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MRP-169 NRC RAI Response NRC Meeting

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August 23, 2007

Weld Overlay Experience: BWRs and PWRs

- Over 800 overlays applied in BWRs during 25 year period, many still operating
- Numerous inservice inspections performed of overlaid BWR welds
- No evidence of flaws growing in overlays or underlying base metal or welds

- PWR Pressurizers
  - Completed 26 plants: 132 nozzles (47% total)
    - End of Fall: 70% of total will be mitigated
    - End of Spring: 89% of total will be mitigated

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MRP-139: Future Plan of Action

- By 12/31/07 - all welds associated with the pressurizer and exposed to pressurizer-like temperatures
- **By 12/31/07 – evaluate all Alloy 82/182 welds to determine the amount of coverage for axial and circumferential flaws**
- **By 12/31/08 - welds ≥ 4" NPS and ≤ 14" NPS and exposed to temperatures equivalent to the hot leg**
- **By 12/31/09 - welds > 14" NPS and exposed to temperatures equivalent to the hot leg**
- **By 12/31/10 - welds exposed to temperatures equivalent to the cold leg (including smaller-diameter HPI welds)**

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Presentation Outline

- Section I: Weld Overlay Background
  - Basic Concepts
  - Weld Overlay Design and Analyses Steps
  - Verification of WOL Effectiveness
- Section II: MRP-169 Review
  - Overview
  - Design and Inspection Requirements
- Section III: MRP-169 RAIs
  - Background and Proposed Schedule
  - Selected RAI Questions and Responses
  - MRP-139 Proposed Interim Guidance
  - Summary of Proposed MRP-169 Update
    - Editorial
    - Substantive

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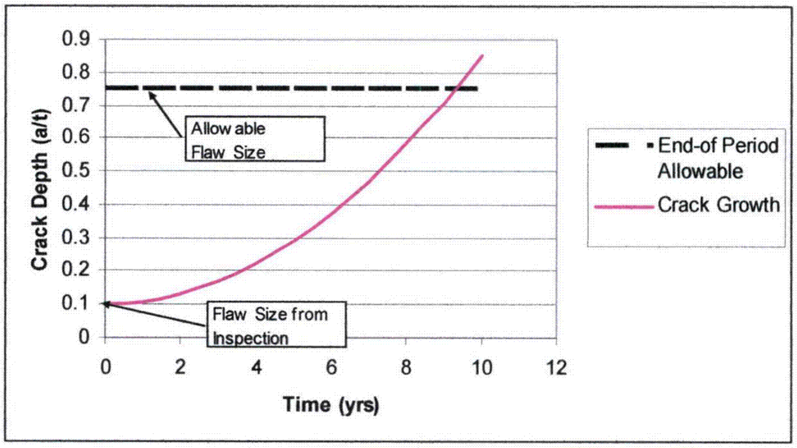
Section I:

Weld Overlay Basics

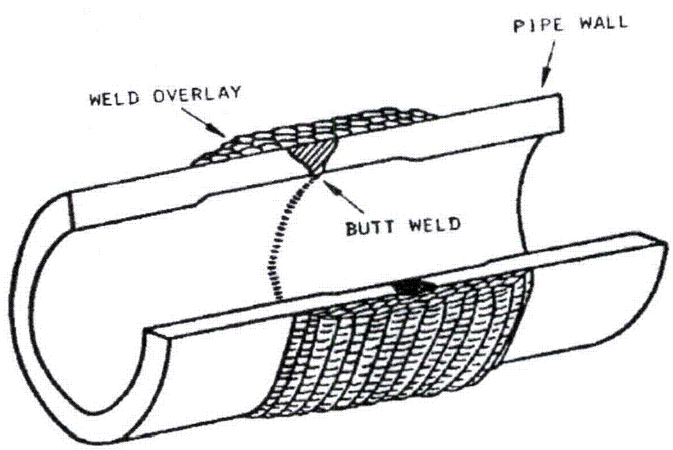
Weld Overlays – Basic Concept

- Evolved from ASME Section XI Rules for Flaw Evaluation in Austenitic Piping and (IWB-3640)
- For IGSCC (in BWRs) and PWSCC (in PWRs), crack growth rates generally too fast to permit successful flaw evaluation by ASME Section XI rules
- Weld overlays invented in 1981, as a means of helping flawed welds pass Section XI flaw evaluation requirements, through
  - Additional structural reinforcement (with SCC resistant material)
  - Favorable residual stress reversal to slow or arrest the growth of existing cracks
- Incorporated into ASME XI and accepted by NRC as permanent repair

ASME Section XI Flaw Evaluation Basic Concept



Piping Weld Overlay Schematic



WOL Design and Analysis Steps

- Basic Structural Sizing – Demonstrate that ASME Section XI evaluation criteria are satisfied with design basis flaw assumption*
- Crack Growth Analysis - Demonstrate that flaw indication doesn't exceed design basis flaw during evaluation period, considering
  - Post-overlay residual stresses
  - Fatigue and stress corrosion crack growth
- ASME Section III Secondary Stress and Fatigue Analysis (of uncracked regions under WOL)

* By definition, this ensures that ASME Section III primary stress margins are satisfied

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Verification of Weld Overlay Effectiveness

- Field Experience
- Prior Experimental Programs (in support of BWR WOLs)
  - 28-Inch Notched Pipe Test
  - Battelle/NRC Degraded Pipe Tests
- MRP-208: Demonstration Program for PWR PWOL s
- Additional residual stress confirmation and inspection qualification underway for large nozzle overlays (MEOG Program)

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Review of WOL Field Experience

- Weld overlays applied as repairs to cracked BWR pipe and safe-end welds since 1981
- Over 800 overlays applied in BWRs during 25 year period, many still operating
- Numerous inservice inspections performed of overlaid BWR welds
- No evidence of flaws growing in overlays or underlying base metal or welds
- Since Jan. 2006, ~130 overlays applied to PWR pressurizer nozzles

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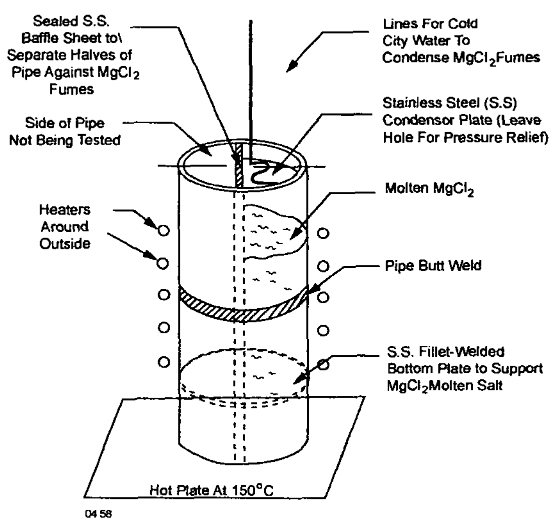
28-Inch Notched Pipe Test



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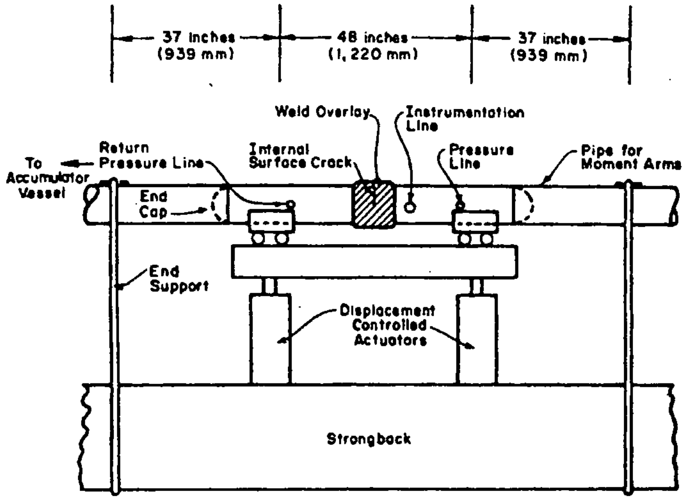
Battelle/NRC Degraded Pipe Tests



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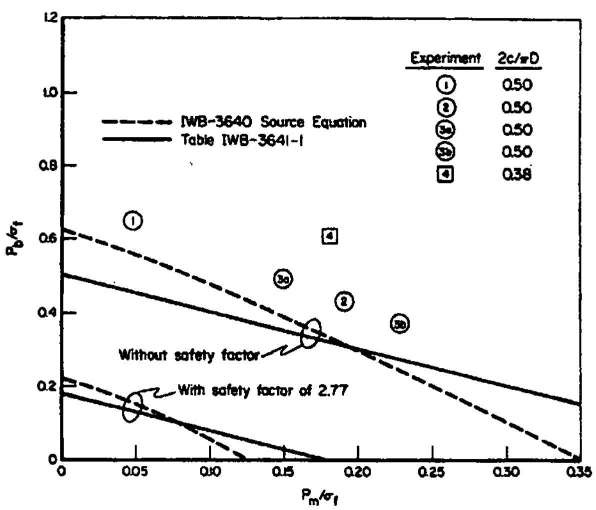
Battelle/NRC Degraded Pipe Tests



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MRP-208: PWOL Mockup / Residual Stress Measurements

- A PWOL mockup was fabricated simulating a PWR surge nozzle, including:
  - Ferritic Nozzle, Tapered SS Safe-end & SS Pipe
  - Two welds + ID repair
  - Alloy-52 WOL
- Design and Residual Stress Analyses Performed
- Residual Stresses Measured before and after WOL application

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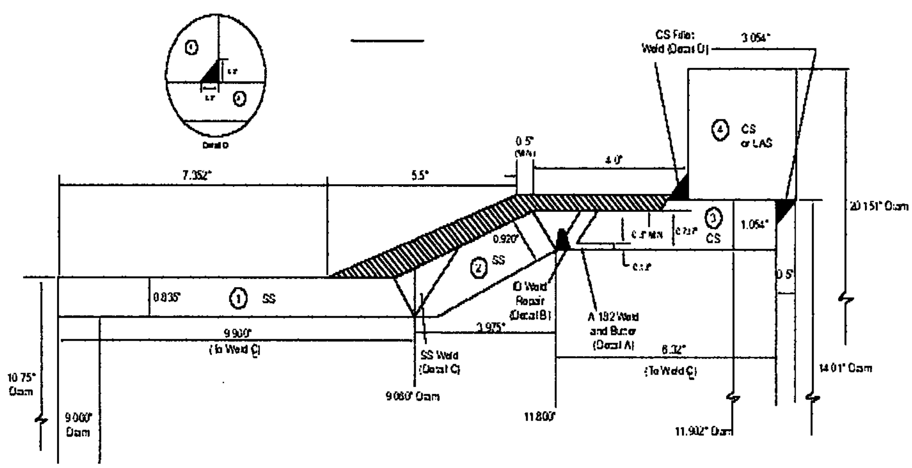
PWOL Mockup Drawing



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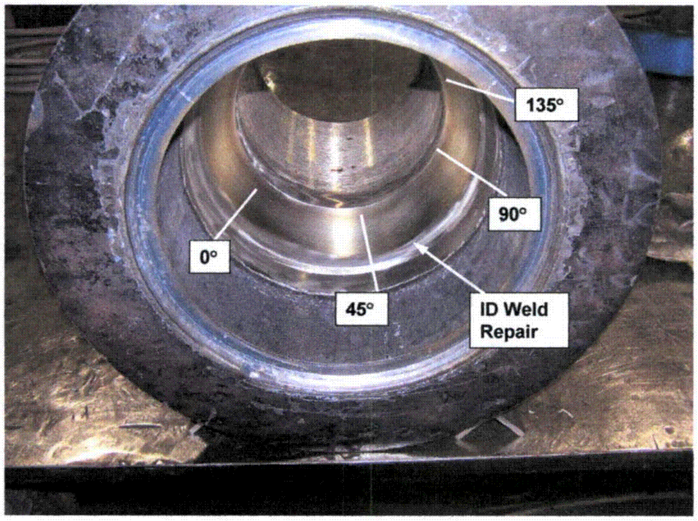
ID of Mockup Showing Residual Stress Measurement Locations



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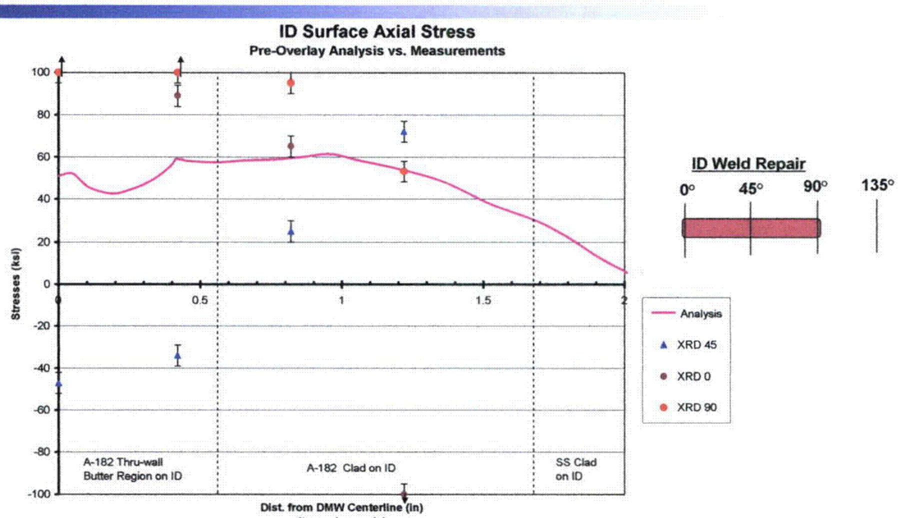
Residual Stress Results Axial: Pre-Overlay



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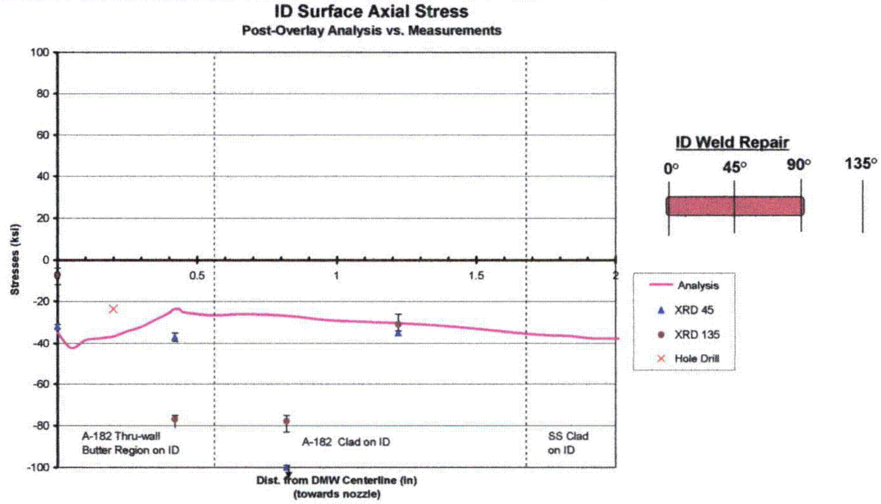
Residual Stress Results
Axial: Post-Overlay



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MEOG Large Diameter (36") Nozzle Overlay Mockup Program

- Additional work underway to support design and welding of large diameter thick components (Including cast base material)
  - Overlay design
    - Optimized overlay design
    - Full structural overlay design
  - Verification of Stress Profile
    - XRD base line measurements prior to overlay
    - XRD and incremental hole drilling at HOLD 1 (preemptive)
    - XRD and incremental hole drilling at HOLD 2 (full structural)
  - Dilution Measurements
    - Verification of Cr (%) (first 2 layers)
  - Shrinkage Data (per weld layer)
    - Axial
    - Circumferential
    - Diametrical

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Section II:

MRP-169 Review

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MRP-169 Overview

- Provides Guidance for Preemptive Weld Overlays (PWOLs) for Mitigation of PWSCC, including:
  - Design & Analysis Requirements
  - Inspection Requirements
  - Consideration for PWOL application at LBB locations
  - Summary of Tests, Analyses and Field Experience Supporting the Effectiveness of WOLs
  - Examples of Overlay Design/Analyses

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MRP-169 Design/Analysis Requirements

- Structural Sizing
- Residual Stress Improvement
- Inspectability Considerations
- Fatigue and PWSCC Crack Growth Analysis
- Section III Stress & Fatigue Evaluation
- Leak Before Break
- As-built Reconciliation and Evaluation of Potential Effects on Other Components

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Summary of MRP-169 Terminology

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

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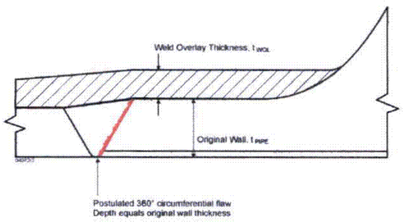
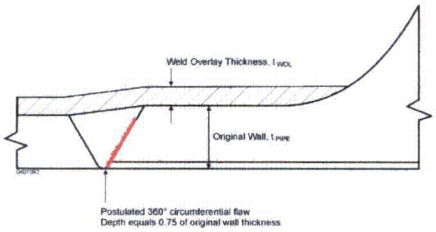
PWOL Design Concepts (as Defined in MRP-169)



Full Structural Overlay (FSWOL)



Optimized Overlay (OWOL)

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PWOL Inspection Requirements

- Inspections immediately after application
  - Construction (acceptance exam) of WOL and underlying HAZ
  - PSI exam - outer 25% (FSWOL) or 50% (OWOL) of original DMW thickness, encompassing PWSCC material + ½" on either side of weld
  - Establishes "buffer zone" (25% of original DMW thickness) between flaw size for which UT technique must be qualified for and overlay design basis flaw
  - Inspectability of adjacent SS weld also needs to be considered
- Subsequent ISI Requirements
  - ISI Schedule dependent on WOL function (repair or preemptive)
  - Exam Volume same as PSI

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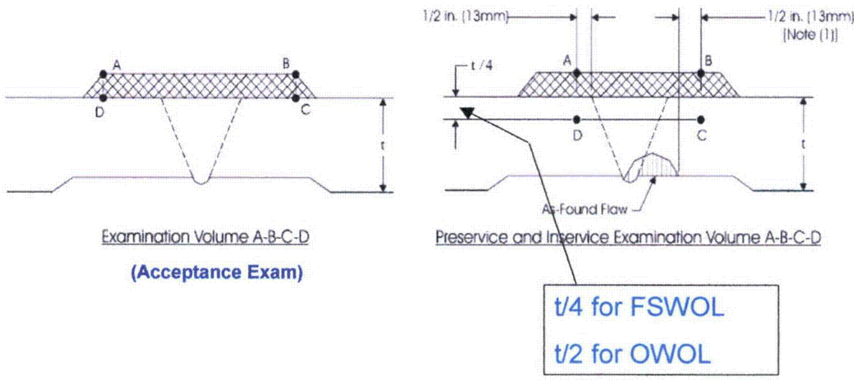
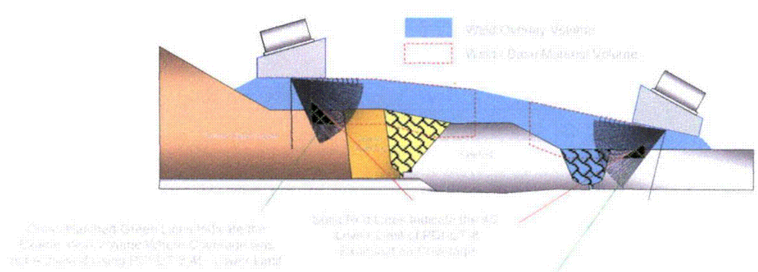
WOL Examination Volumes



PWOL Design Inspectability Considerations



Typical Overlay Design/Analysis Results

From Structural Sizing

Nozzle	WOL Thickness (in.)		Minimum Length (in.)
	Optimized Structural	Full Structural	
Pressurizer Spray	0.21	0.292	4.28
Pressurizer Surge	0.21	0.427	6.27
RCS Hot Leg	0.48	1.05	11.30

Required for Resid. Stress & Inspectability

Nozzle	WOL Thickness (in.)	WOL Length (in.)
Pressurizer Spray	0.30	7.19
Pressurizer Surge	0.44	9.81
RCS Hot Leg	0.48	11.60

Section III:

RAI Questions & Responses

NRC RAI Background

- MRP-169 submitted to NRC for review in Sept. 2005
- NRC Requests for Additional Information (RAIs) received in August 2006
- Responses submitted in draft form for discussion at 8/23/07 meeting
- Parallel Section XI Code Cases in process, but MRP would like to resolve NRC concerns and obtain SER in time for anticipated large diameter PWOL applications beginning in Fall 2008

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NRC RAI Background (continued)

- Reasons for seeking NRC approval of MRP-169 (even though parallel ASME Code actions in progress):
  - "Optimized weld overlay" (OWOL) concept defined in MRP-169. Needed for viability of large RCS nozzle overlays expected to commence in Fall 2008
  - MRP-169 includes more technical detail than typically included in Code Cases – effectively a Technical Basis Document
  - MRP-169 includes requirements and technical bases in areas outside of normal ASME Code purview

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MRP-169 RAI – Proposed Schedule

Timeframe	Milestone
July 2007	Draft Responses for MRP Review and Comment
August 23, 2007	MRP/NRC Staff Meeting to Present and Discuss Draft RAI Responses
Early September, 2007	Finalize and Submit RAI Responses
November, 2007	Resubmit revised MRP-169 for SER
March, 2008	Request NRC SER on revised MRP-169 by this date to support Fall 2008 applications

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MRP-169 RAIs – Significant Questions and Responses

- General Question #2: The treatment of pre-emptive full structural, design, and optimized weld overlays (WOLs) is confusing
- Response: Summary Table developed summarizing each overlay type with attendant design and inspection requirements from MRP-139/169 and Code Cases

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Weld Overlay Design Summary Table

Weld Overlay Type	Pre-WOL Inspection Completed?	Design Basis Flaw for WOL	Crack Growth Design Basis	Post-WOL Exam Volume (PSI and ISI)	Post-WOL In-service Inspection Schedule (MRP-139/169 vs. ASME Code Cases)
Repair – Full Structural	Yes	100% thru-wall, full circ.	Actual observed flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 25% of Code DMW Exam Volume	MRP-139/169; (Cat. F) Once in the next 5 years, and then if no growth 100% in subsequent 10 year interval CC N-740-1: Once in the next two RFOs, and then if no growth, a 25% sample population on a 10 year basis
Preemptive – Full Structural	No	100% thru-wall, full circ.	Assumed 75% flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 25% of Code DMW Exam Volume	MRP-139/169; (Cat. F) Once in the next 5 years, and then if no growth 100% in subsequent 10 year interval CC N-740-1: Once in the next two RFOs, and then if no growth, a 25% sample population on a 10 year basis
Preemptive – Full Structural	Yes	100% thru-wall, full circ.	Assumed 10% flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 25% of Code DMW Exam Volume	MRP-139/169; (Cat. B) 100% every interval (10 years) CC N-740-1; A 25% sample population on a 10 year basis
Repair – Optimized	Yes	75% thru-wall, full circ.	Actual observed flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 50% of Code DMW Exam Volume	*MRP-139/169; (Cat. F) Once in the next 5 years, and then if no growth 100% in subsequent 10 year interval CC N-754: Once in the next two RFOs, and then if no growth, a 25% sample population on a 10 year basis (outer 50%)
Preemptive – Optimized	No	75% thru-wall, full circ	Assumed 50% flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 50% of Code DMW Exam Volume	*MRP-139/169, (Cat. F) Once in the next 5 years, and then if no growth 100% in subsequent 10 year interval CC N-754: Once in the next two RFOs, and then if no growth, a 25% sample population on a 10 year basis
Preemptive – Optimized	Yes	75% thru-wall, full circ	Assumed 10% flaw shall not exceed design basis flaw size in next inspection interval	WOL + outer 50% of Code DMW Exam Volume	*MRP-139/169; (Cat. B) 100% every interval (10 years) CC N-754: A 25% sample population on a 10 year basis

* Based on Proposed MRP-139 Interim Guidance

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MRP-169 RAIs – Significant Questions and Responses

- General Question #3: Discuss inconsistencies between MRP-169 and MRP-139
- Response:
  - Classification of WOLs with clean pre-WOL inspections
    - MRP-139 → Cat B for FSWOLs, Cat C for "stress improvement"
    - MRP-169 → Cat B for FSWOLs and OWOLs
  - Classification of WOLs with no pre-WOL inspections (or inspected and found cracked)
    - MRP-139 → Cat F for FSWOLs, Cat G for "stress improvement"
    - MRP-169 → Cat F for FSWOLs and OWOLs
- Proposed Interim Guidance & Technical Justification to resolve this inconsistency follow

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Proposed MRP-139 Interim Guidance on OWOL Classification

- OWOL concept developed after publication of MRP-139 and therefore not addressed in it.
- OWOLs provide both stress improvement function <u>and</u> structural reinforcement function
  - Not same level of reinforcement as a FSWOL, but
  - Inspection volume and analysis requirements adjusted accordingly
- Therefore OWOLs are not "stress improvement only", and
  - Cat B (not C) recommended for OWOLs with clean pre-WOL Exam
  - Cat F (not G) recommended for OWOLs on flawed welds or welds with no pre-WOL inspection

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Current MRP-139 Categories & Inspection Requirements

MRP-139 Inspection Category	Applies to:	Examination Extent and Schedule
B	Inspected, uncracked, Reinforced by FSWOL	Existing Code Examination Program or Approved Alternative
C	Inspected, uncracked, Mitigated by SI	50% within next 6 years; if clean, then Code program or approved alternative
F	Inspected, cracked, Reinforced by FSWOL	Once in next 5 years; if no new indications/growth, then Code program or approved alternative
G	Inspected, cracked, Mitigated by SI	100% at 2 RFO intervals. If no new indications/growth after 2 exams then Code program or approved alternative

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Technical Justification for Proposed MRP-139 Interim Guidance

Overlay Designs from MRP-169

Nozzle	WOL Thickness (in.)		Minimum Length (in.)
	Optimized Structural	Full Structural	
Pressurizer Spray	0.21	0.292	4.28
Pressurizer Surge	0.21	0.427	6.27
RCS Hot Leg	0.48	1.05	11.30

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Technical Justification for Proposed MRP-139 Interim Guidance

Resulting Safety Factors

		ANSC Results:		
Nozzle Type:	**Case:**	**360° Flaw Depth (assumed)**	**Pm + Pb (at limit load)**	**Safety Factor on Pm + Pb**
RPV Hot Leg	FSWOL	2.33	36.44	3.01
	OWOL	1.75	44.18	2.94
	OWOL1	2.33	18.20	1.21
PZR Surge	FSWOL	1.28	29.51	5.36
	OWOL	0.96	41.54	6.45
	OWOL1	1.28	14.14	2.19
PZR Spray	FSWOL	0.875	31.57	4.35
	OWOL	0.656	47.24	5.79
	OWOL1	0.875	23.54	2.88

FWOL:100%TW, 360° flaw, design basis
OWOL: 75% TW, 360° flaw, design basis
OWOL1: 100% TW, 360° flaw, extreme condition not permitted by OWOL design and inspection requirements

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MRP-169 RAIs – Significant Questions and Responses (cont'd)

- Inspection Question #1- Please verify that if an ASME Section XI, Appendix VIII, inspection is not performed pre-WOL, the WOL must be full structural, not optimized structural.
- Response - MRP-169 being revised to permit OWOLs to be used either preemptively or as repair (for indications up to 50% through wall)
  - Consistent with post-WOL inspection requirements
  - Consistent with MRP-139 treatment of stress improvement (permitted for repairs with limitations)

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MRP-169 RAIs – Significant Questions and Responses (cont'd)

- Inspection Question #2 - Please discuss what calculations need to be completed prior to startup or provide technical justification for any calculations not completed until after startup
- Response –
  - Structural sizing calculations sufficient to define WOL design for purposes of structural integrity and thus safety for plant startup
  - Remaining calculations (residual stress, crack growth, and Section III fatigue) are only to substantiate the life of the design
  - NRC regularly approves completion of these within one month after restart for repair overlays

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MRP-169 RAIs – Significant Questions and Responses (cont'd)

- Inspection Question #3 - Please clarify potential conflict between MRP-169 and MRP-139 (RE: Approved Alternatives - RIISI)
- Response –
  - MRP-169 states: PWOL examinations may not be eliminated or reduced as a result of RIISI considerations
  - Upon reconsideration, MRP would like to retain RI-ISI option for WOLs, at some time in the future, pending sufficient experience and technical justification

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MRP-169 RAIs – Significant Questions and Responses (cont'd)

- Inspection Question #5 – Discuss how post-WOL exam requirements can be satisfied for plants that perform ISI from ID
- Response –
  - WOL construction and PSI exams are performed from OD regardless of whether pre-and post-overlay inservice inspections are performed from the ID or OD.
  - For ISI examinations performed from inside surface, application of an overlay may require some additional qualification

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MRP-169 RAIs – Significant Questions and Responses (cont'd)

- Inspection Question #6 – Discuss performance demonstration qualifications for OWOLs which may require inspecting outer 50% of underlying DMW
- Response – Criteria and mockup samples are being developed to qualify procedures and personnel to examine required expanded volume for optimized overlays
  - Demonstration mockup already exists for surge nozzle
  - Large diameter qualification sample (sufficient for RPV inlet/outlet nozzle inspection qualification) currently being fabricated

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MRP-169 RAIs – Significant Questions and Responses (cont'd)

- LBB #1 – Not all welds previously approved for LBB by NRC can be inspected by a qualified examination. How does MRP-169 address the LBB requirement for pre-inspection for these types of welds?
- Response – General requirement is that a qualified examination of the weld must be performed to show no cracking as part of demonstrating LBB. However, for LBB welds with inspection limitations (due to CASS) or in which inspections detect cracking, overlay must be FSWOL

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MRP-169 RAIs – Significant Questions and Responses (cont'd)

- LBB #2 – Please clarify that LBB analyses need to be performed for PWOLs applied to welds in piping systems that were approved for LBB.
- Response – Review existing LBB calculations for flaw tolerance and assess plant risk using existing PRA event trees.

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MRP-169 RAIs – Significant Questions and Responses (cont'd)

- Stress Analysis #1 – Please justify the appropriateness of the 10 ksi ID surface stress criterion
- Response –
  - Limiting ID surface stress levels to less than 10 ksi ensures very low probability of initiating new PWSCC cracks after application of WOLs
  - 20 ksi justified as safe value (below which PWSCC initiation very unlikely) for RPV top head penetrations in MRP-95
  - MRP-169 also imposes separate crack growth criteria, which, in conjunction with required pre- and post-overlay inspections, provide protection against propagation of pre-existing cracks that would violate overlay design basis

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MRP-169 RAIs – Significant Questions and Responses (cont'd)

- Stress Analysis #4 – Discuss why stress distributions in mock-up PWOL are different from those in example nozzle PWOLs
- Response –
  - PWOL mockup simulates a surge nozzle. Surge nozzle stress contour plots will be added to revised MRP-169
  - Mockup residual stresses in Section 5 were reported at room temperature for comparison to XRD measurements, surge nozzle example in Section 8 was reported at operating temperature
  - Post-overlay residual stresses for mockup and surge nozzle example do not differ significantly under consistent conditions
  - Detailed stress plots are provided in RAI response that demonstrate this point

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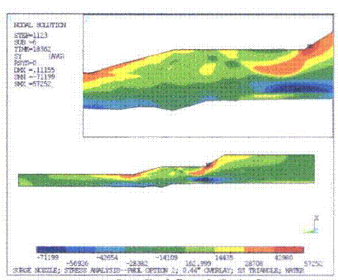
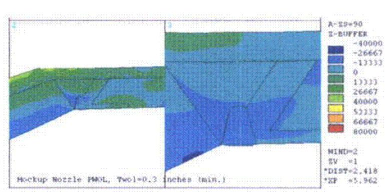
PWOL Mockup Stresses vs. Surge Nozzle WOL Calculations



Surge Nozzle Example (Section 8)



PWOL Mockup (Section 5)

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Summary of Proposed MRP-169 Update

- Editorial Changes and Clarifications to Address RAIs
- Substantive Changes:
  - Allow use of OWOLs for repair of flaws (limited to flaw depths < 50%)
  - Allow RI-ISI at some future date, pending successful operating experience with PWR overlays
  - Include Results of PWOL Mockup Residual Stress Testing and Analysis
  - Update Environmental FCG Law (More recent ANL report)
  - FSWOL requirement for LBB of uninspectable welds or welds with flaws detected

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Summary/Conclusions

- Responses prepared to all NRC RAIs
- Some RAIs plus field experience with PWOLs have resulted in suggested changes to original MRP-169 requirements
- Proposed Interim Guidance and Technical Justification developed for MRP-139 to address categorization of OWOLs
- After reaching agreement with NRC on RAI responses, they will be finalized and submitted
- MRP-169 will be revised accordingly and submitted (Nov 2007)
- Requesting NRC approval (SER) of Revised MRP-169 by Spring 2008 to support potential Fall 2008 RPV Nozzle Applications

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