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MRP-169 OWOL Inspection NRC Meeting

Dennis Weakland
First Energy
MRP Chairman

Ronald Swain
Electric Power Research Institute
Project Manager

Pete Riccardella
Structural Integrity Associates
Principal Investigator

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Introduction

Dennis Weakland

Presentation Outline

- Section 1: Introduction
  - Background
  - Proposed schedule
- Section 2: OWOL Inspection qualification
- Section 3: Proposed solution
- Section 4: Discussion & Summary

Weld Overlay : BWRs and PWRs

- Over 800 overlays applied in BWRs during 25 year period, many still operating
- Numerous (> 2000) in-service inspections performed on overlaid BWR welds
- No evidence of flaws growing in overlays or underlying base metal or welds
- An effective mitigation technique against PWSCC
- Used for PWR Pressurizer nozzle mitigation
    - End of Spring 2008: 89% of total were mitigated

NRC RAI Background

- In 2005, EPRI developed guidelines for PWOL mitigation strategy, MRP-169 provided technical basis for Full-Structural and Optimized WOLs
- NRC issued RAIs on August, 2006 and February 2008 respectively
- Responses to all RAIs submitted to NRC in April 2008 and incorporated into MRP-169, Rev. 1
- Currently only outstanding issue regards OWOL inspection qualification

NRC RAI Background (Cont'd)

- Approval/SER on MRP-169 before summer 2008 was requested during 2007 NRC meeting to support the applications of OWOL
- Initial OWOL implementation (fall 2008) was postponed due to NDE qualification concern and associated lack of SER on MRP-169
- Proposed Solution
  - New more conservative design analysis requirement to demonstrate that OWOL is effectively FSWOL for axial flaws
  - Revised inspection requirement (outer 25% for axial + outer 50% circumferential flaws)

MRP-169 Proposed New Schedule

Timeframe	Milestones
November 2008	NRC resumes reviewing MRP-169 revision 1.0
January 2009	Submission of MRP-169 Addendum to NRC
May 2009	SER of MRP-169 and Addendum
Fall 2009/spring 2010	Implementation of OWOL by utilities

Status of PWOL Inspection PDI

Carl Latiolais & Ronald Swain

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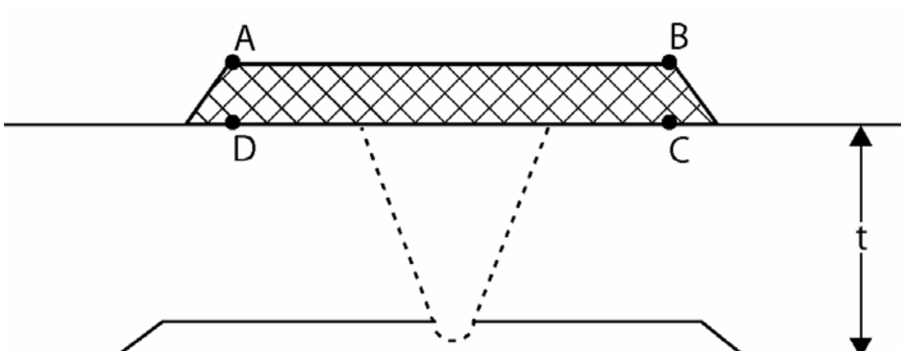
Inspection & Mitigation of Alloy 82/182 butt welds

PWOL inspection Project Description

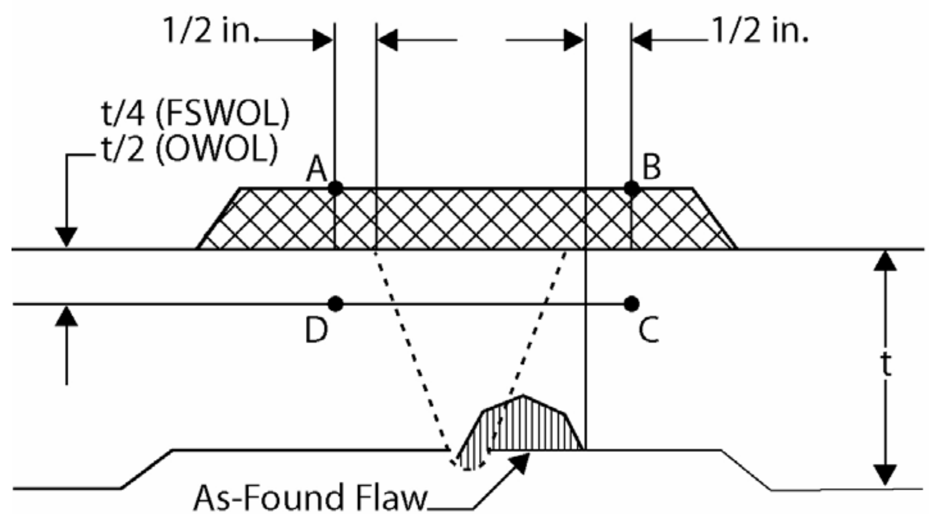
– **Fabricate samples to support the following tasks:**

- Obtain residual stress data for mitigation to support the application of PWOL (Optimized design) on large diameter components
- Develop procedures and techniques to examine beyond the outer 25% of the original base material in order to satisfy MRP-169 OWOL inspection requirements (outer 50%)
- Develop procedures and techniques to examine cast SS base material under weld overlays
- Expand currently qualified WOL procedure thickness ranges
- Develop Relief Requests and/or ASME Code revision to support qualification of the UT techniques developed

WOL Examination Volumes



WOL Acceptance Examination Volume A-B-C-D



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

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Inspection & Mitigation of Alloy 82/182 butt welds PZR Surge Line and Shutdown Cooling Mockups

- Smaller Diameter Configurations
  - All have cast safe-ends
  - Mock-ups have flaws at 50% and 75% of the original weld and base material thickness
  - Flaws located in cast base material and in weld
  - Mockup construction, characterization, and NDE evaluation performed in 2007

Inspection & Mitigation of Alloy 82/182 Butt Welds RCS Mockup

- 36” diameter, 3.4” thick RCS piping overlay mockup
  - Contains cast safe-end
  - Flaws located in cast base material and in weld
  - Half of circumference of overlay is optimized design thickness (0.7”), while other half is full-structural design thickness (1.4”)
  - Optimized overlay contains flaws ranging down to outer 50% of original weld and base material
  - Full-structural overlay contains flaws ranging down to outer 25% of original weld and base material
  - Mockup construction and residual stress design data collection completed in Feb. 2008
  - Mockup characterization and initial evaluation of NDE techniques completed in August 2008
  - UT technique qualification has been unsuccessful, to date
    - Due to difficulties with detection of axial flaws 50-75% thru-wall

Inspection & Mitigation of Alloy 82/182 Butt Welds RCS Mockup

- To further investigate difficulties with detection of axial flaws, an additional mockup was fabricated using an alternate flaw implantation technique
  - UddCom block
    - Non-blind mockup
    - Constructed to simulate metal path of RCS mockup
    - 2 axial flaws included (50% and 75% thru wall)
    - Weld solidification flaws (more faceted crack morphology)
  - Pre-overlay scan of the mockup ensured detectability of flaws prior to overlay
  - Post overlay scan revealed similar detection issues for 50% thru-wall axial flaw
- Further UT technique development may be required before detection of axial flaws at these depths can be qualified

Summary of Overlay UT Results

Surge/SDC: flaws in weld	RCS: flaws in weld
Detected & sized all circ and axial flaws in outer 25%	Detected & sized all circ & axial flaws in outer 25%
Detected all circ flaws, and some axial flaws outer 25 to 50% range	Detected and sized all circ flaws outer 25 to 50% range
Sizing - Not yet qualified outer 25 to 50% range (technique refinement)	Can't detect axial flaws outer 25 to 50% range

Surge/SDC: flaws in cast SS	RCS: flaws in cast SS
Limited detection of circ & axial flaws (Some flaws missed) -Not qualified	No detections
Sizing not qualified	Sizing not qualified

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Summary

- Current UT results show that procedures for detection and sizing of circ and axial flaws in the outer 25% of weld and wrought base material can be qualified for both full-structural and optimized weld designs
- UT of overlaid cast stainless steel cannot be qualified at this time
  - NOTE: Cast stainless is not included in the weld overlay examination volume, as defined in Code Case N-770 or MRP-139 interim guidance
- UT of optimized weld overlays on non-cast materials is expected to be qualified to detect and size circ flaws down to the outer 50% of weld and base materials, while axial flaw detection will likely be limited to the outer 25%, in the near term
- Future Action: Establish qualification requirements for OWOL and begin qualifying vendors

Alternate Design / Inspection Approach for OWOLs

Pete Riccardella

NDE Qualification Status

- NDE Qualification to outer 50% can be achieved for circ flaws
- Axial flaw qualification currently limited to outer 25%

Alternative OWOL Approach

- Proposed OWOL design that will be supported by PDI qualified NDE:
  - OWOL design based on 360° circumferential flaw, 75% thru-wall
  - Design will be shown to meet Section XI Appendix C flaw evaluation rules for 100% thru-wall axial flaw
  - Fatigue and PWSCC crack growth will be performed to show no growth for 75% assumed initial axial flaw
  - NDE to be conducted with expanded UT procedure which is PDI qualified to 50% thru-wall <u>for circ flaws only</u>
  - NDE <u>for axial flaws</u> to be performed using existing, FSWOL procedure (PDI qualified to 75% thru-wall)

Analysis Results for RPV Hot Leg Nozzle OWOL

- Analysis of plant specific RPV hot leg nozzle indicates that OWOL design is governed by circ flaws
  – 34” OD nozzle; 2.5” DMW thickness
  – OWOL thickness = 0.5” (excluding buffer layer)
  – Section XI Appendix C analysis indicates acceptable axial flaw size is 100% through DMW
  – Residual stress and crack growth analyses indicate no growth for 75% thru-wall axial flaw
- Therefore, the overlay design is effectively full structural for axial flaws

ASME XI Appendix C Evaluation Procedure for Axial Flaws

$$\sigma_h = \frac{3S_m}{SF}\left[\frac{t/a - 1}{t/a - 1/M_2}\right] \qquad (7)$$

where

$M_2 = [1 + 1.61\, \ell^2/(4\, Rt)]^{1/2}$

σ_h = nominal hoop stress = $PD/2t$

D = nominal outside diameter of the pipe

ℓ = total flaw length

a = flaw depth

R = mean radius of the pipe

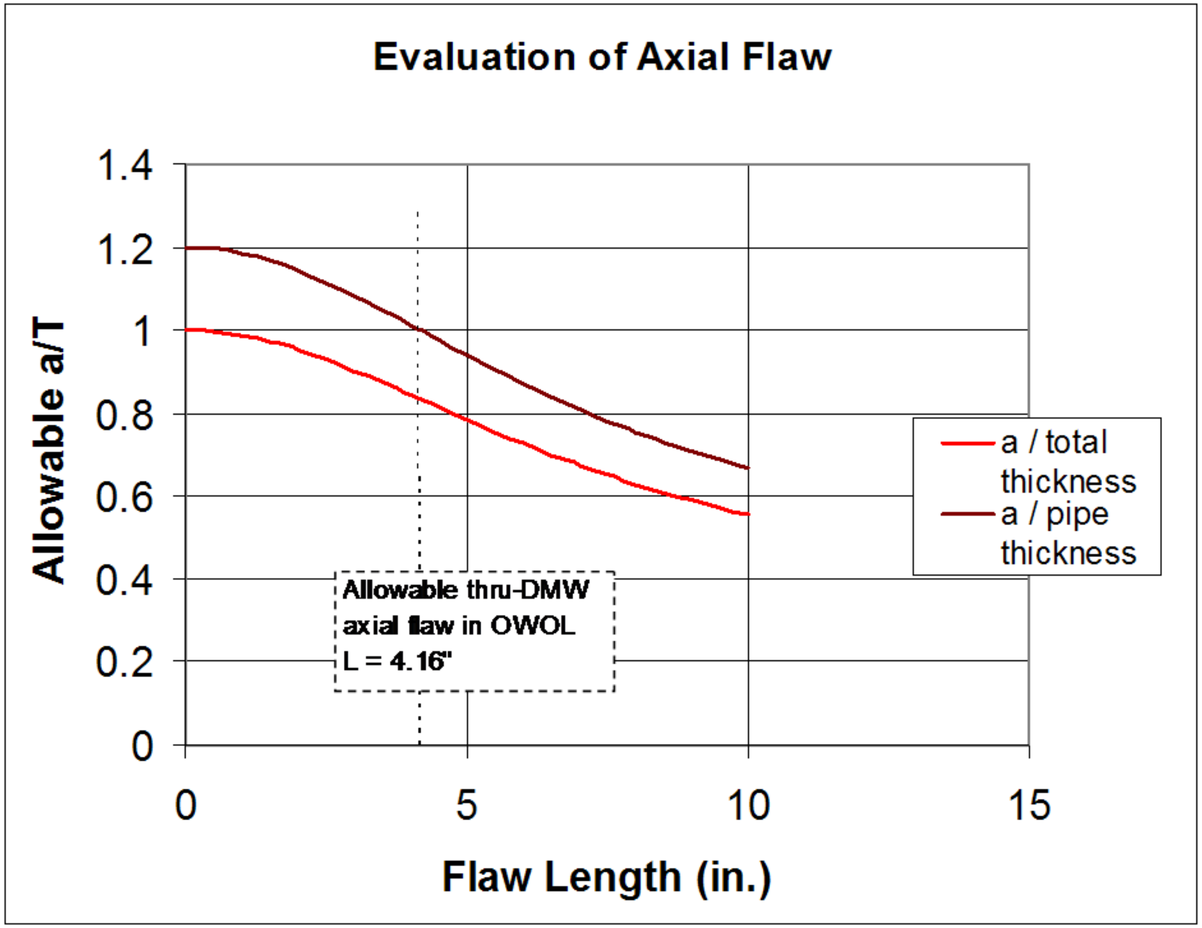
t = nominal thickness

SF = Safety Factor; 3.0 for Level A and B Service Loadings, 1.5 for Level C and D Service Loadings

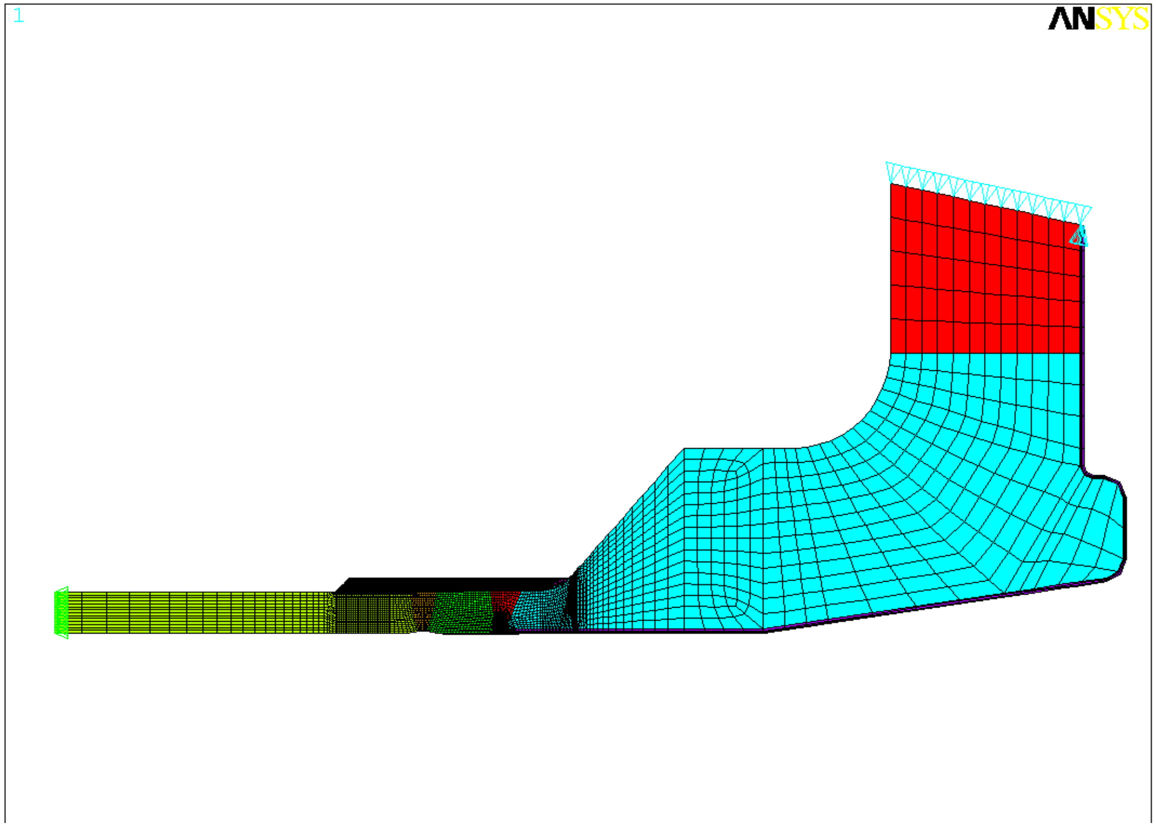
(b) Upper bounds on the applicability of Eq. (7) are set at flaw depths of 75% of the wall thickness. Equation

ASME XI Axial Flaws Evaluation Applied to Hot Leg Nozzle OWOL

P	2235 psi
Do Pipe	34 in.
twol	0.5 in.
tpipe	2.5 in.
3Sm,pipe	48.3 ksi
3Sm,wol	69.9 ksi
SF	3

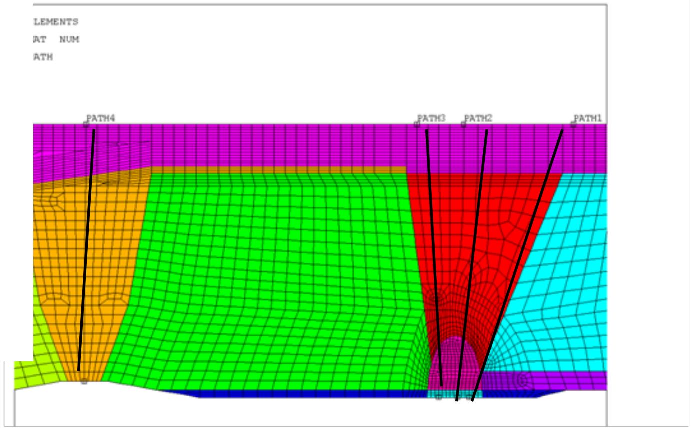


FEM of RPV Outlet Nozzle OWOL

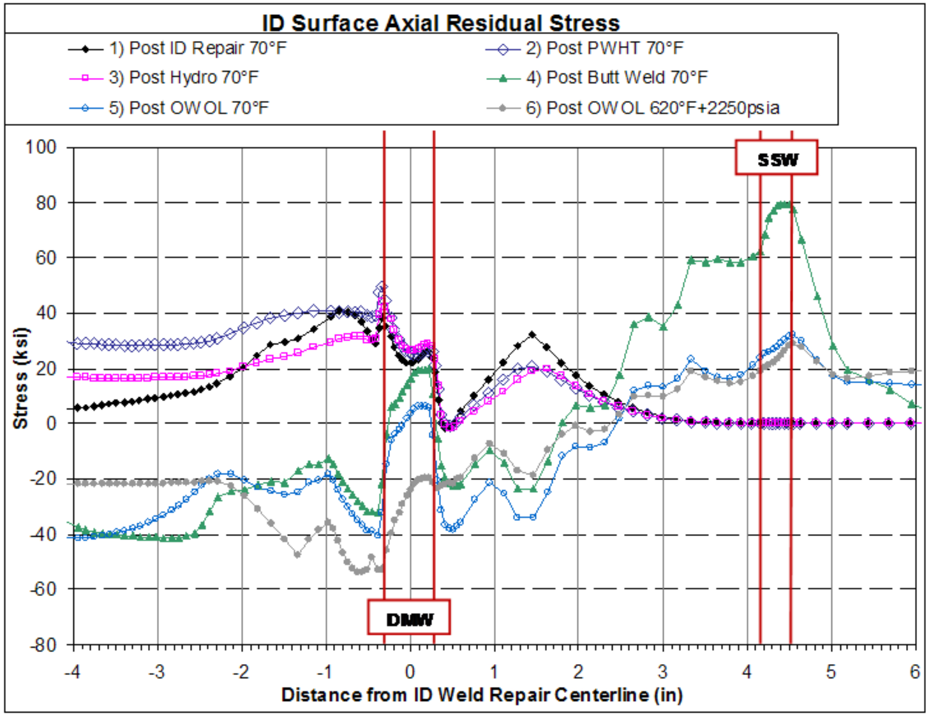


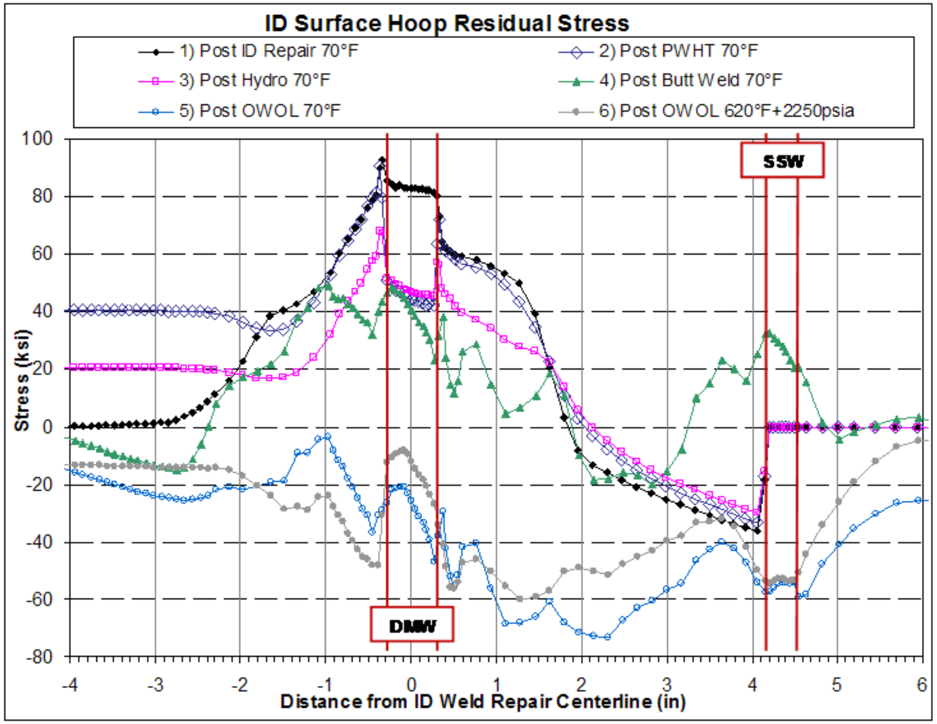
Finite Element Model

Stress Paths for Fracture Mechanics Evaluation

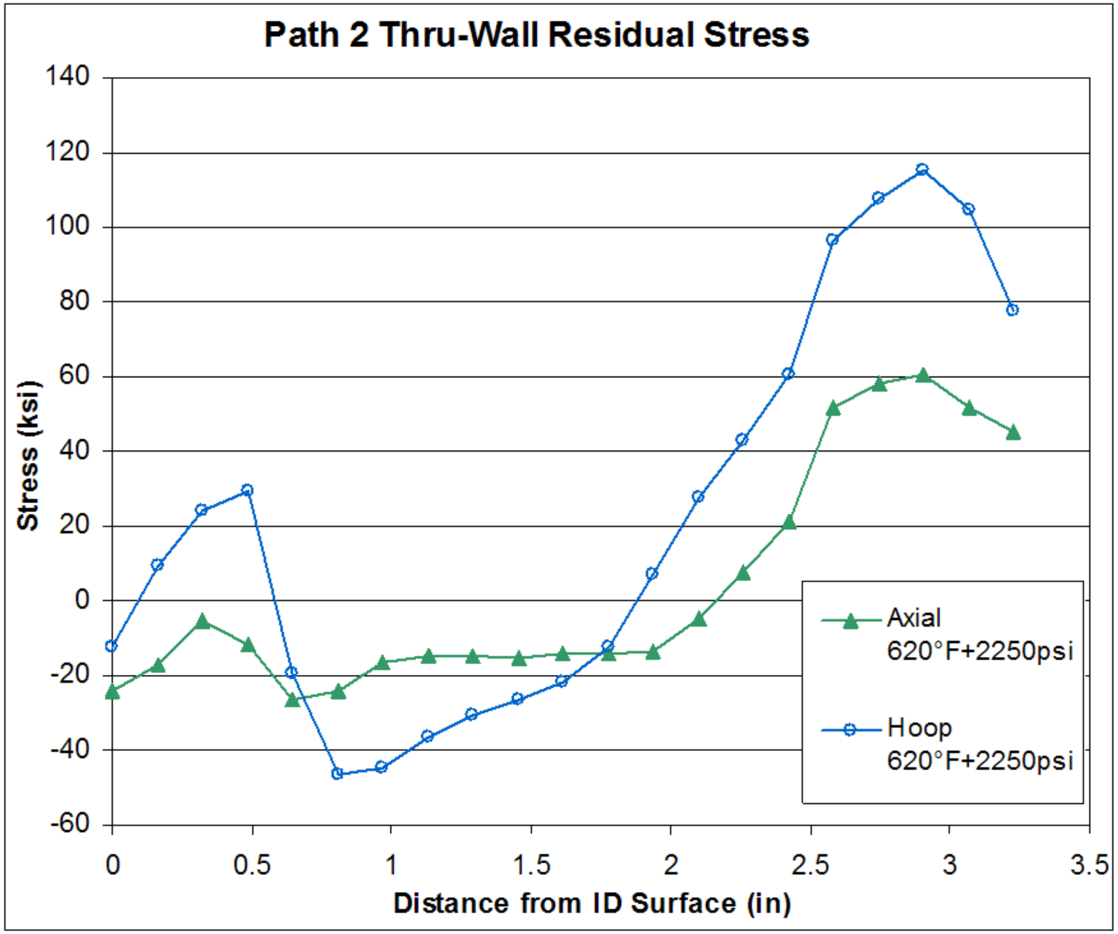


RPV Outlet Nozzle ID Surface Residual Stress Results





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



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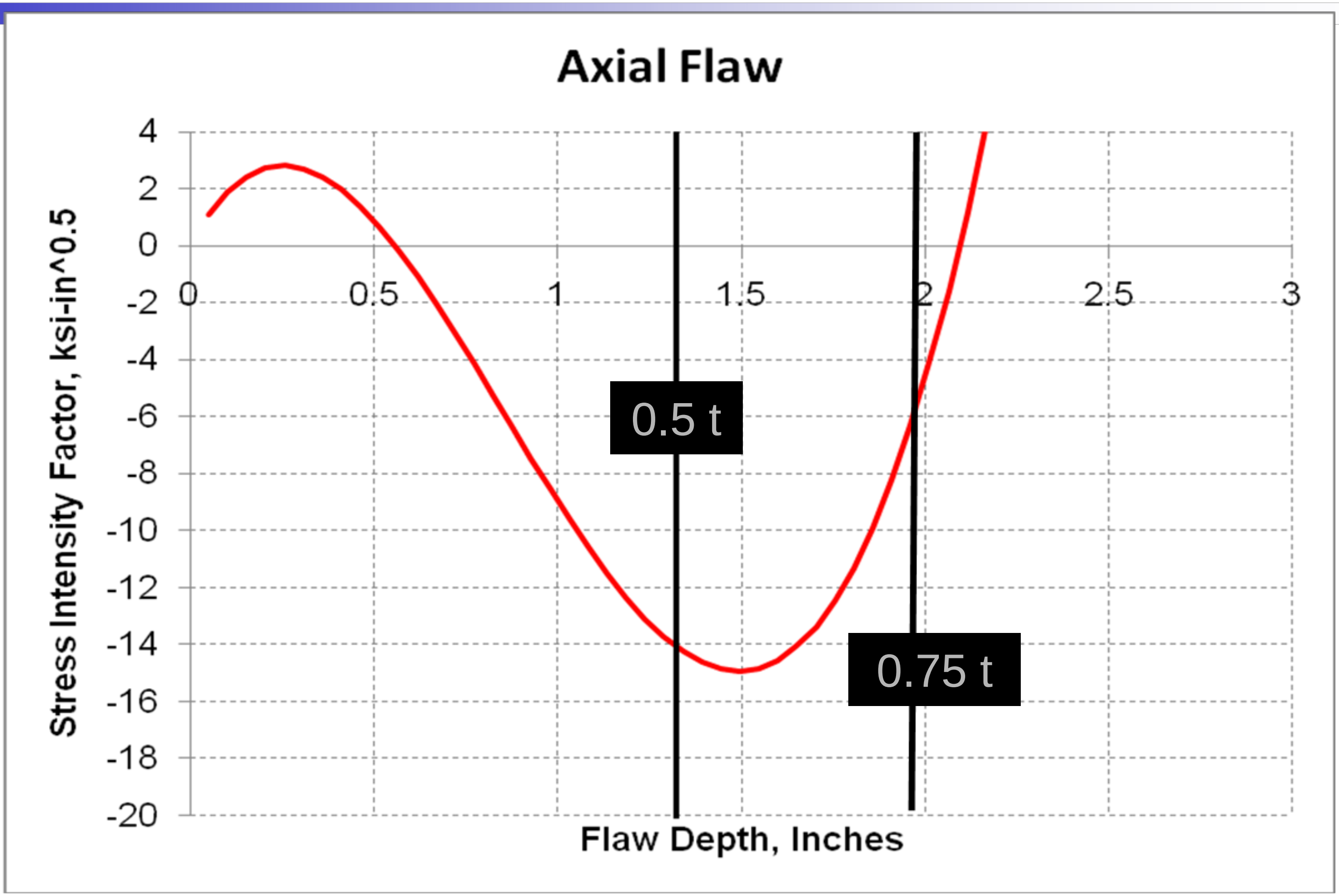
Crack Growth Evaluation for Axial Flaws



Conclusions

- Alternate OWOL Design/Analysis approach proposed that will be supported by NDE qualification capability for axial flaws
  - Provides same design margins as FSWOL for axial flaws
- Circ flaws more critical from structural Integrity standpoint (axial flaws will not cause pipe rupture)
- MRP-169 addendum will be issued to address alternative approach
- MRP-169 approval needed to support initial OWOL applications in fall 2009

Discussion & Summary

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