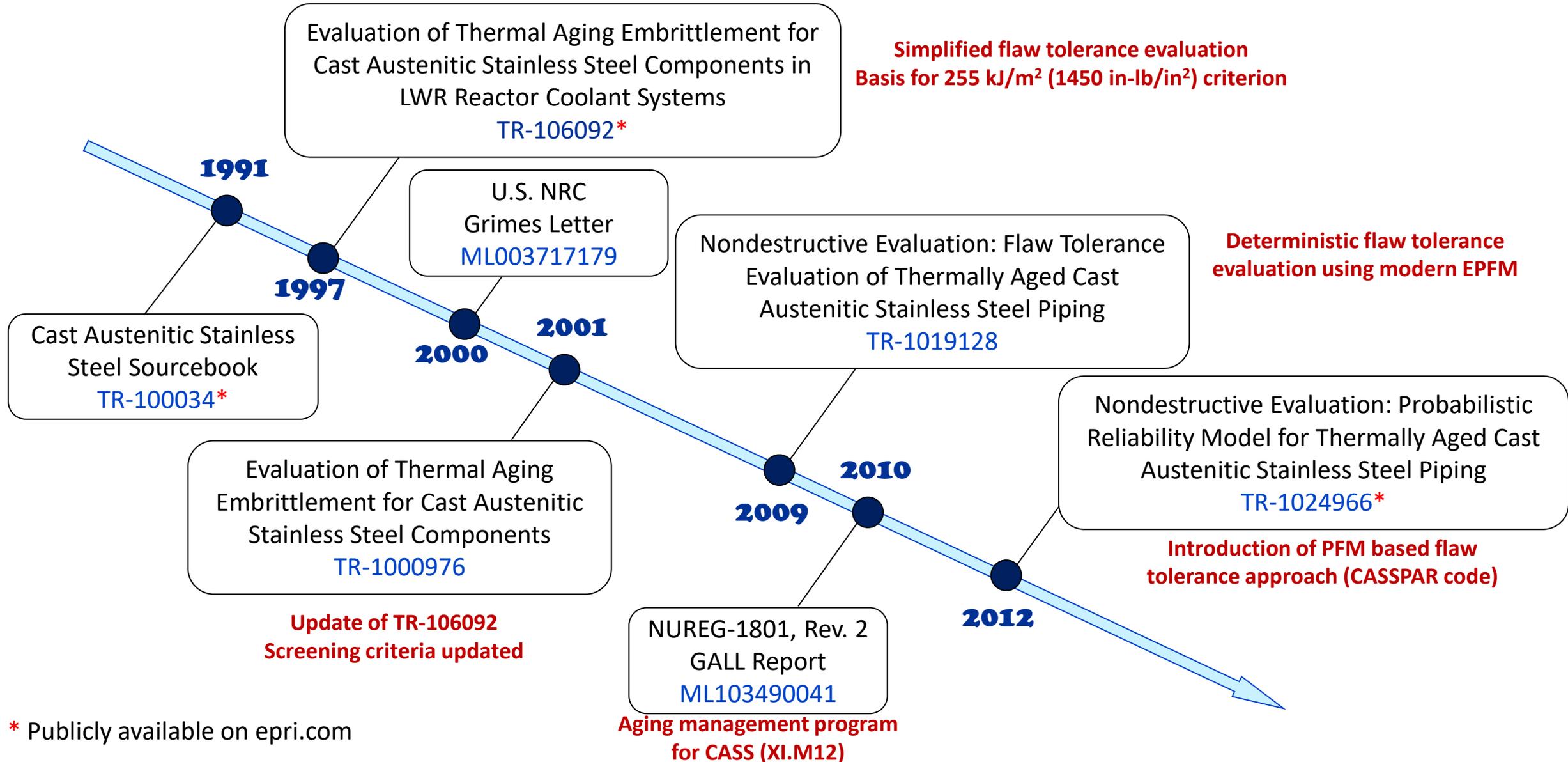
Background

- CASS materials have been used in many RCS piping system components in PWRs
- Thermal aging is known to occur in CASS materials, at a greater rate, for those with a higher delta ferrite percentage (i.e., reduction in toughness and increase in strength)

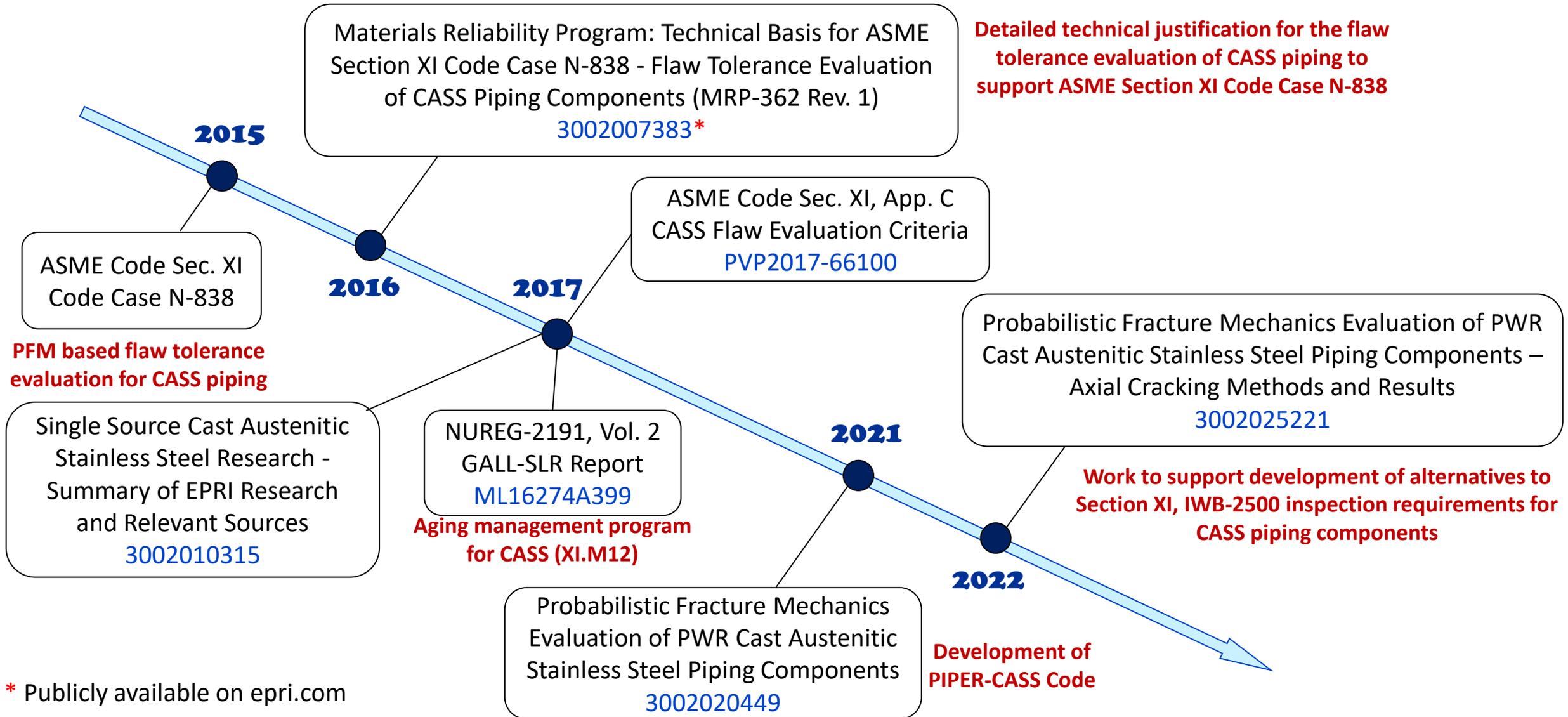


Highly non-uniform grain structure due to austenite and ferrite segregation

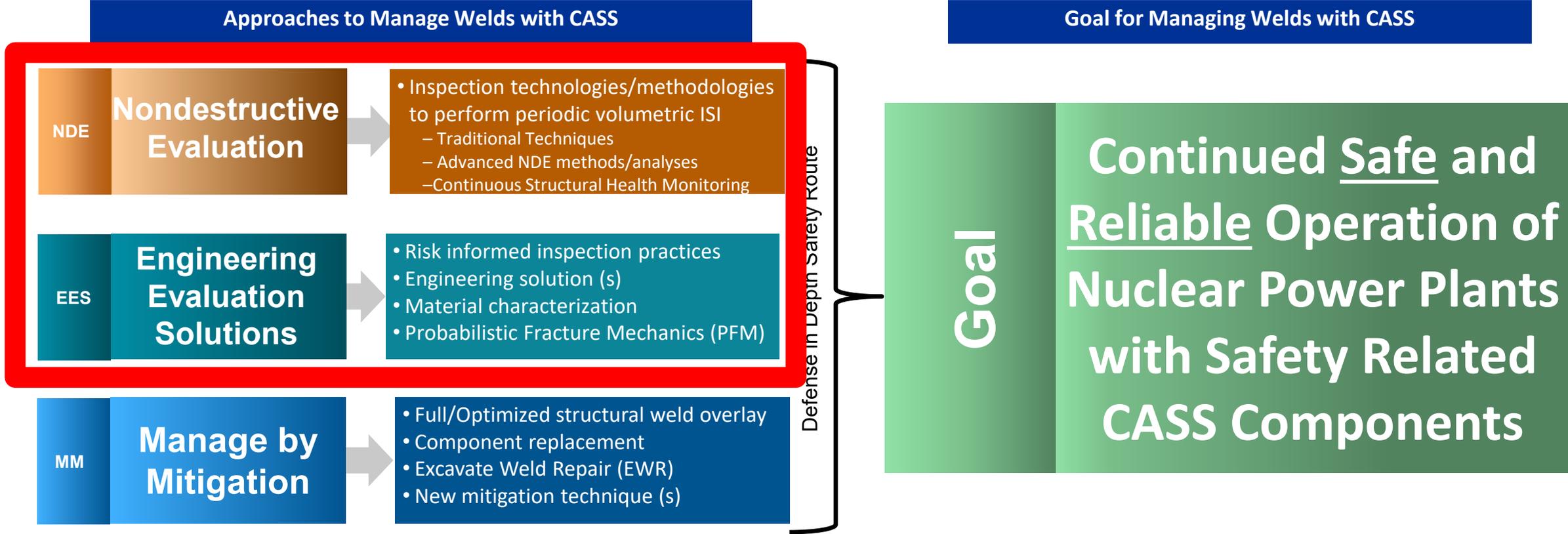
Background - EPRI CASS Flaw Research Timeline (1/2)

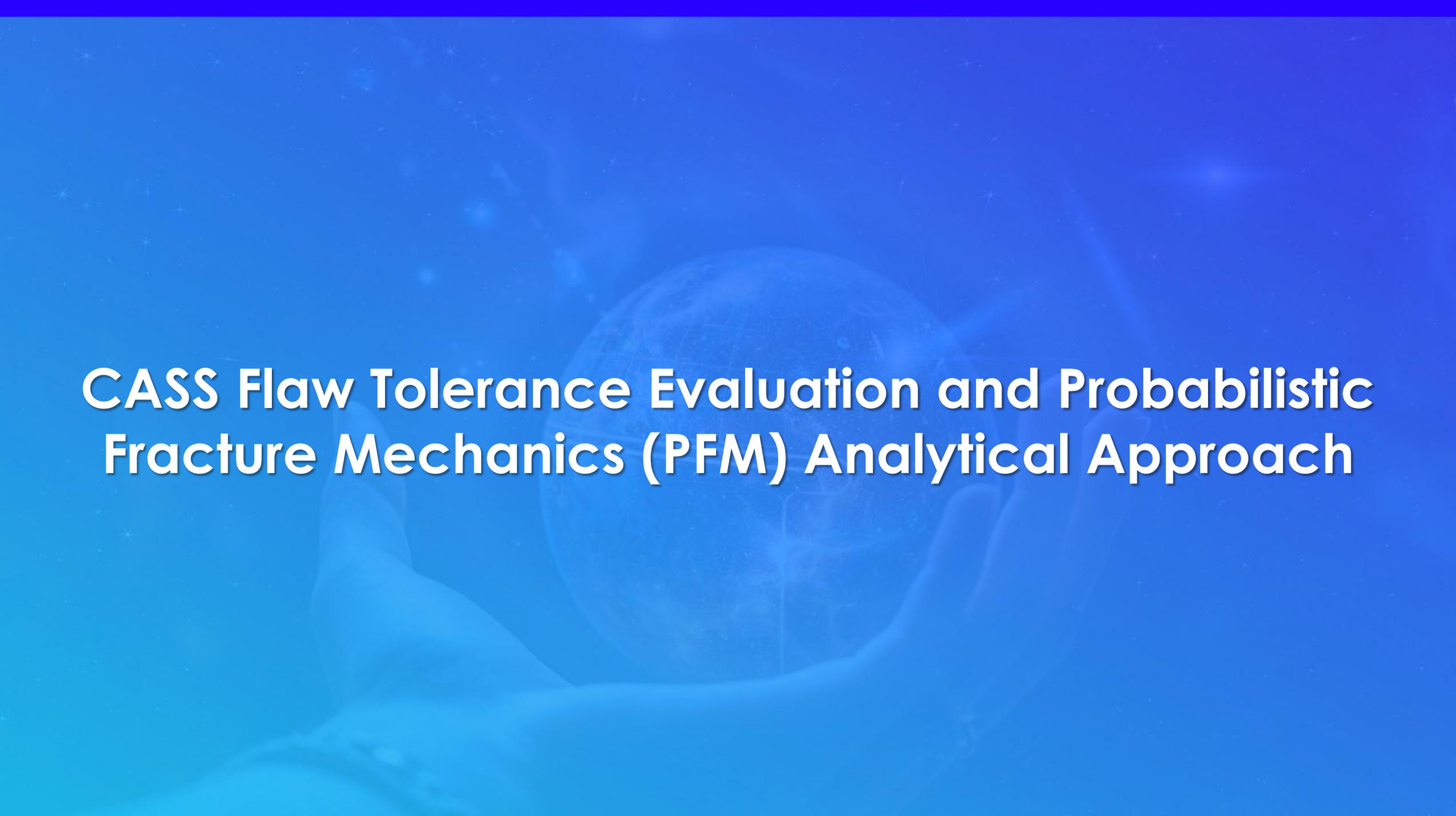


Background - EPRI CASS Flaw Research Timeline (2/2)



Overview - Multi-faceted Approach for CASS Research





CASS Flaw Tolerance Evaluation and Probabilistic Fracture Mechanics (PFM) Analytical Approach

Flaw Tolerance Evaluation for CASS – Approaches

- Use Deterministic Fracture Mechanics Analysis to Calculate Acceptable Flaw Sizes in CASS Piping
 - Assume worst case material properties
 - Define all inputs as bounding (i.e., conservative) values
 - Perform a single calculation using appropriate analytical solutions (EPFM) for expected failure mode
 - Calculate result in terms of maximum tolerable flaw sizes to maintain structural factors (i.e., Code margins)

OR

- Use an ASME Code-approved alternative method using a probabilistic fracture mechanics (PFM) approach

Drivers for Applying PFM Analyses

- Research has shown that CASS material microstructure is not conducive to reliable ultrasonic testing (UT) techniques especially when:
 - Detecting and sizing of axially oriented flaws is required
 - Depth sizing circumferential flaws is required
- Thermal embrittlement of aged CASS material results in degraded material toughness, reducing acceptable flaw sizes
- In 2019, EPRI began a project using probabilistic fracture mechanics (PFM) to evaluate the effect of these limitations
 - This work is supporting the development alternatives to Section XI, IWB-2500 inspection requirements for CASS piping components

Overall Objectives – Applying PFM based on RR Results

- Objective 1 (axial cracking):
 - Investigate axial fatigue cracking assuming no benefit of periodic NDE nor online leak detection
 - Demonstrate that detection of axial cracks is not necessary to maintain structural and leak tight integrity
- Objective 2 (circumferential cracking):
 - Investigate circumferential fatigue cracking assuming periodic NDE without a qualified flaw depth-sizing process (i.e., length only)
 - Demonstrate that an **alternative flaw evaluation** procedure ensures structural and **leak tight integrity**

Results of Research

- Developed ASME Code Cases to provide alternate requirements for CASS piping
 - ASME Record 23-2033 proposes a Code Case to exclude applicable CASS locations from requirement to detect **axially oriented flaws** during volumetric examinations
 - ASME Record 24-1062 proposes a Code Case implementing an alternative to IWB-3642 for flaw evaluation of **circumferentially oriented flaws** without crediting depth sizing capability
- **EPRI report 3002023893 (MRP-479)** provides technical basis for both ASME Records 23-2033 and 24-1062
 - Freely downloadable at:
<https://www.epri.com/research/products/000000003002023893>

Additional EPRI Publications Supporting PFM Analysis for CASS NDE

- Technical Update [3002020449](#) - Probabilistic Fracture Mechanics Evaluation of PWR Cast Austenitic Stainless Steel Piping Components), published August 2021
- Technical Update [3002025221](#) - Probabilistic Fracture Mechanics Evaluation of PWR Cast Austenitic Stainless Steel Piping Components – Axial Cracking Methods and Results), published November 2022

Record 23-2033: Overview

Inspection of CASS without Axial Flaw Detection Capability

Alternative Requirements

- Provides alternative volumetric examination requirements that do not require circumferential scans for detecting axial cracking at circumferential butt welds in CASS piping components
- Axial scans to detect circumferential flaws still required

Scope

- Includes PWR piping and vessel nozzle butt welds with CASS base materials in the main loop and surge line
 - Does not apply to AP-1000 SG to RCP nozzle-to-nozzle weld
 - Does not apply to branch lines other than the surge line
 - For surge lines, does not apply to PWRs operating with frequent power level cycling
 - Piping components in plants that have a nominal gross power output less than 700 MWe and were licensed and authorized for operation after January 1, 2024 (New Reactor Designs)
- Applies to portions of exam volume where the UT beam would need to pass through CASS to examine that volume
 - Not necessarily limited to CASS base material
 - However, does not apply to PWSCC-susceptible material and ferritic material

Record 24-1062: Overview

Evaluation of Circumferential Flaws without Crediting Depth Sizing

Alternative Requirements

- Proposed Code Case for alternative to IWB-3642 for flaw evaluation requirements for circumferentially oriented flaws in CASS piping components (to address flaw-depth sizing challenge for CASS)
- Alternative flaw evaluation follows the Nonmandatory Appendix C process, except that a depth (a/t) of 1.0 is assumed
 - Alternative permits acceptance of flaws not demonstrated to have an a/t less than 0.75, but *flaws that are visibly leaking remain unacceptable* per IWB-3522

Scope

- Scope includes PWR main loop piping and vessel nozzle circumferential butt welds with CASS materials
 - Surge line and branch line piping **not included**
 - Piping components in plants that have a nominal gross power output less than 700 MWe and were licensed and authorized for operation after January 1, 2024 (New Reactor Designs) **not included**
- Consistent with technical basis, application of alternative flaw evaluation limited to:
 - RMS error on length sizing ≤ 1 inch
 - End-of-evaluation period total flaw angle ($2\theta_f$) $\leq 32^\circ$
- Can be used in successive outages to continue to accept a flaw without measurable growth; following detection of growth, can accept only until the outage following detection of growth (assuming flaw is still acceptable per updated evaluation)

Status of ASME Code Actions for CASS

- Standards Committee review and approval ballots sent out after Dallas 2025 Code Meeting
- (To date there are no negatives or comments)
- Both ballots scheduled to close 1/20/2026



Advancements in Flaw Making Technology

Flaw Implantation Development

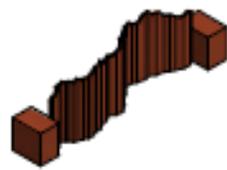
- Work underway is focused on developing reliable methods to implant flaws to known depths greater than 25% of the wall thickness that do not leave unfavorable ultrasonic signatures



EDM Electrode 1a
SCALE 1 : 1



Side
SCALE 1 : 1



EDM Electrode 2a
SCALE 1 : 1



Side
SCALE 1 : 1



EDM Electrode 3a
SCALE 1 : 1



Side
SCALE 1 : 1



Bottom
SCALE 1 : 1

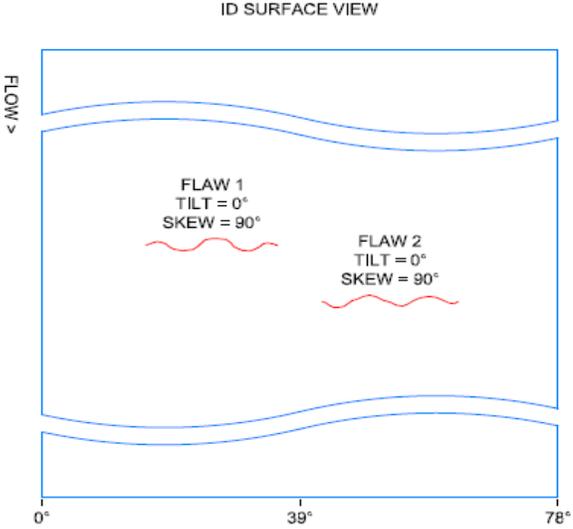
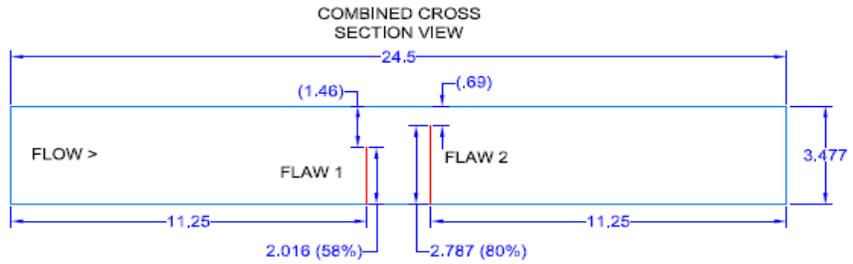
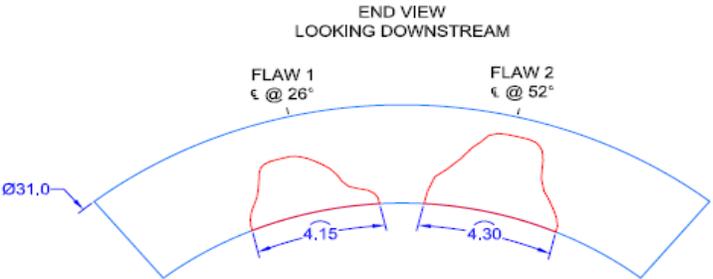


Bottom
SCALE 1 : 1



Bottom
SCALE 1 : 1

Flaw Implantation Development (Continued)



NOTES:

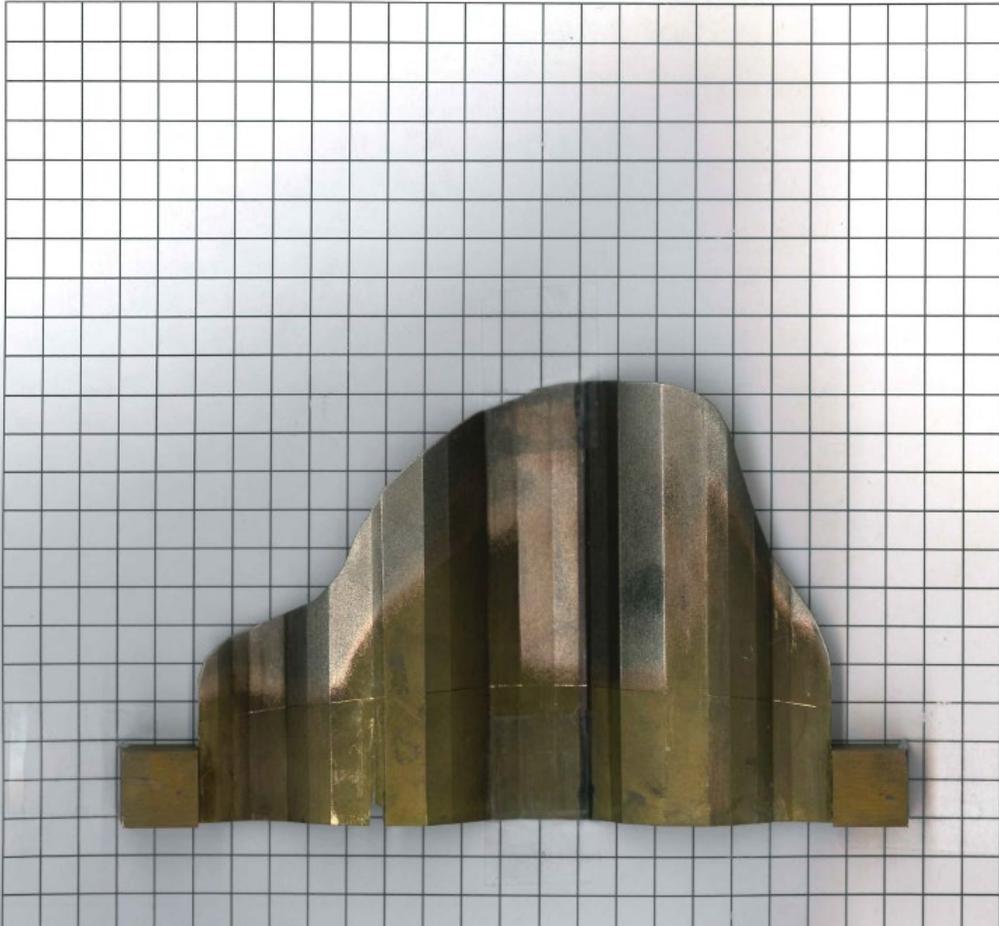
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		DESCRIPTION						REV
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		DESCRIPTION: DETAILED FLAW VIEWS NON-SECURE AS-BUILT DRAWING SPECIMEN ID: 347-31-01P						
PREPARED BY: M. MCCALLUM	DATE: 18 JUNE 2024	DWG. NO. 347-31-E01P				REV. 00		
 <small>Digitally signed by Robert F. Szijgyo Date: 2024.06.19 21:20:56 -0400</small>		DATE: 19 JUNE 2024	SCALE: 1:4		SHEET 1 OF 1			

Flaw Implantation Development (Continued)

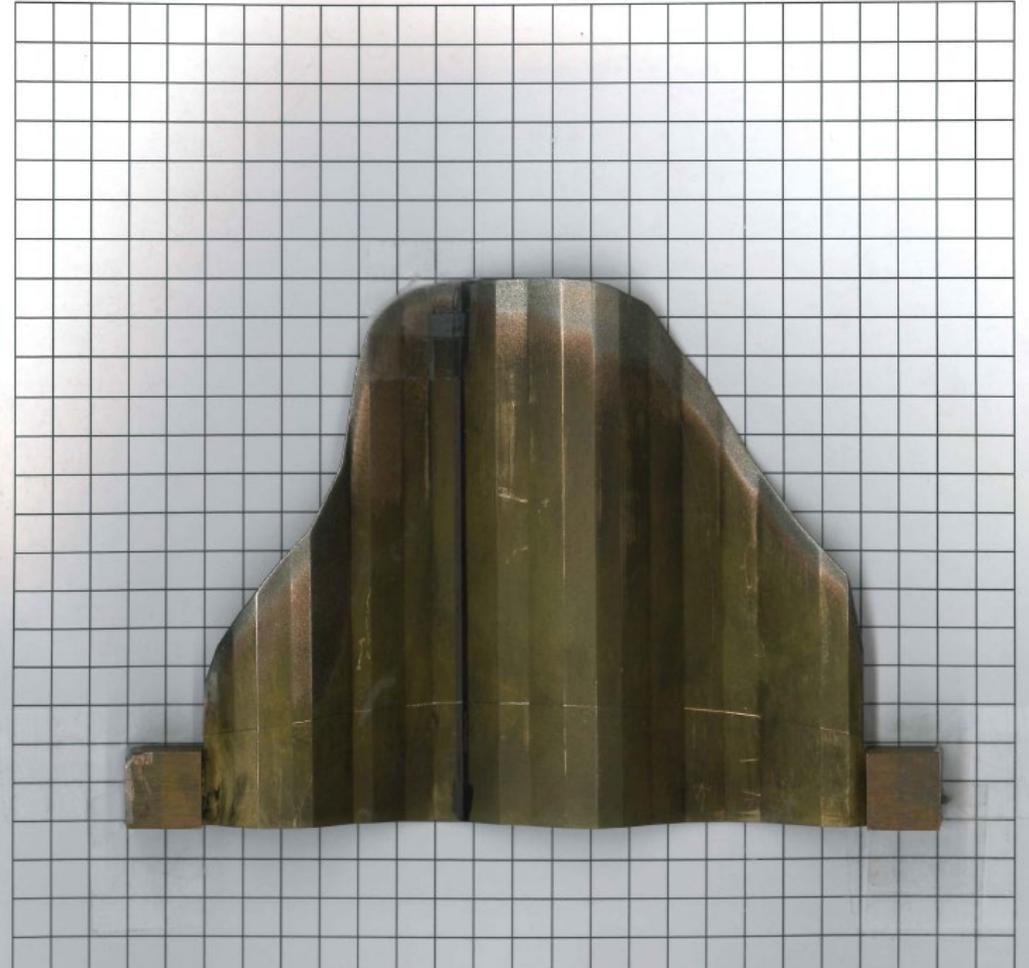
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Grid Size: 0.25"

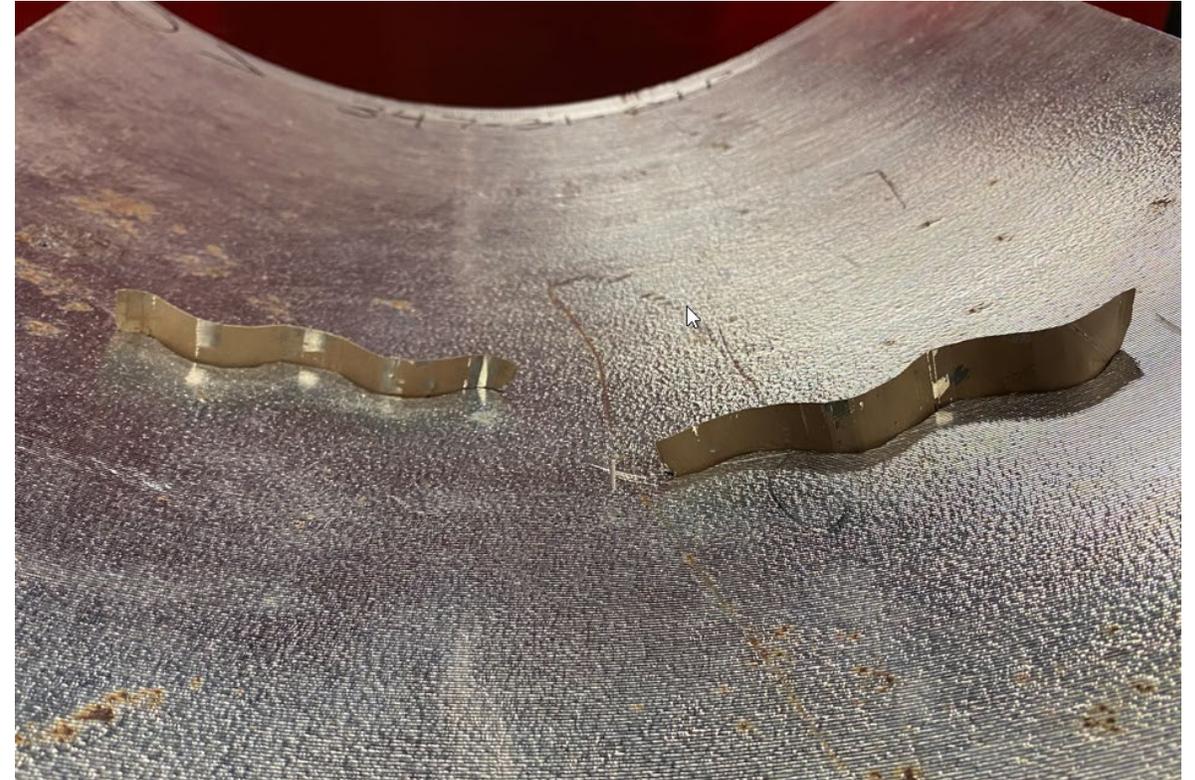


Flaw #: 2

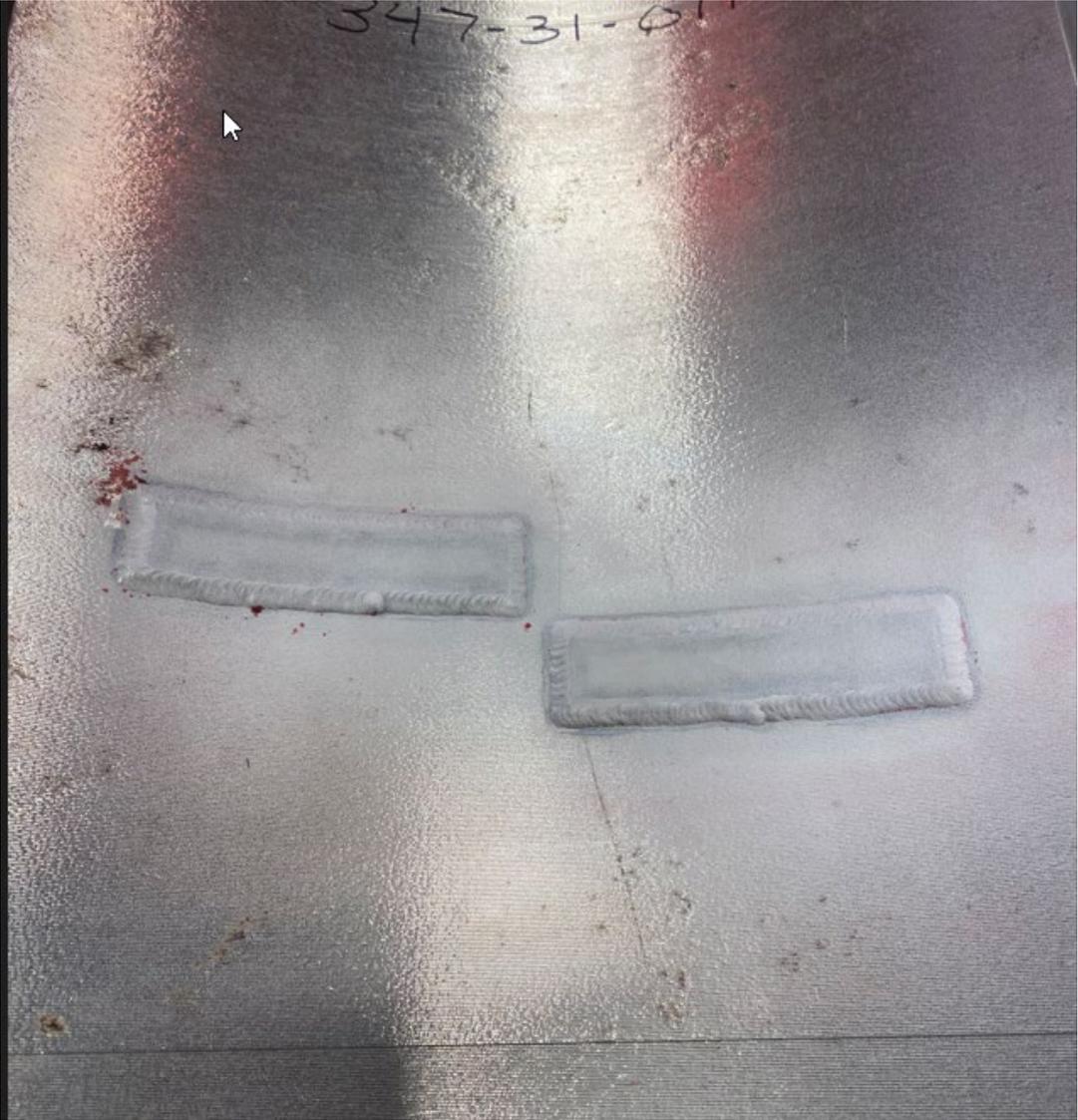
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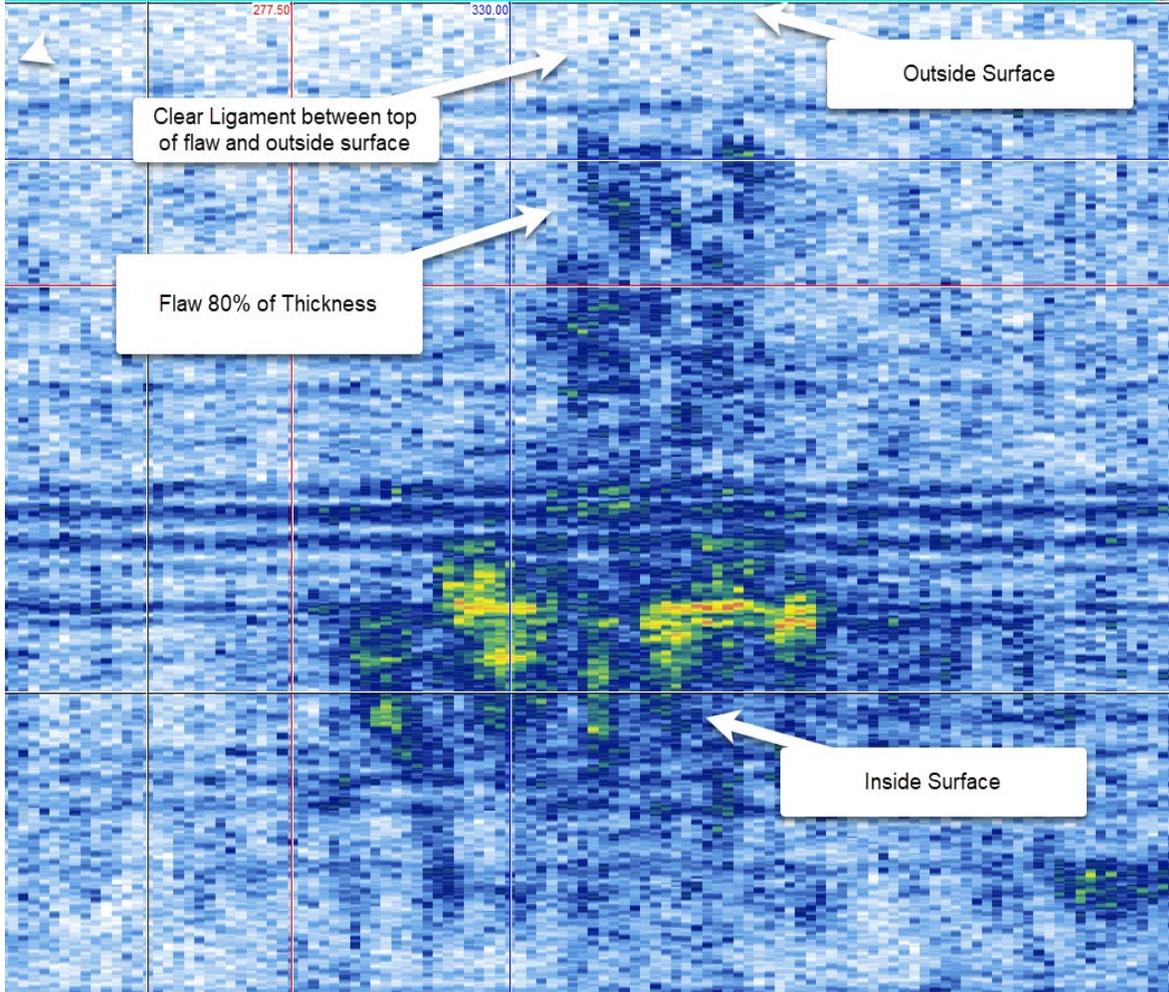
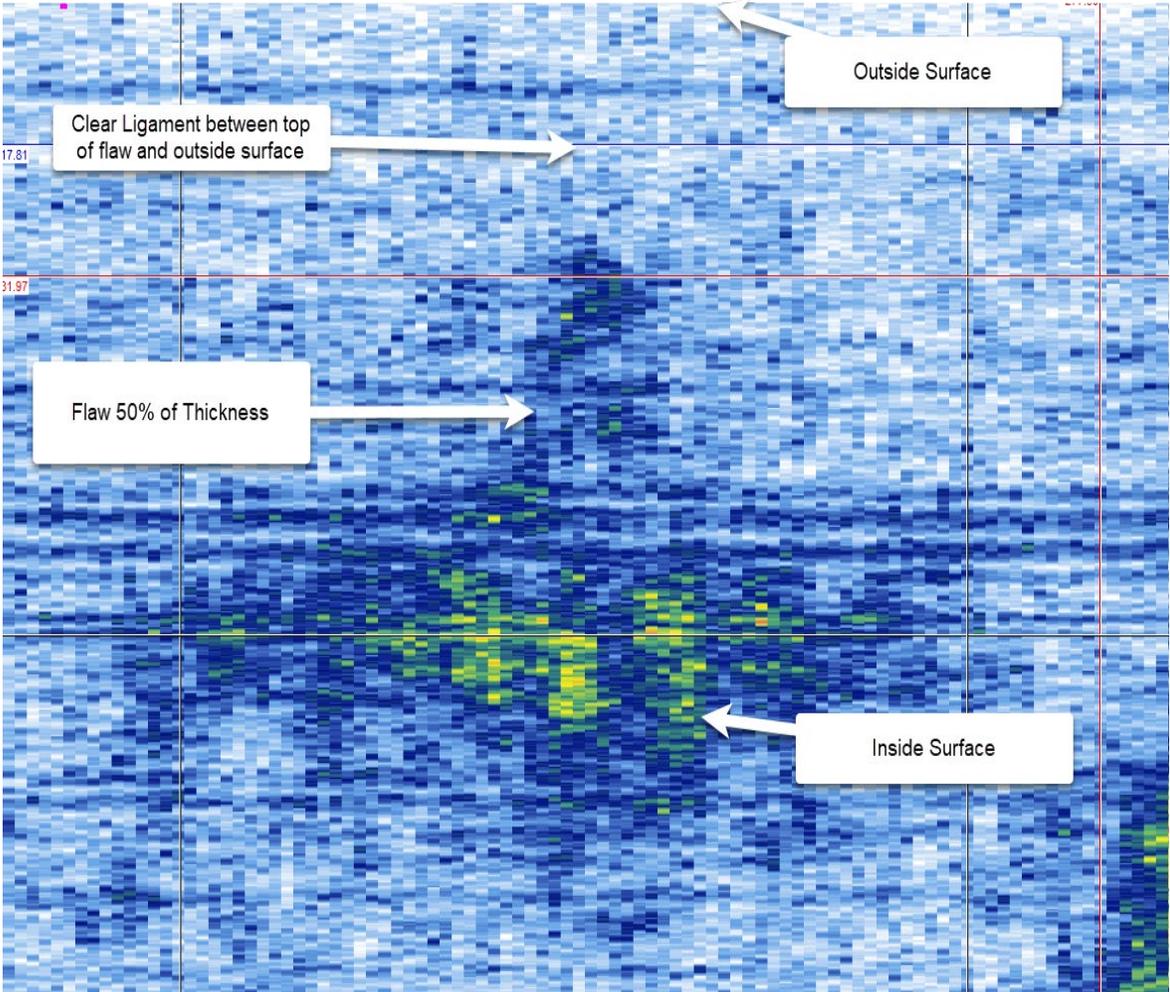
Flaw Implantation Development (Continued)



Flaw Implantation Development (Continued)



Flaw Implantation Development (Continued)





SUMMARY

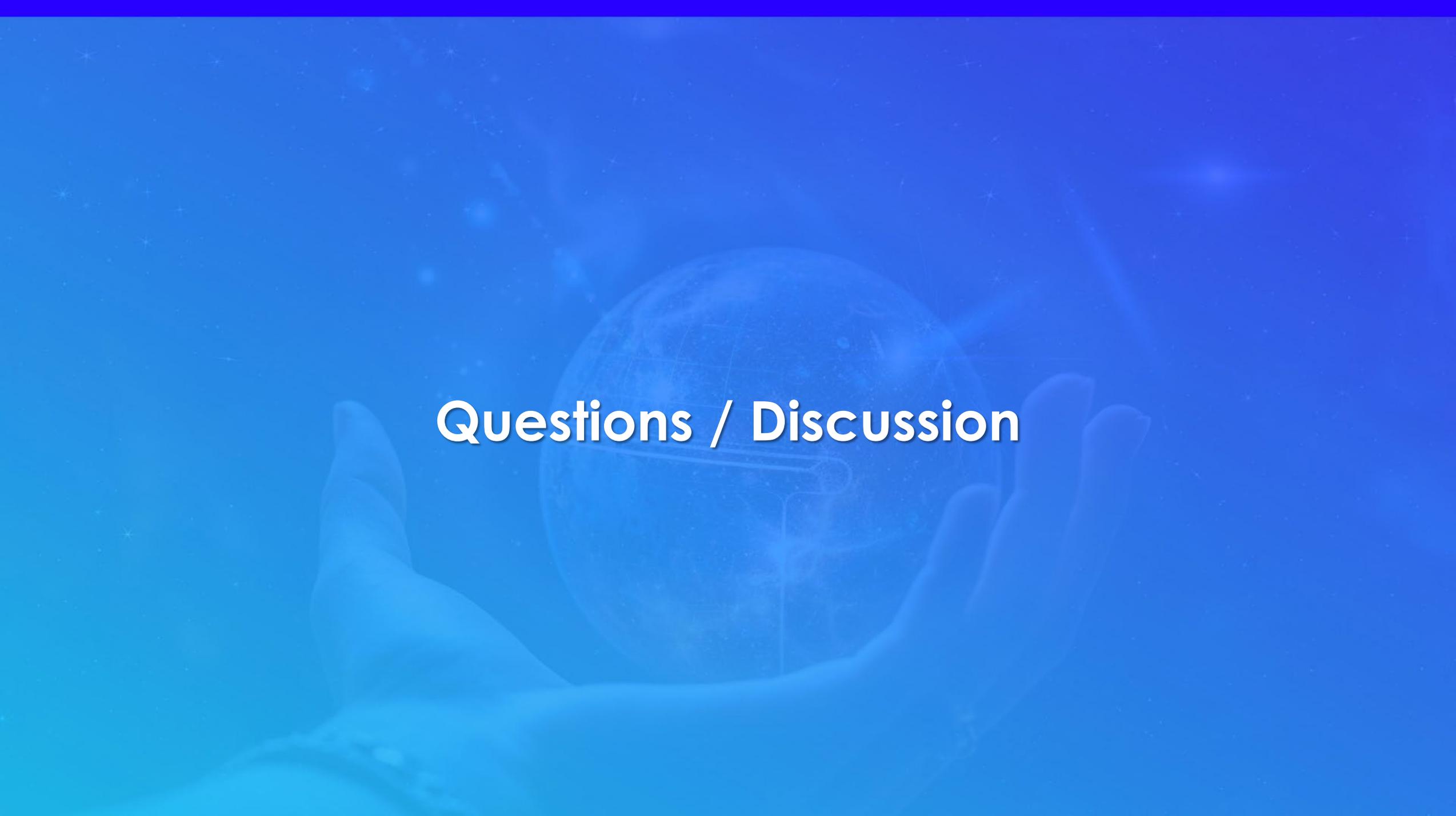
PFM Analysis
and Flaw
Evaluation
Methodology

Specimen
Design & Flaw
Fabrication
Techniques

ASME Code
Actions

Understanding
UT Techniques
& Procedures

Continued Safe and
Reliable Operation
of Nuclear Power
Plants with Safety
Related CASS
Components

The image has a monochromatic blue color scheme. In the center, a pair of hands is shown from the wrists up, cupping a globe of the Earth. The globe is semi-transparent, revealing a grid of latitude and longitude lines. The background is a deep blue with a subtle pattern of white stars and faint, glowing lines, suggesting a cosmic or digital theme. The overall composition is symmetrical and centered.

Questions / Discussion



Preferred Industry Direction for UT of CASS

November ASME Code Discussion

- At Section XI, TG-Appendix XI Committee, development of Supplement 9 was discussed
 - Most CASS exams have been eliminated with RI-ISI programs
 - Current requirement to use Code Case N-824 (Appendix III, Supplement 2) provides industry best practices for CASS UT examination
 - OE shows no CASS cracking
 - No basis to justify the level of effort to develop Supplement 9 performance demonstration program
- Action: Pursue development of a technical basis to forego development of Supplement 9 and stay with Appendix III Supplement 2 (Code Case N-824) for CASS exams

Problem Statement (Ronnie's Take)

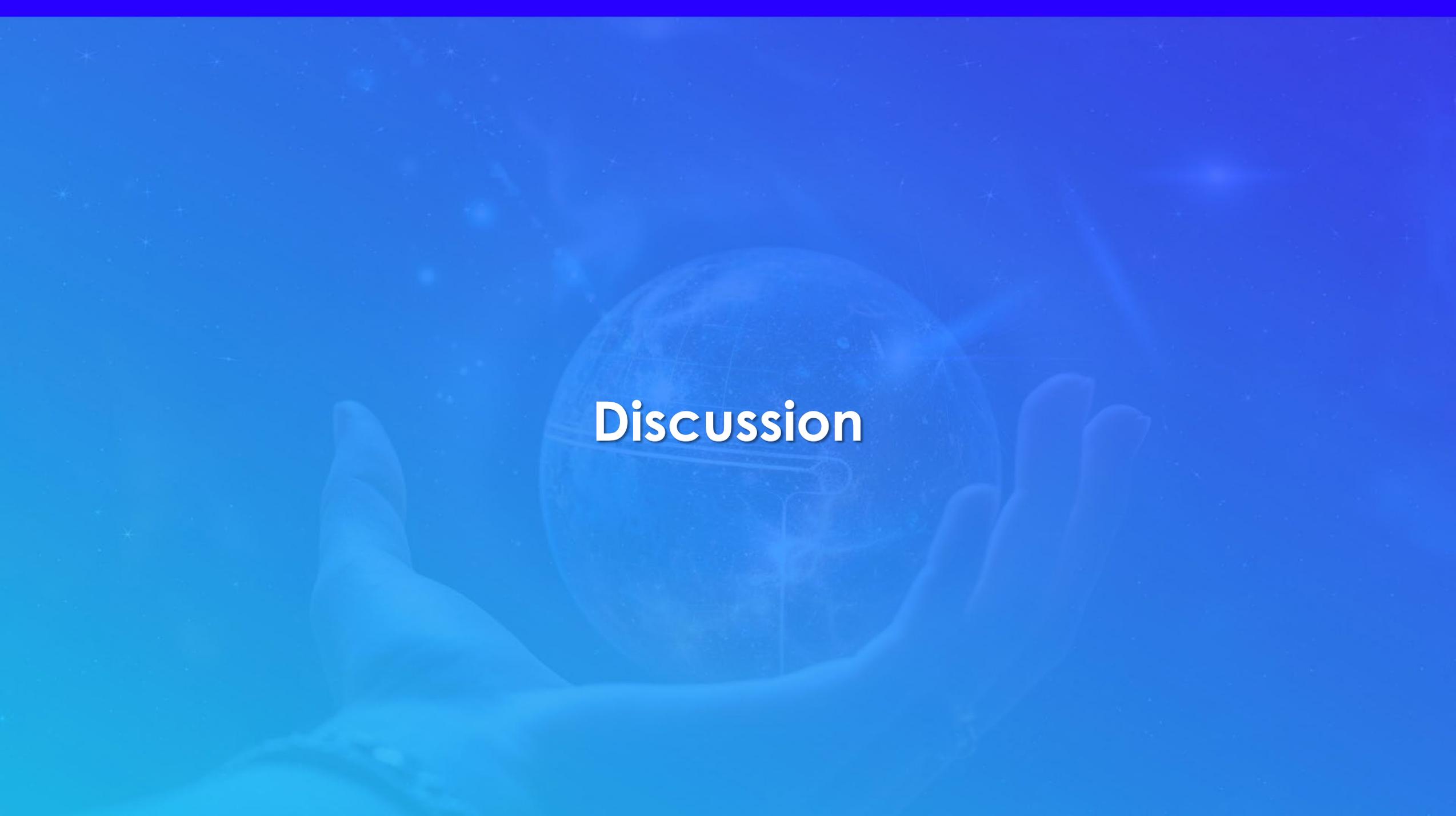
- As I look at this issue, the following arguments readily arise:
 - Operating experience shows no CASS cracking issues
 - Industry surveys show that RI-ISI has eliminated most large-bore CASS exams
 - Most, if not all, remaining main loop exams are done from the ID (better detection case)
 - CE Surge lines are ~1" thick, CF8M material and doesn't pose typical CASS UT difficulties
 - Building cracked CASS mockups has been problematic
 - Industry is already required to use best industry practices for examination of CASS, per N-824 and Appendix III, Suppl 2 (encoded PA with optimized frequencies)

Bottom line: Efforts to develop new flaw-building technologies, a library of primarily main-loop mockups and all the relevant qualification procedures and rules and then putting all the vendors and technicians through the program doesn't appear to improve the safety case provided by the status quo and is, therefore, not currently justifiable

Likely Recommendation: Forego pursuit of Supplement 9 and monitor situation based on the current examination regiment

My Planned Approach for Project

1. Review history, issues, and approved approach for UT of CASS
 - A. Attempt to develop technical basis to eliminate efforts for Supp 9
 - B. If case can be made,
 - 1) publish publicly-available report in 2026, and
 - 2) develop the following ASME Section XI Code actions:
 - i. Modify Appendix I to point to Appendix III for examination of CASS, instead of Appendix VIII
 - ii. Delete Appendix VIII references/placeholders for Supplement 9



Discussion



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