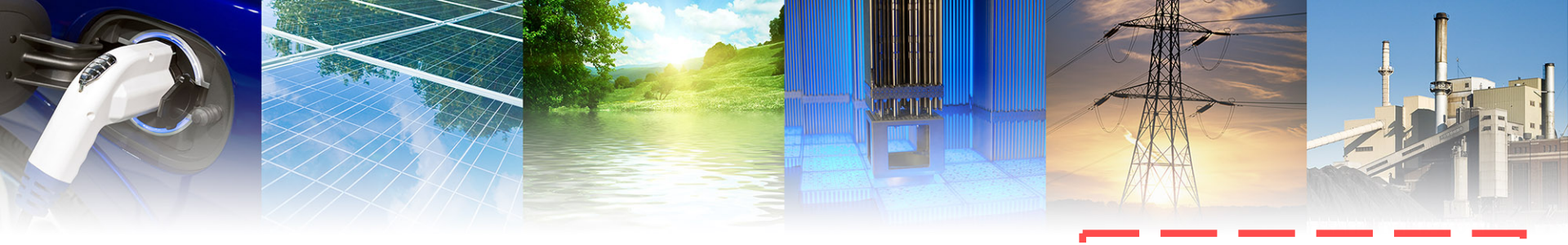

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Text in blue italics were added to original presentation slides in response to questions during the meeting

Mitigation – Excavate and Weld Repair

Industry/U.S. NRC Materials Program Meeting
Rockville, MD
Thursday June 6, 2013

Steve McCracken, Jon Tatman and Eric Willis
EPRI Welding & Repair Technology Center

Excavate and Weld Repair (EWR) Key Contributors

Eric Willis, Steve McCracken, Jon Tatman, Jack Spanner
EPRI

Pete Riccardella, Richard Smith, Francis Ku
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Brad Thigpen
Areva

Danny Cordes
Southern Nuclear

Michael Hill
Hill Engineering

Reference:
Topical Report: Application of the Excavate and Weld Repair Process for Repair and Mitigation of Alloy 182 and 82 in PWRs. EPRI, Palo Alto, CA: 2010. 1021012.

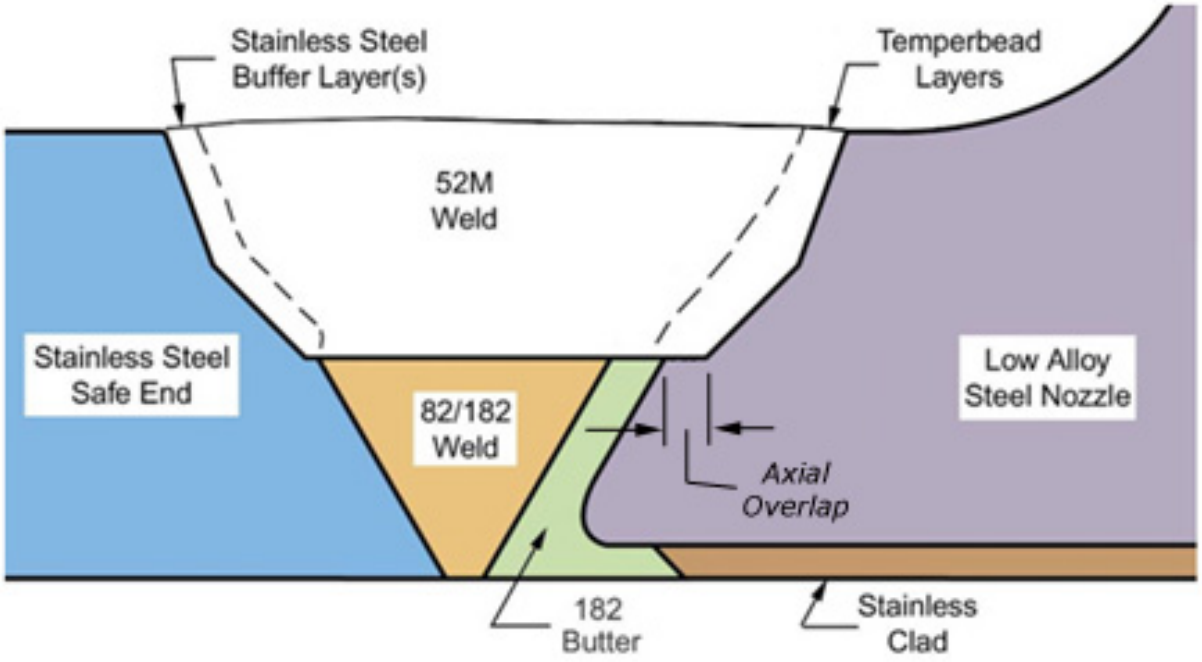
Presentation Roadmap

- Excavate and Weld Repair (EWR) Description
- EWR Code Case
- New EWR N-770-3 Inspection Items
- Residual Stress Analyses
- Partial Arc EWR:

  Mockup, Stress Analysis, and Strain Validation
- Future Work

Excavate and Weld Repair (EWR)

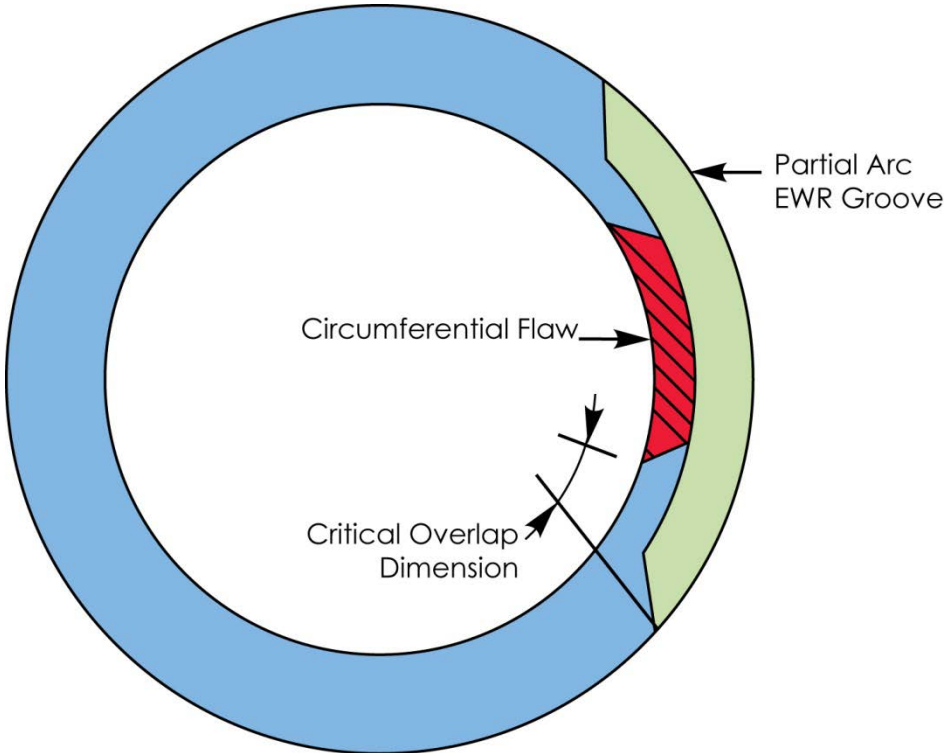
- Excavate & weld repair (EWR) for SCC repair or mitigation
  - Removes outer portion of SCC susceptible weld metal and replaces with resistant weld metal
  - Repair or mitigation option for DM welds with limited access
  - Unlimited excavation depth
  - Full 360° excavation
  - Permits reducing flaw to acceptable size
  - Considers stress improvement / reversal



Schematic of EWR for 82/182 Repair/Mitigation

Partial Arc EWR

- Partial arc EWR for limited life SCC repair
  - Partial arc EWR only removes a section of the SCC susceptible weld metal and replaces with resistant weld metal
  - Emergent repair option
  - Unlimited excavation depth
  - Permits reducing flaw to acceptable size
  - Limited life of one to two refueling cycles
  - No relief from DMW inspection scope or schedule



Schematic of Partial Arc EWR

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Summary of EWR Section XI Code Case
ASME Record # 10-1845

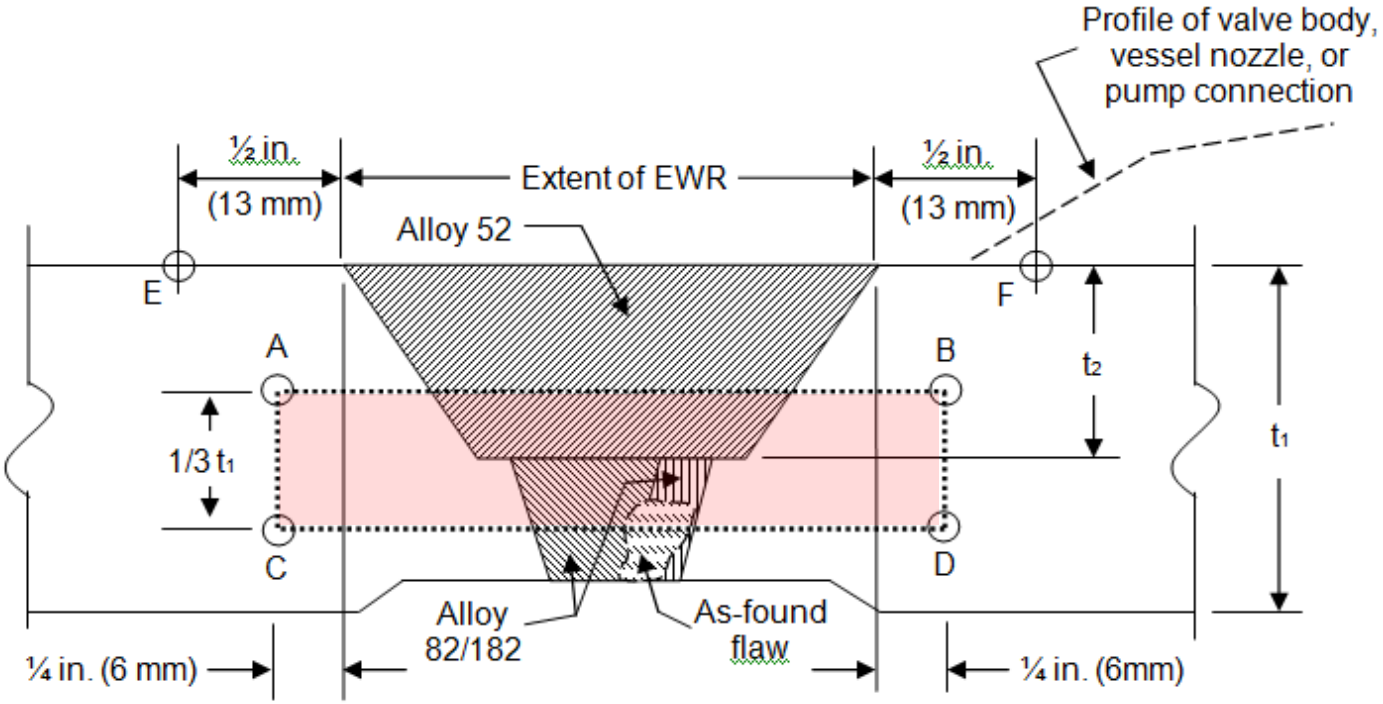
- Key elements of draft EWR code case
  - EWR can be used for SCC repair or mitigation of dissimilar or similar metal welds in PWR or BWR environments
  - Two types of EWR defined
    - **Type 1**: Meets specified residual stress criterion (d 10ksi at NOP & NOT on wetted surface of SCC susceptible material)
    - **Type 2**: Does not meet residual stress criterion or residual stress analysis was not performed
  - Weld acceptance standards & NDE specifics in EWR case
  - ISI & PSI requirements will be in N-770-3 for PWRs
  - *Full 360° EWR is designed such that the thickness of new SCC resistant weld metal is capable of supporting all design loads*
  - *Fatigue and postulated CGR analyses are required*

EWR Volumetric (UT) Examination

- *New SCC resistant EWR weld metal will be examined by UT and meet acceptance standards per the EWR Code Case*
- Proposed PSI / ISI examination volume is 1/3 thickness centered along EWR excavation depth
  - Current proposal from ASME EWR Task Group
  - *PSI / ISI requirements will be included in revised N-770-3 for PWRs*
- UT qualification requirements per EWR Code Case Appendix II or Appendix VIII Supplement 13 (new supplement)
  - Code Case Appendix II and new Supplement 13 will be developed in parallel
- Discussions ongoing pertaining to:
  - Proposed examination volume
  - Qualification requirements, demonstration approach, and PDI samples

N-770-3 EWR Proposed Examination Volume

FIG. 6(a) EXAMINATION VOLUME FOR EXCAVATE AND WELD REPAIR (EWR)

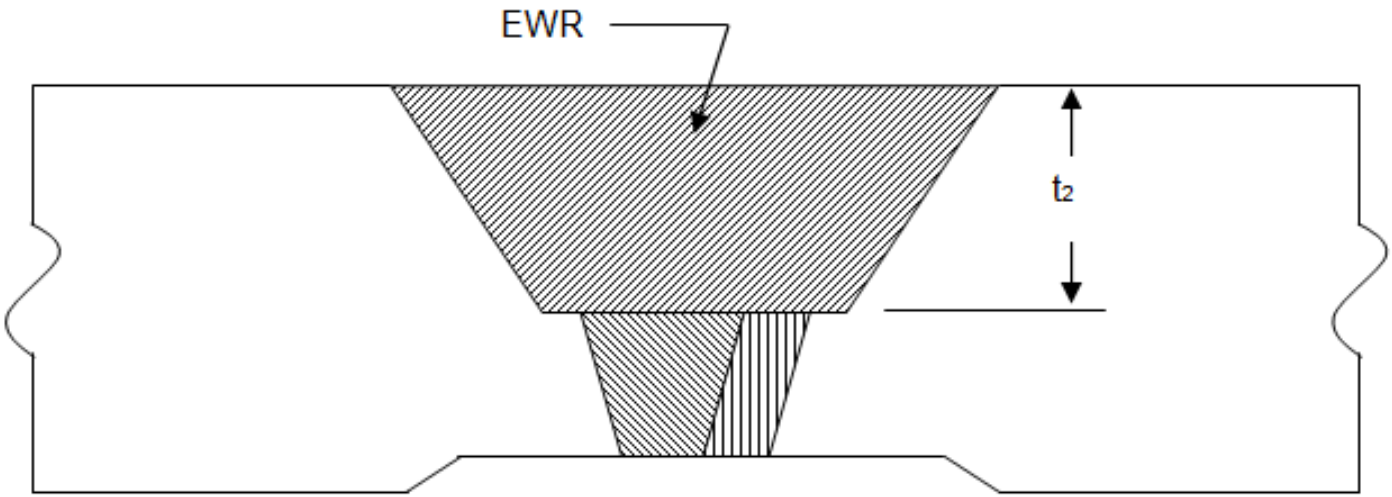


Examination Volume A-B-C-D
Surface Examination Extent E-F

GENERAL NOTES:
(a) Examination volume A-B-C-D is centered at excavation depth t_2.
(b) For axial or circumferential flaws, the axial extent of the examination volume shall extend at least ½ in. (13 mm) beyond the as-found flaw and at least ½ in. (13 mm) beyond the toes of the EWR, including any weld end butter, where applied.

EWR Thickness Used for IWB-3514 Acceptance

FIG. 6(b) DEFINITION OF THICKNESS t_2 FOR APPLICATION OF IWB-3514 ACCEPTANCE STANDARDS



GENERAL NOTES:
(a) The nominal wall thickness is t_2 for flaws in the EWR volume.

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N-770-3 New EWR Inspection Items

- For PWSCC repair or mitigation (PWR DMWs) TG EWR proposed following new Inspection Items in N-770-3
  - **Category L-1**,
    "Uncracked butt weld mitigated with full 360° Type 1 EWR"
  - **Category L-2**,
    "Uncracked butt weld mitigated with full 360° Type 2 EWR"
  - **Category M-1**,
    "Cracked butt weld repaired with full 360° Type 1 EWR"
  - **Category M-2**,
    "Cracked butt weld repaired with full 360° Type 2 EWR"
  - **Category N**,
    "Cracked butt weld repaired with partial arc EWR"

Inspection Item L-1

Uncracked butt weld mitigated with full 360° Type 1 EWR

- Volumetric examination per case Appendix II or Section XI Appendix VIII new EWR Supplement
- Acceptance standards per N-770-3 -3132.1
- Examine all welds no sooner than the third refueling outage and no later than 10 yr following EWR mitigation
  - Examination volumes that show no indication of cracking shall be placed into a population to be examined on a sample basis
  - Twenty-five percent of this population shall be added to the ISI Program and shall be examined once each inspection interval
- Examinations that reveal crack growth or new cracking shall be examined during each of the next three refueling outages

Same as uncracked stress improvement (Item D) – but better –

EWR Item L-1 provides stress reversal and resistant material

Inspection Item L-2

Uncracked butt weld mitigated with full 360° Type 2 EWR

- Volumetric examination per case Appendix II or Section XI Appendix VIII new EWR Supplement
- Acceptance standards per N-770-3 -3132.1
- Examine once during the first or second refueling outage following EWR
  - Examination volumes that show no indication of cracking shall be examined once each inspection interval
- Examinations that reveal crack growth or new cracking shall be examined during each of the next three refueling outages

Same as uncracked optimized WOL (Item F-2) – one mitigation – resistant material but no stress reversal.

Assume crack initiation & crack growth is arrested at EWR interface

Inspection Item M-1

Cracked butt weld repaired with full 360° Type 1 EWR

- Volumetric examination per case Appendix II or Section XI Appendix VIII new EWR Supplement
- Acceptance standards per N-770-3 -3132.1
- Examine once during the first or second refueling outage following EWR
  - Examination volumes that show no indication of crack growth or new cracking shall be placed into a population to be examined on a sample basis
  - Twenty-five percent of this population shall be added to the ISI Program and shall be examined once each inspection interval
- Examinations that reveal crack growth or new cracking shall be examined during each of the next three refueling outages

Same as cracked stress improvement repair (Item E) – but better –

EWR Item M-1 provides stress reversal and resistant material

Inspection Item M-2

Cracked butt weld repaired with full 360° Type 2 EWR

- Weld surface visual examination
- Volumetric examination per case Appendix II or Section XI Appendix VIII new EWR Supplement
- Acceptance standards per N-770-3 -3140 and -3132.1
- Examine once during the first or second refueling outage following EWR
  - Examination volumes that show no indication of cracking shall be examined once each inspection interval
- Examinations that reveal crack growth or new cracking shall be examined during each of the next three refueling outages

Inspection Item N

Cracked butt weld repaired with partial arc EWR

- Examination volume is 1/3t thickness centered at EWR excavation depth including ½” on each side of the partial EWR
- Weld surface visual examination
- Volumetric examination per case Appendix II or Section XI Appendix VIII new EWR Supplement
- Acceptance standards per N-770-3 -3140 and -3132.1
- Examine to same frequency as Inspection Items A-1, A-2, or B, as applicable for the weld repaired by partial arc EWR
  - Item A-1 Hot Leg >625°F; Item A-2 Hot Leg d625°F; Item B Cold Leg e525°F and <580°F
- When the design life is less than one refueling cycle, the partial arc EWR shall be examined prior to the end of the design life

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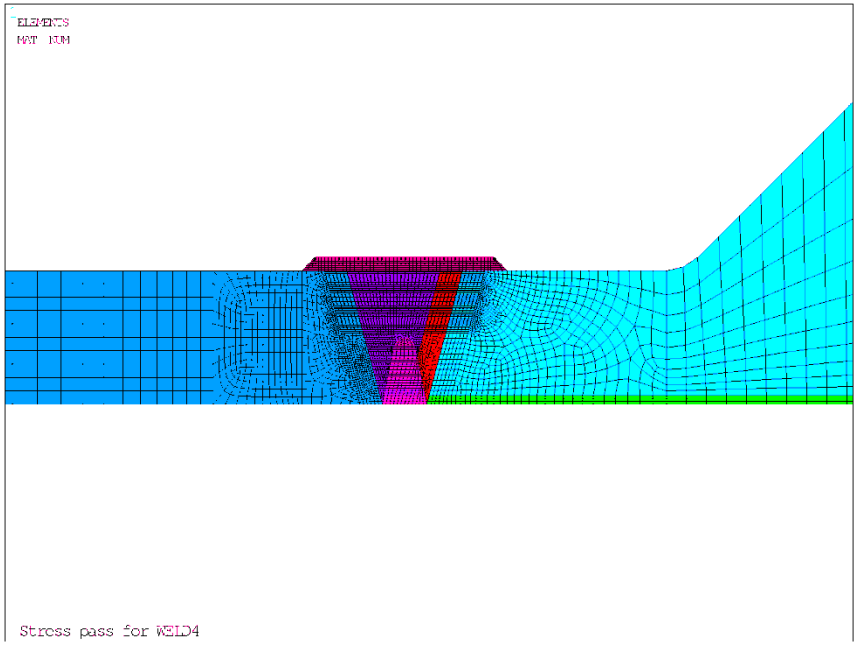
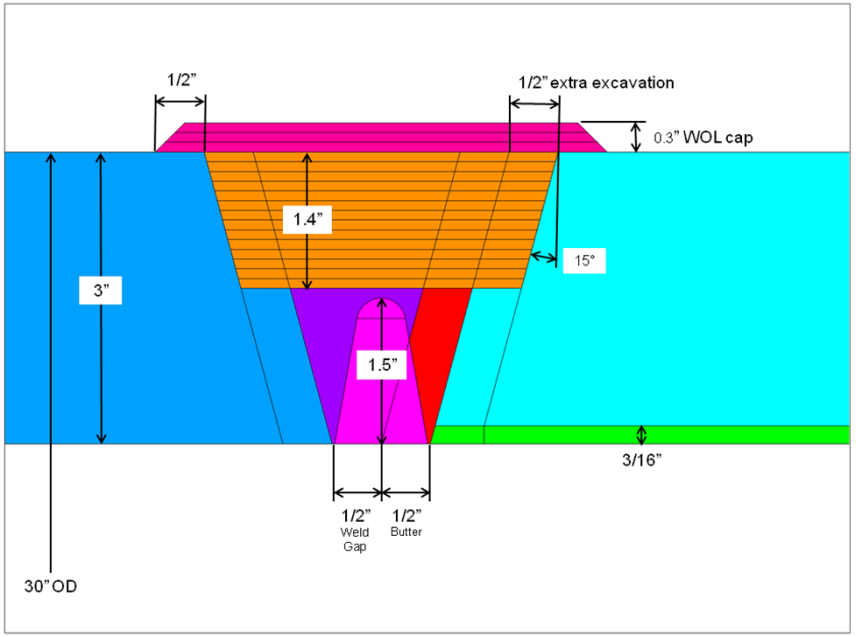
Residual Stress Modeling by SIA

30” Diameter Nozzle; 3” thick w/ Nozzle Butter and 50% ID Repair





Modeling performed by Structural Integrity Associates

EWR Cases Considered

0. Pre-EWR
1. 50% deep, narrow EWR, no WOL cap
2. 50% deep, narrow EWR, with WOL cap
3. 25% deep, narrow EWR, no WOL cap
4. 25% deep, narrow EWR, with WOL cap
5. 50% deep, wide EWR, no WOL cap
6. 50% deep, wide EWR, with WOL cap
7. 25% deep, wide EWR, no WOL cap
8. 25% deep, wide EWR, with WOL cap

EWR Model Stress Model Conclusions

- Wide range of EWR configurations studied
  - 50% & 25% cavity depth from outside surface
  - Narrow and wide cavities
  - With and without WOL Cap
- EWR produces significant residual stress improvement
  - Although not complete reversal like WOL or MSIP
  - Best configuration is 50% deep and wide EWR
  - WOL cap produces only modest improvement
- Improvement most apparent in circumferential crack stress intensity factors

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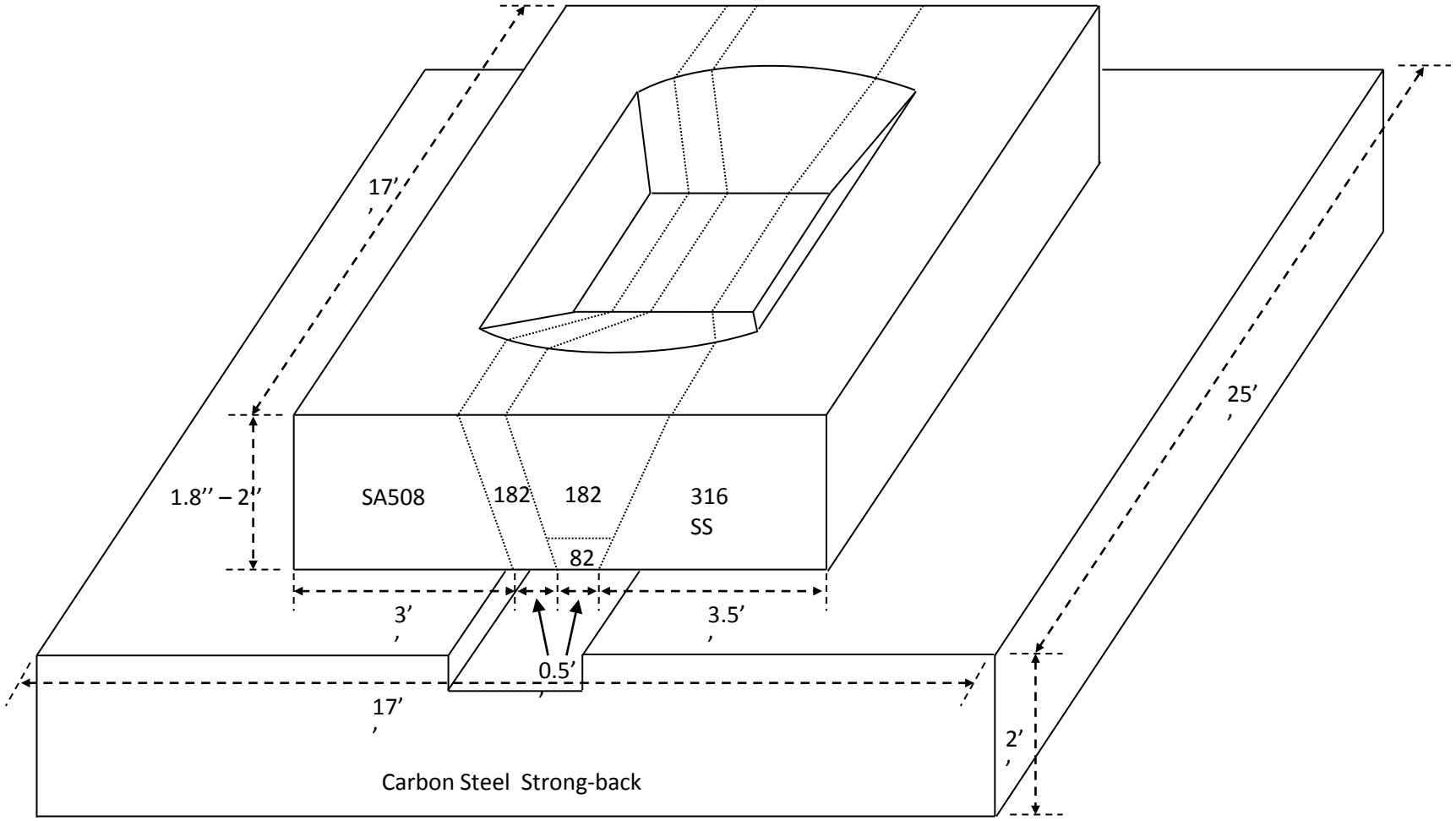
EWR Partial Arc Mockup Fabrications

- Fabrication of two EWR partial arc mockups are currently in-progress at EPRI-WRTC weld lab
- Weld traveler developed to ensure proper documentation and identical fabrication of the EWR partial arc mockups
- EWR partial arc mockup fabrications, residual stress analyses, and 3D modeling are scheduled to be completed by end of 2013

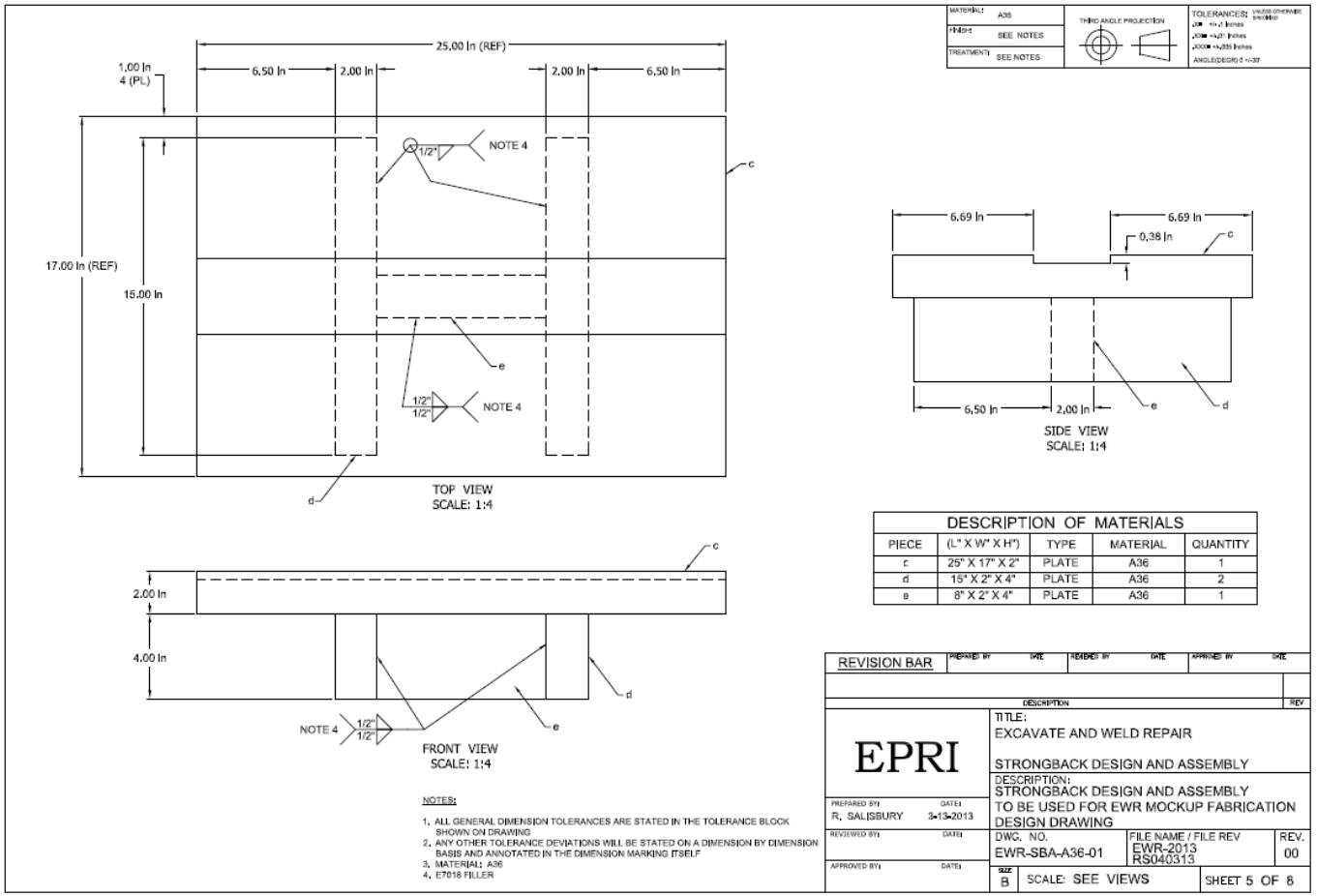
EWR Partial Arc Mockup Sketch

(not to scale, dimensions approximated)



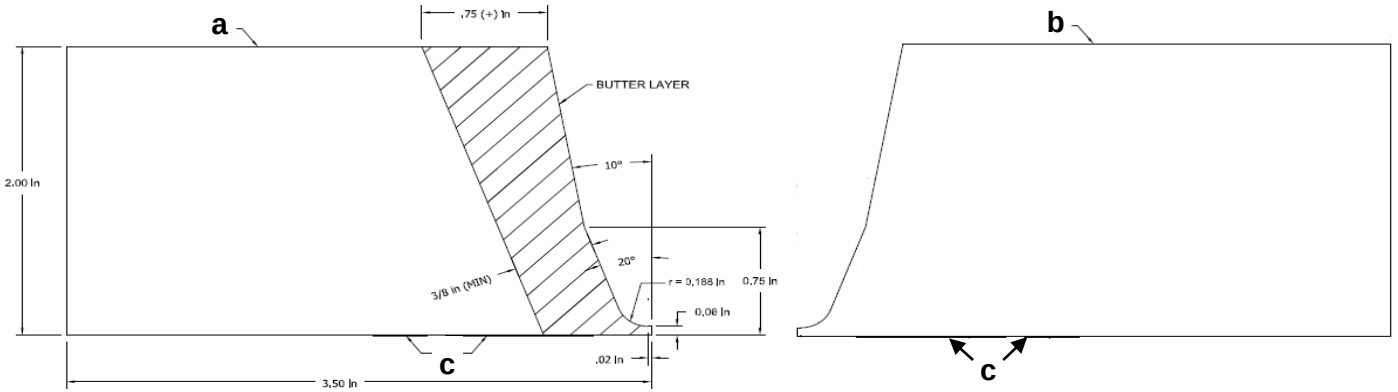
Strong-back Design

- Modeling performed by Structural Integrity Associates to ensure strong back design simulates rigidity of actual field conditions
- *Strong-back design simulates large heavy wall pipe conditions*



Partial Arc Mockup Joint Design

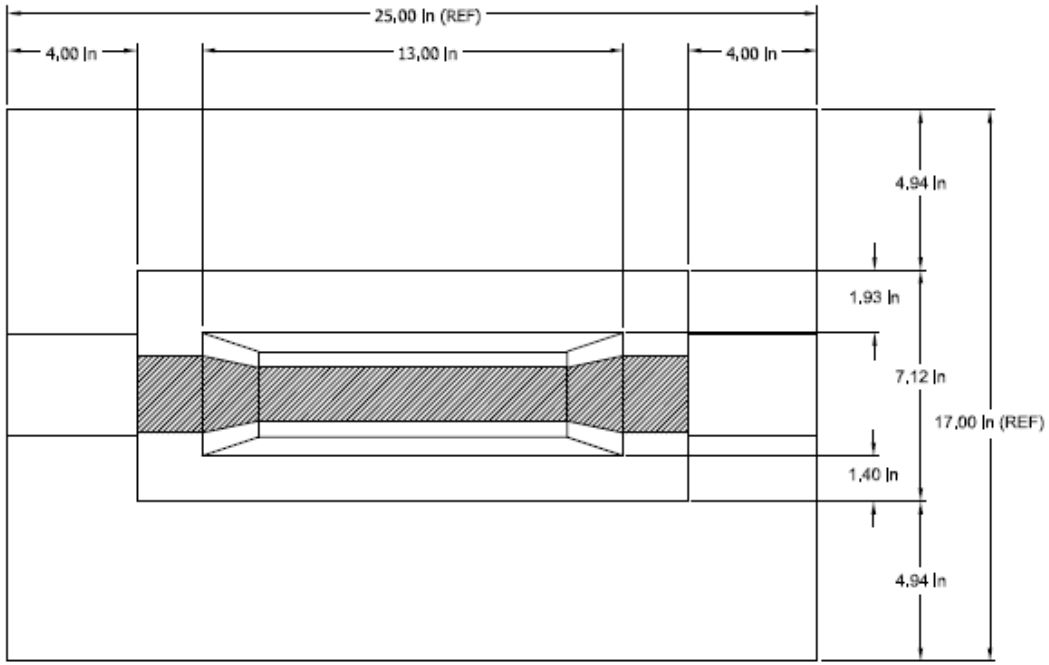
- Compound J-prep joint configuration for initial 82/182 weld
  - **a**: SA508 Class 3, **b**: SA240 (316L), **c**: weldable strain gauges



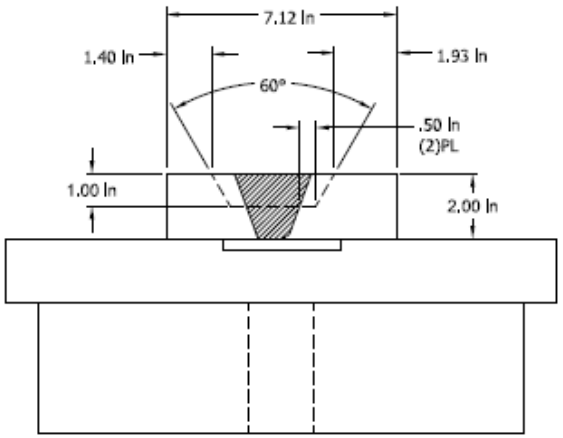
- Strain gauges installed for post-fabrication stress/strain analysis
  - Analyses to be performed by **Hill Engineering**
- Stress and strain analysis of mockups will be used for comparison to 3D partial arc model
  - Modeling to be performed by **Structural Integrity Associates**

Partial Arc Excavation Machining and Weld Fabrication

- Excavation within mockup to be machined following completion of the 82/182 compound J-prep weld
- Temperbead welding techniques to be used to ensure adequate HAZ tempering of SA-508 Class 3 material



TOP VIEW ~ (HIDDEN LINES HAVE BEEN REMOVED IN THIS VIEW FOR CLARITY) ~ SCALE: 1:4



SIDE VIEW
SCALE: 1:4

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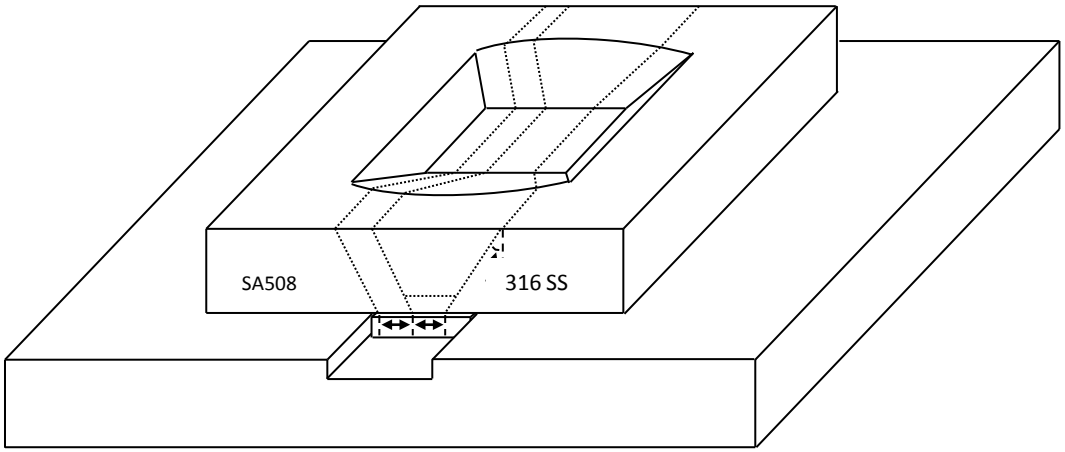
Future WRTC Work to Implement EWR Option

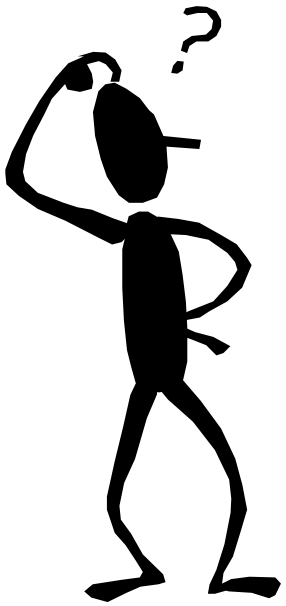
- Complete EWR Partial Arc Mockup
  - Temperbead
  - Low dilution
  - Bead placement
  - Strain measurement
  - Metallography
  - Impact testing



- Complete 3-D model and analyses for partial arc case
- Continue ASME code case development
  - New EWR Code Case
  - N-770-3 revision
  - Appendix VIII new supplement
- Consider pilot plants for future implementation of new EWR case

Consider providing sections of LAS HAZ from this mockup for CGR testing

Questions or Comments?



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