UPDATE ON OWOLS

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at

Industry Briefing to NRC on PWSCC Mitigation Research

Rockville, MD

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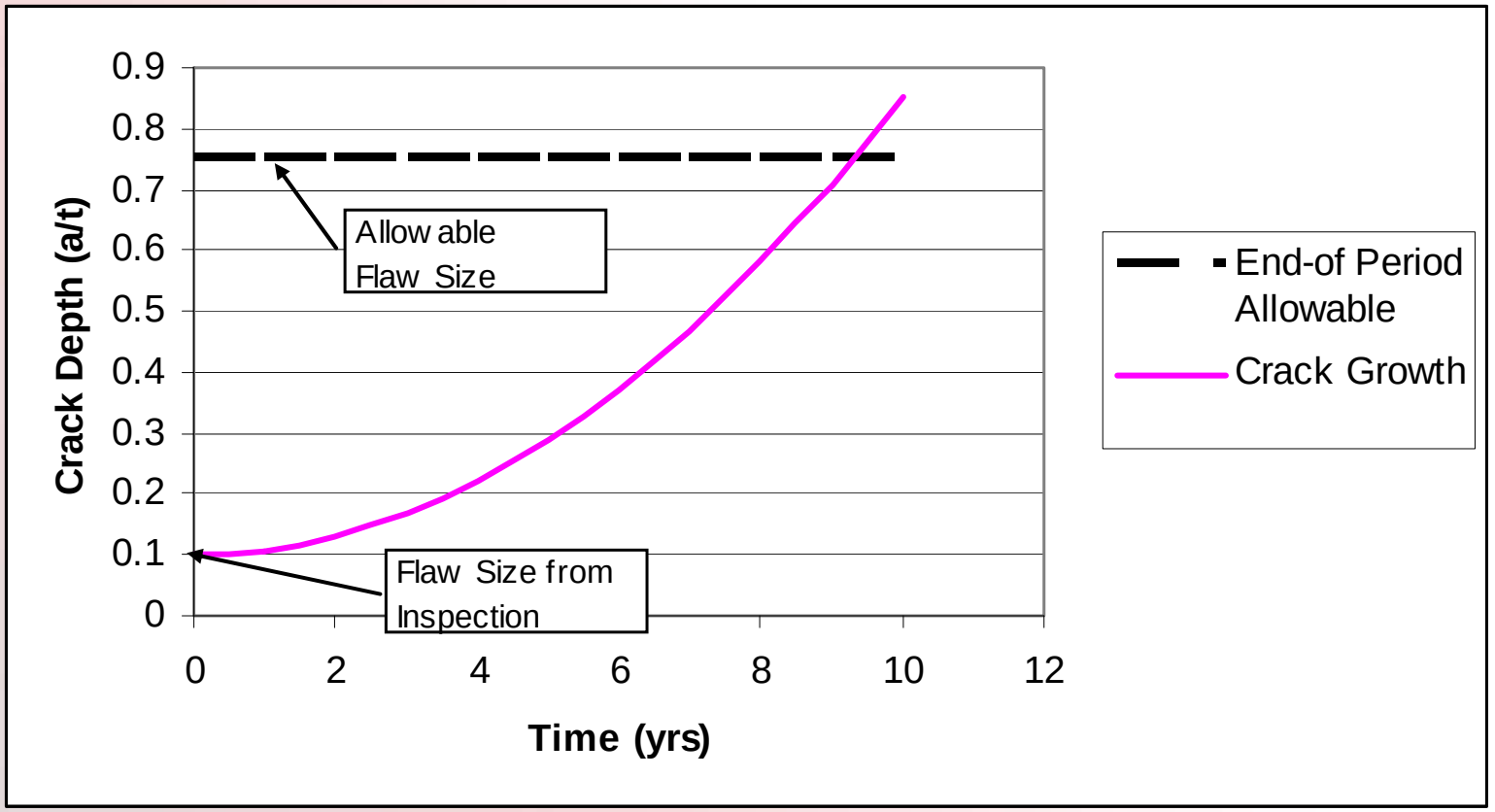
Outline of Presentation

- Weld Overlays (the basics)
- Verification of Weld Overlay Effectiveness
  - Overview of Prior Programs
  - Recent Large Diameter OWOL Mockup
- Current OWOL Design/Analysis Results
- NDE Qualification Issues/Solutions

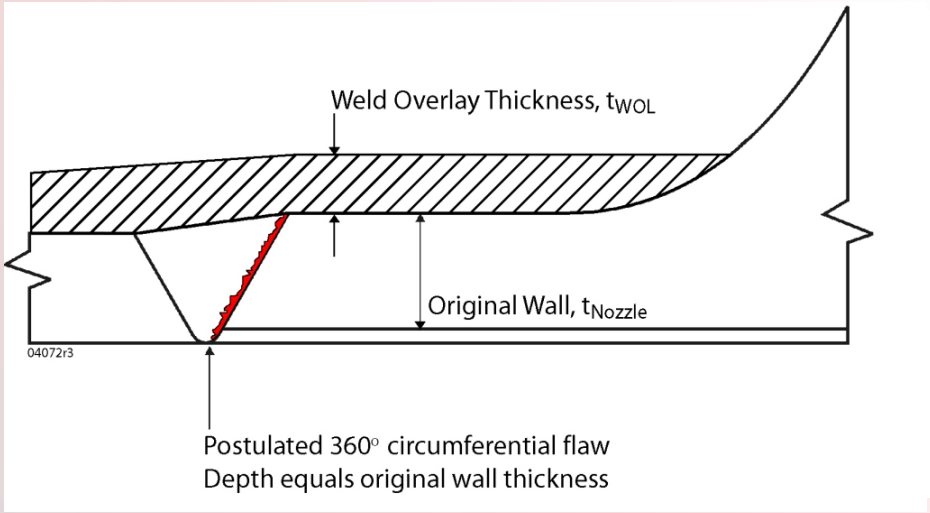
ASME Section XI Flaw Evaluation Concept

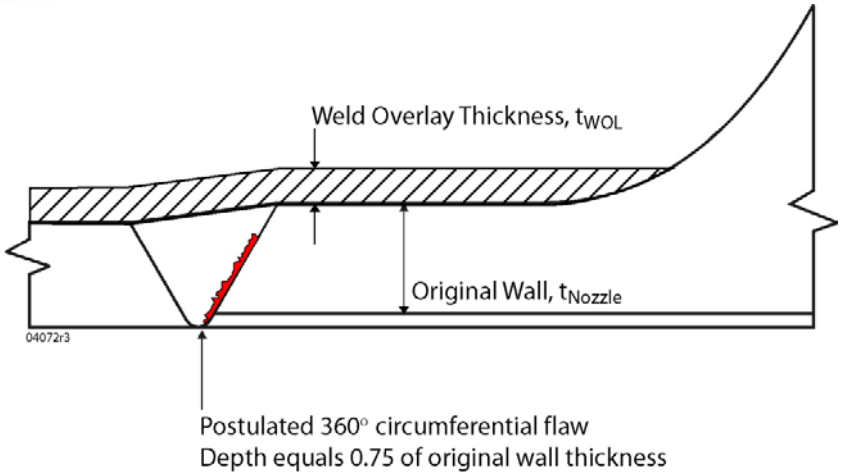


Weld Overlay Attributes

- Weld overlays (both repair and preemptive) possess attributes that enable SCC susceptible welds to pass Section XI flaw evaluation:
  - Structural reinforcement to ASME XI margins with large “design basis” flaws assumed
  - Crack growth barrier of SCC resistant material
  - Favorable residual stress reversal (both ID surface and thru-wall gradient)
- They also enhance inspectability

WOL Design Concepts





Full Structural Overlay (FSWOL)

Optimized Overlay (OWOL)

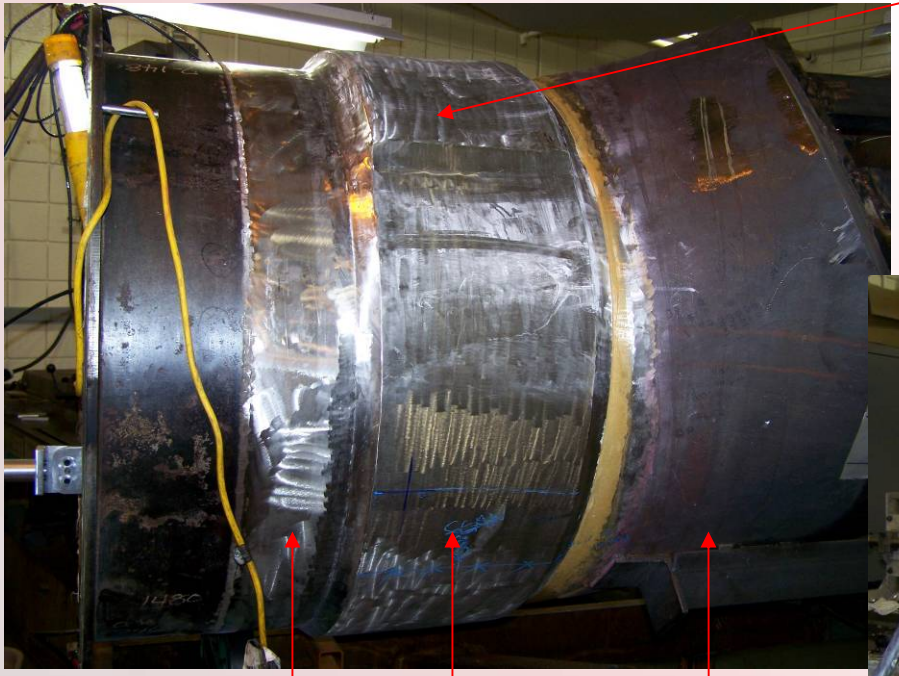
Summary of WOL Terminology

WOL Function	WOL Type
Mitigation (PWOL)	Full Structural
	Optimized
Repair (WOL)	Full Structural
	Optimized

Prior Experimental Verification of Weld Overlay Effectiveness

- 28-Inch Notched Pipe Test
- Battelle/NRC Degraded Pipe Tests
- EPRI/MRP PWOL Mockup (simulated surge nozzle)
- Documented in MRP-169, Rev. 1

EPRI 36-inch Diameter Mockup with WOL



FSWOL

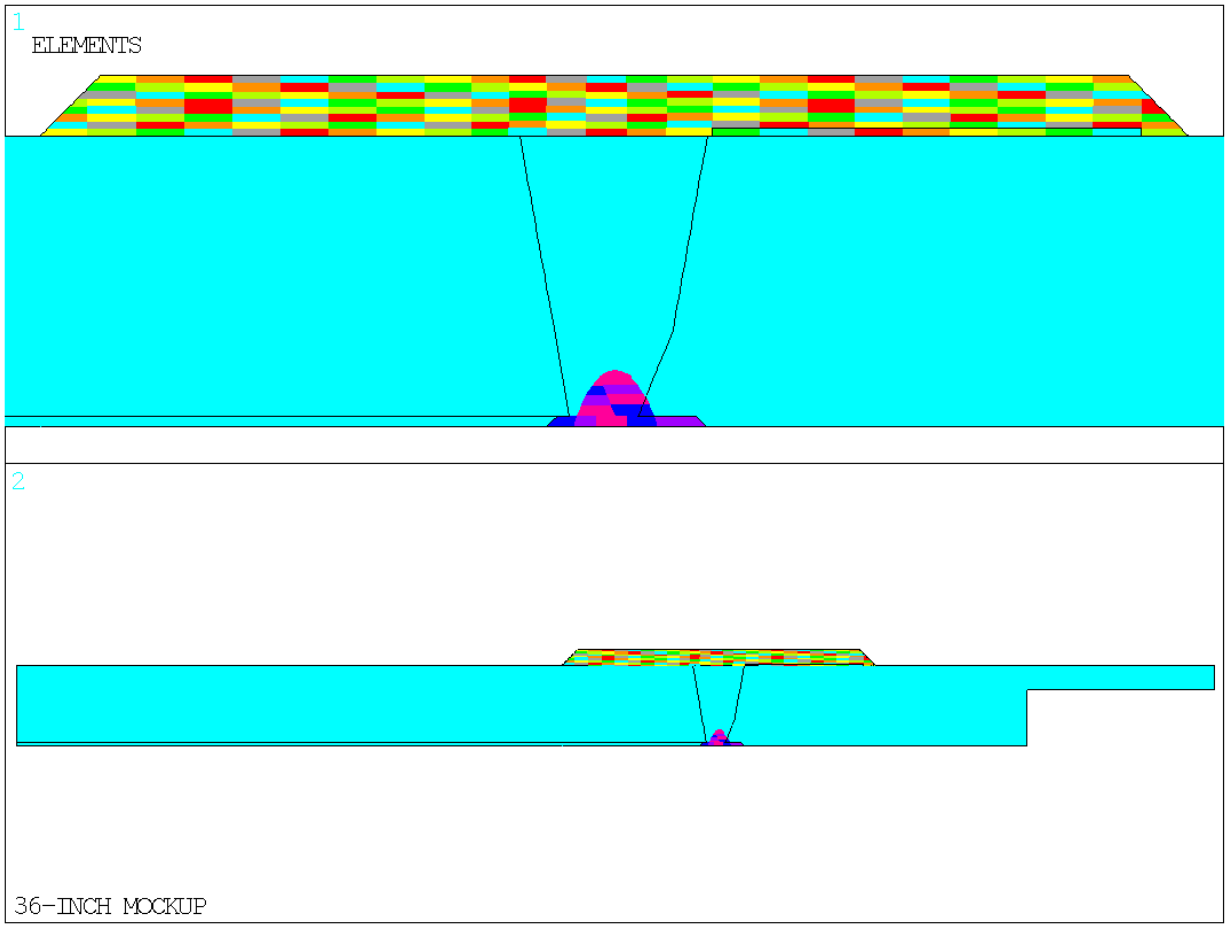
DMW

Stainless Steel

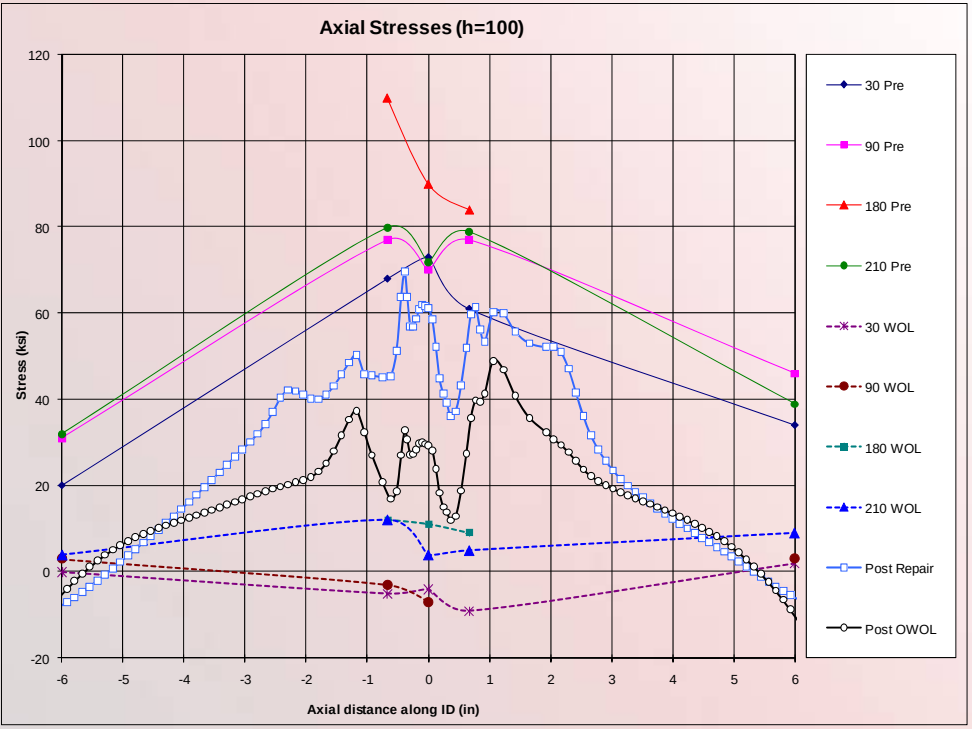
OWOL

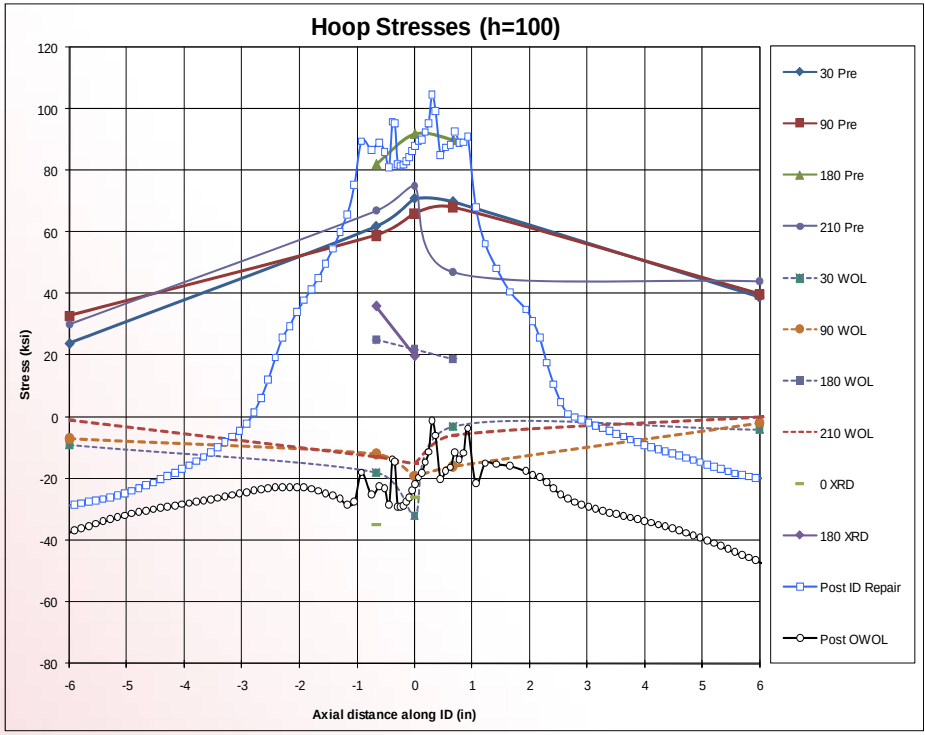
Clad Carbon Steel piping

36-inch Mockup – Finite Element Model



Residual Stress Analysis vs. Measurements (EPRI 36” Mockup)





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Summary of Mockup Results (In Terms of Stress Improvement due to Overlay)

		Average Delta (ksi)		Minimum Delta (ksi)	
		Axial	Hoop	Axial	Hoop
36" Mockup	Analysis	25.20	80.27	19.30	77.64
	Measured	75.71	75.29	61.00	57.00
PWOL (surge) Mockup	Analysis	78.45	82.21	63.02	18.35
	Measured	127.29	73.50	107.00	47.00

Verification of Weld Overlay Effectiveness – Field Experience

- **BWRVIP-75**
  - **Published in 1999**
  - **Evaluated WOL performance in 33 BWRs (262 overlays still in service)**
  - **15 years of service history w/no evidence of crack growth or new crack initiation**
  - **Included several A-82/52 overlays on DMWs (1st performed at VY in 1986)**
  - **Accepted as basis to extend WOL inspection schedules relative to NRC Generic Letter 88-01**

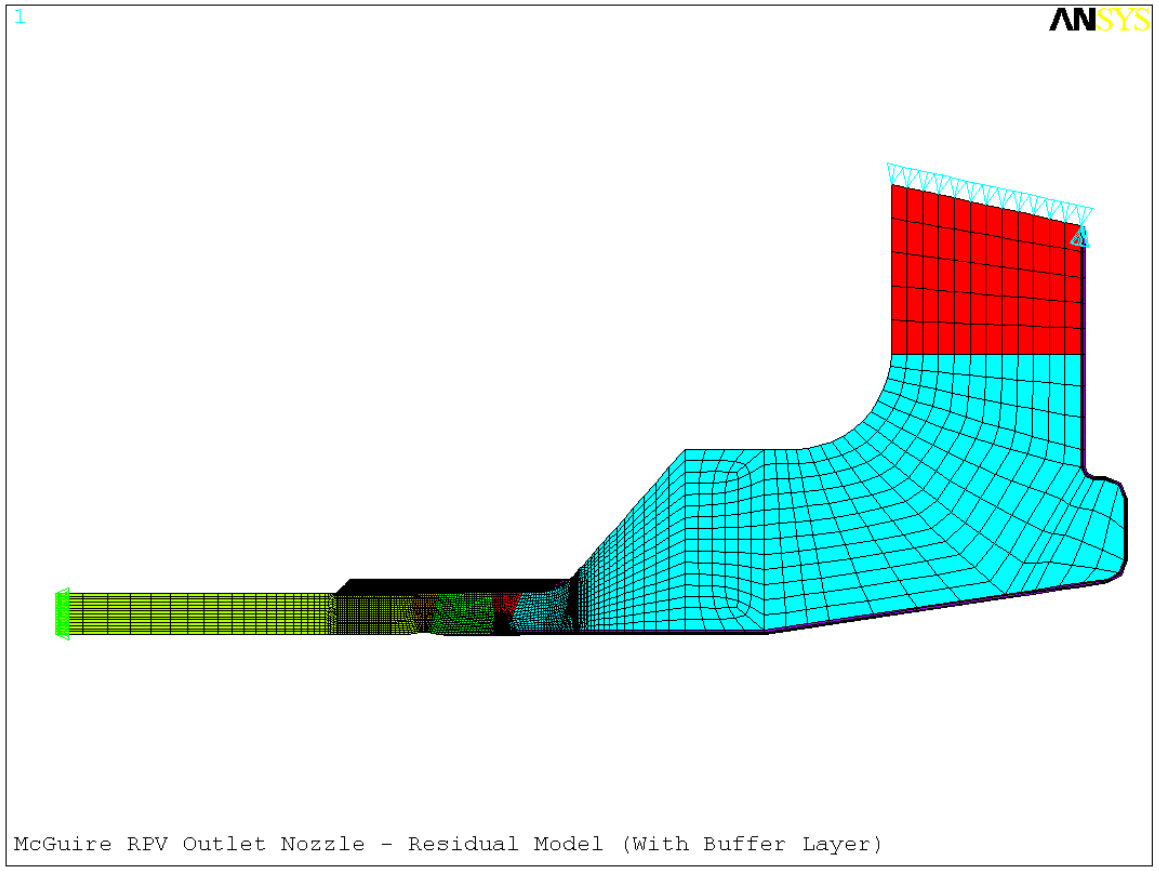
Verification of Weld Overlay Effectiveness – Field Experience (cont'd)

- Experience since BWRVIP-75
  - Flawless performance of BWR overlays has continued (some in place ~25 yrs)
  - Numerous DMW overlays applied to PWRs (beginning w/TMI in 2003)
  - PWR overlay OE still young, but to date has paralleled BWR performance

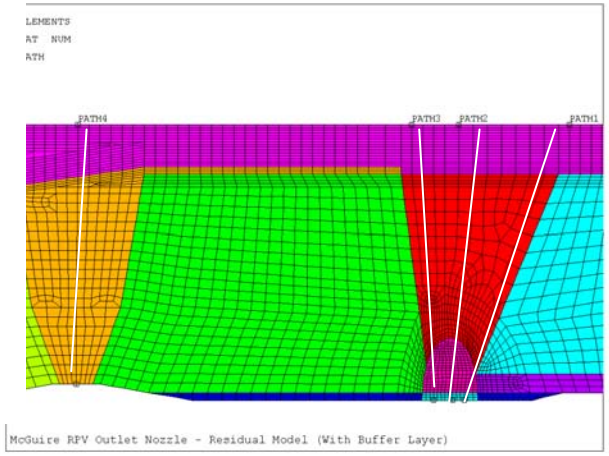
Current Large Diameter OWOL Design & Analysis Results

- Structural Sizing
- Residual Stress
- Crack Growth

Typical RPV Nozzle WOL Design - FEM

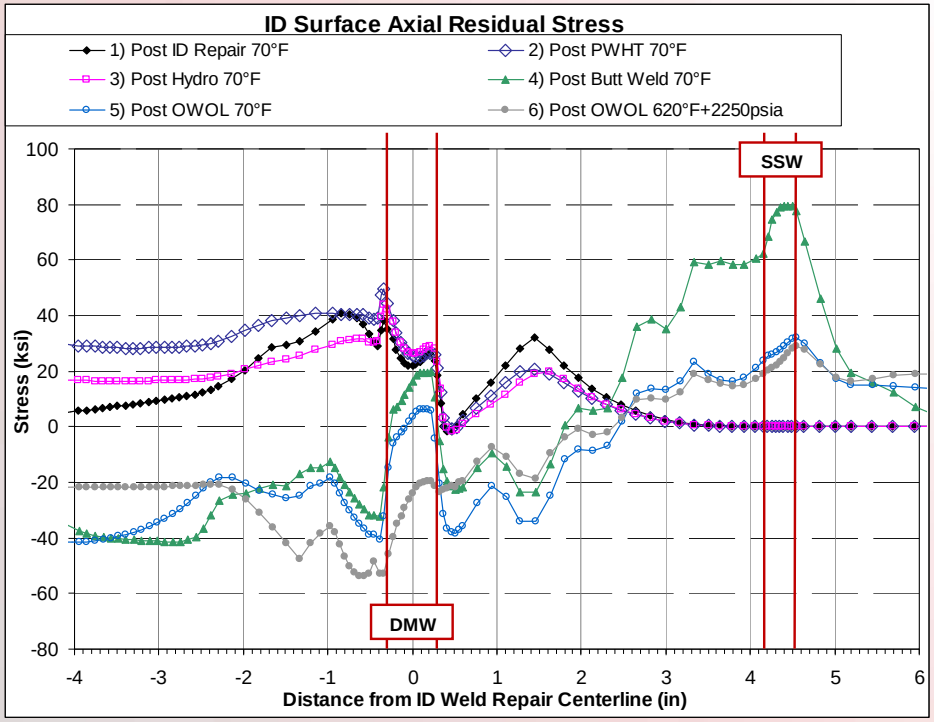


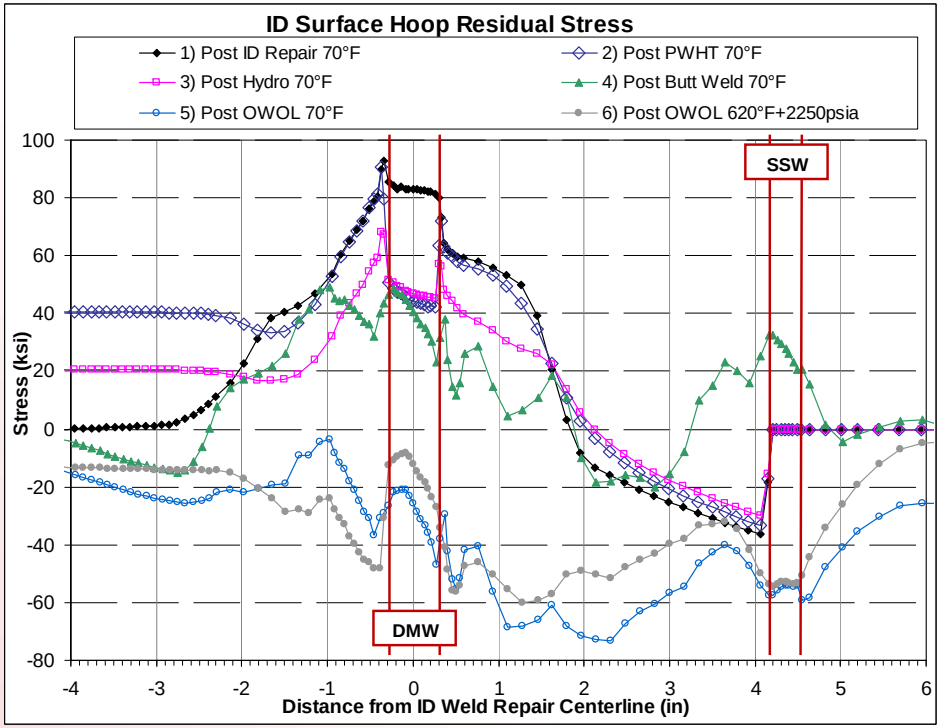
Stress Paths for Fracture Mechanics Evaluation



Finite Element Model

RPV Nozzle ID Surface Residual Stress Results





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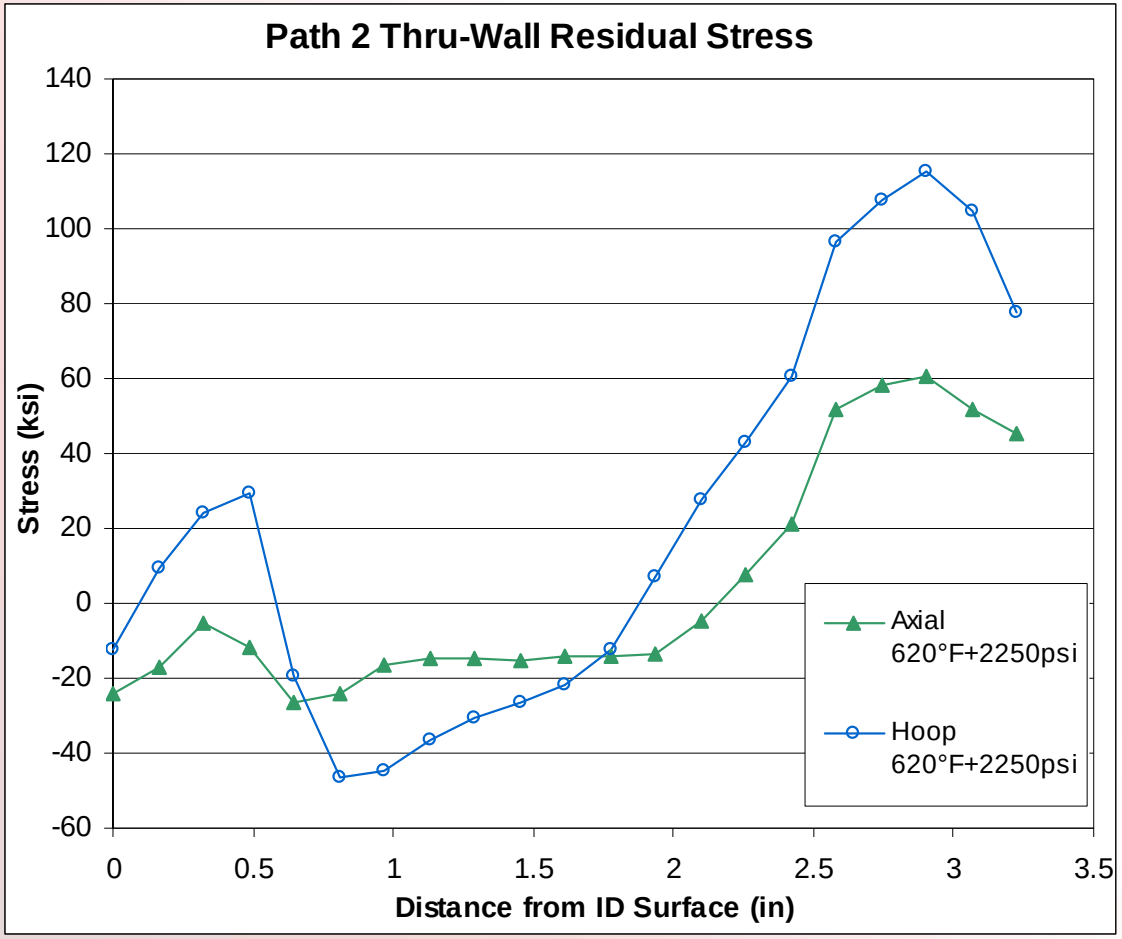
RPV Nozzle Thru-Wall Path Stresses (Resid + Op. Temp & Press)



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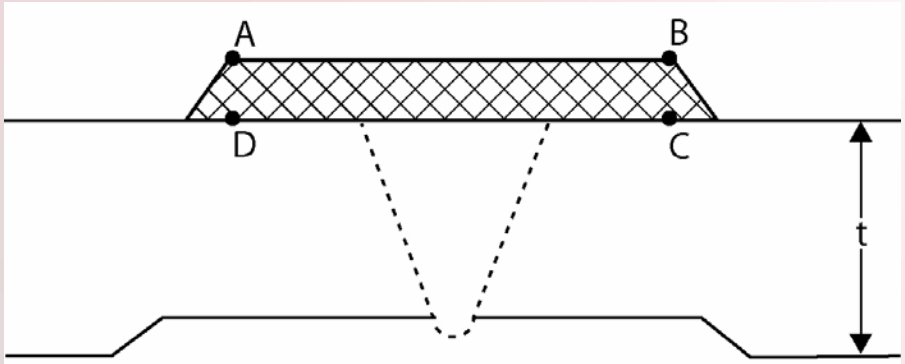
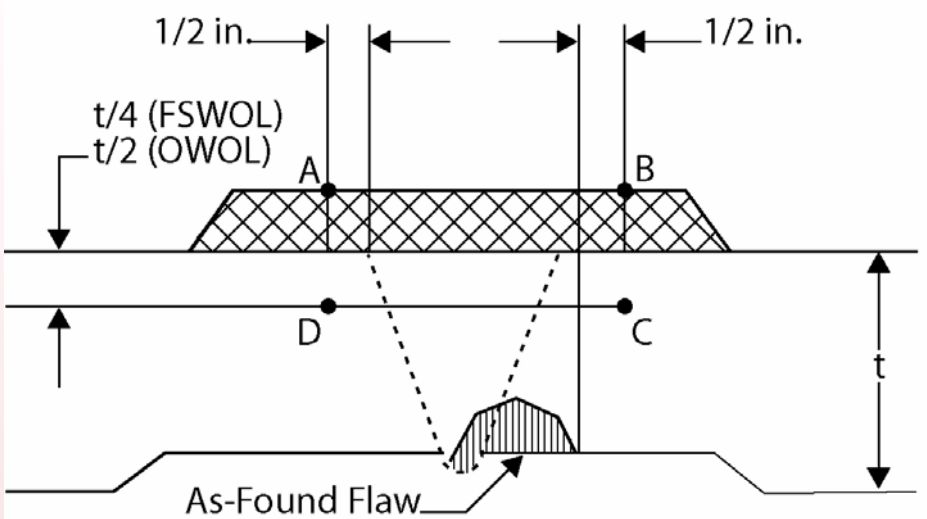
WOL Examination Volumes



WOL Acceptance Examination Volume A-B-C-D



Preservice and Inservice Examination Volume A-B-C-D

OWOL NDE Qualification Status

- EPRI/PDI has fabricated 3 new blind test specimens for OWOL UT Qualification
  - Specimen 1 - Shutdown Cooling Nozzle (13” OD)
  - Specimen 2 - Surge Nozzle (14” OD)
  - Specimen 3 - RCP Nozzle (37” OD)
- All Specimens “material faithful” (i.e. SS safe-end w/Alloy-182 weld to CS/LAS nozzle and Alloy-52 WOL
- Axial and circ flaws embedded at depths down to 50% thru original DMW thickness
- Specimens/flaws/demonstrations & acceptance criteria comply with intent of ASME XI, Appendix VIII, Supplement 11

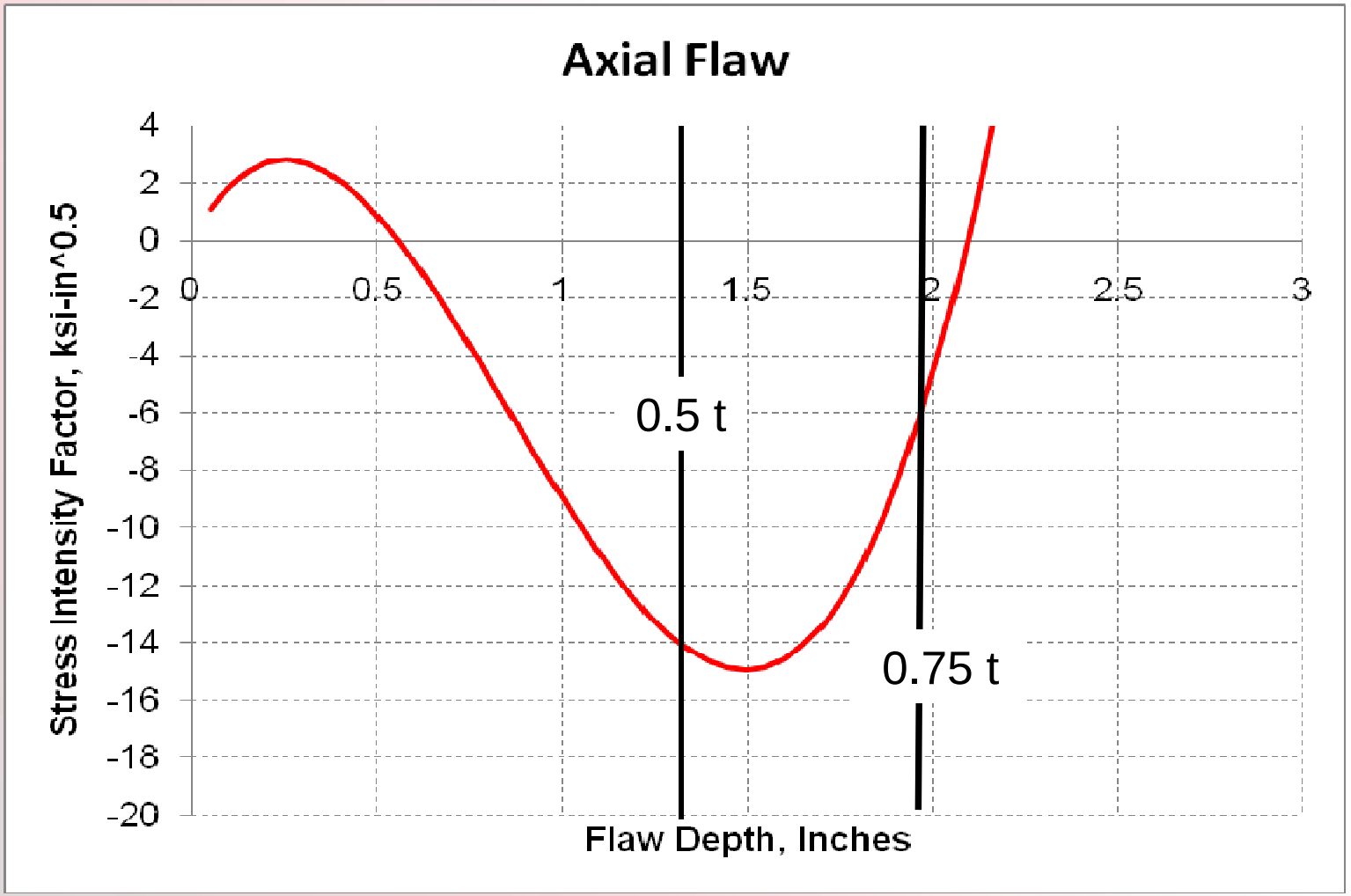
Status of SI UT Qualification Effort

- Detection for all circ flaws successfully demonstrated
- Thru-wall depth sizing of circ. flaws successfully demonstrated
- Length sizing issues on individual circ. flaws detected has been noted; overall RMS for length sizing not reported
- Axial flaw inspection not attempted on largest specimen (PDI fingerprinting issues)
- Two smaller OWOL specimens examined for axial flaws with one missed detection noted

The Hybrid WOL Approach

- If full PSI UT qualification not achieved in time for initial OWOL application, following approach will be proposed on an interim basis:
  - OWOL design will be established based on 360° circumferential flaw, 75% thru-wall
  - NDE will be conducted with expanded UT procedure which is PDI qualified to 50% thru-wall for circ flaws only
  - Design will be shown to meet Section XI Appendix C flaw evaluation rules for 100% thru-wall axial flaw (including fatigue and PWSCC crack growth with 75% assumed initial flaw)
  - NDE for axial flaws will be performed using existing, FSWOL procedure (PDI qualified to 75% thru-wall)

Crack Growth Evaluation for Axial Flaws



OWOL Conclusions

- EPRI 36” Dia. Mockup further demonstrates OWOL residual stress improvement
  - 60~75 ksi ID surface stress improvement due to overlay
  - Analysis technique updated to provide reasonable agreement with test data (accurate for hoop stress; conservative for axial stress)
- OWOL NDE qualification achieved for circ flaws; still some issues with axial flaw qualification
- OWOLs demonstrated to be effectively full structural for axial flaws:
  - Therefore, hybrid approach proposed in interim, until full qualification achieved

WELD ONLAY MITIGATION & REPAIR

William Sims

Entergy

July 16, 2008

CONTENTS

- Repair Concepts
- Non-Structural Onlay Evaluations
- Structural Onlay Evaluations
- Examination Requirements

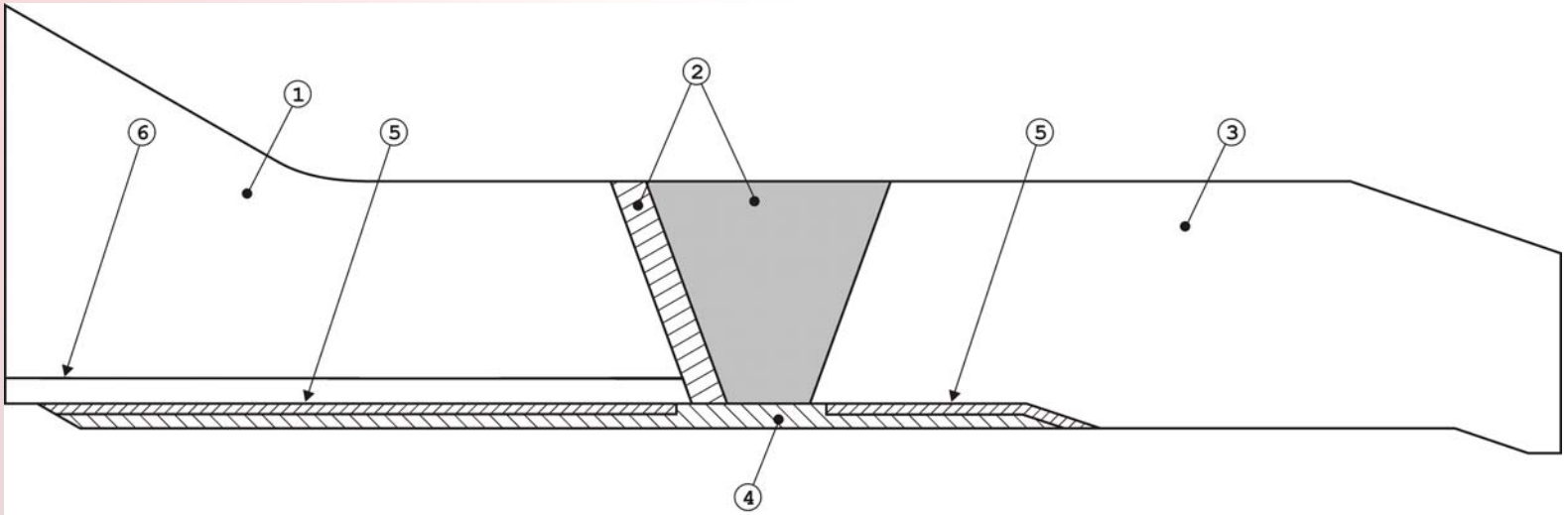
REPAIR CONCEPTS

- Non-Structural Onlay (Preemptive)
  - – Provides Protection from Environment
  - – Implemented for Indication-Free Conditions or Small Flaw Conditions
- Structural Onlay (Repair)
  - – Provides Protection from Environment
  - – Design Basis is Through-wall Circumferential Flaw
  - – Equivalent to “Full Structural Overlay”

NON-STRUCTURAL ONLAY EVALUATIONS

- Onlay Sizing
  - ~3/16” Thick
- Allowable Circumferential and Axial Flaws Developed
  - Compliance with Section XI
  - Onlay Not Considered
- Onlay Evaluation
  - Finite Element Model
  - Stress Analysis for All Loads/Load Combinations
  - Section III Code Compliance
  - Fatigue Crack Growth Analysis
  - Onlay Integrity Evaluation
- Indications Identified During ISI Examination Compared to Allowable Flaws

NON-STRUCTURAL ONLAY

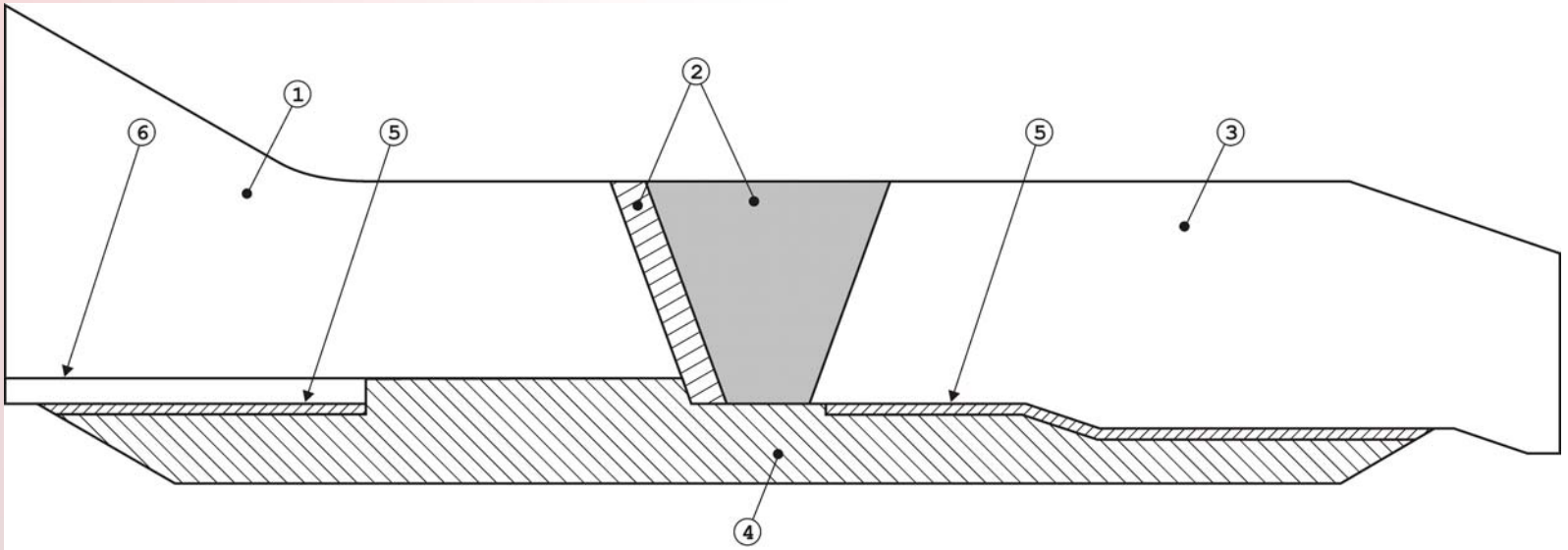


PARTS LIST		MATERIALS
1.	NOZZLE FORGING	A-508 CL.2
2.	WELD/BUTTER	ALLOY 82/182
3.	SAFE-END	SA-336 GR.F8M
4.	WELD ONLAY	ALLOY 52M
5.	BUFFER LAYER	ER308L
6.	CLADDING	ER308L

STRUCTURAL ONLAY EVALUATIONS

- Onlay Sizing
  - Methodology Similar to That for “Full Structural Overlays”
- Onlay Evaluation
  - Finite Element Model
  - Stress Analysis for All Loads/Load Combinations
  - Section III Code Compliance
  - Fatigue Crack Growth Analysis
    - Based upon Through-wall Circumferential Flaw with 8:1 Aspect Ratio
  - Thickness Accounts for Fatigue Crack Growth
- Nozzle Cladding
  - Non-Structural
  - Must be Removed
- Indications Identified During ISI Examination Evaluated to Determine Required Thickness

STRUCTURAL ONLAY



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Preemptive Mitigation Onlay Implementation

- Will be Installed per 10CFR50.59
- Meets ASME Code Requirements
  - Guidance from Code Cases N-740,N-770, and N-XXX (07-1682)

EXAMINATION REQUIREMENTS

- Pre-Repair UT
  - PDI Qualified
- Onlay UT
  - Guidance from Code Cases N-740 and N-770
  - Laminations and Planar Flaws
- Post-Repair UT
  - PDI Qualified