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Excavate and Weld Repair (EWR) Concept

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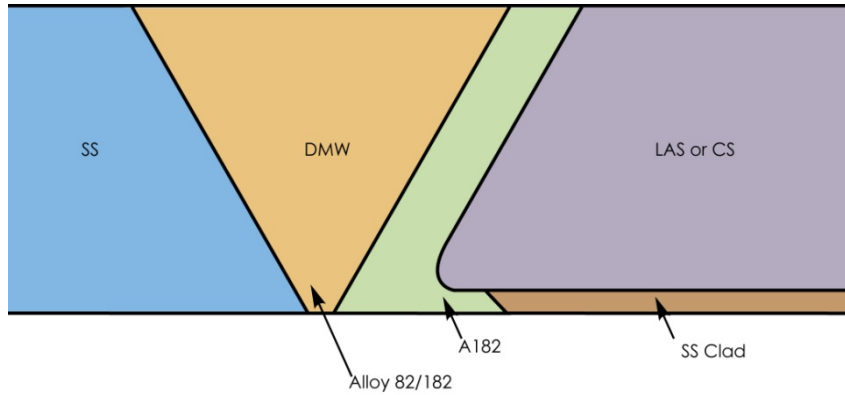
Structural Integrity Associates

Presentation Topics

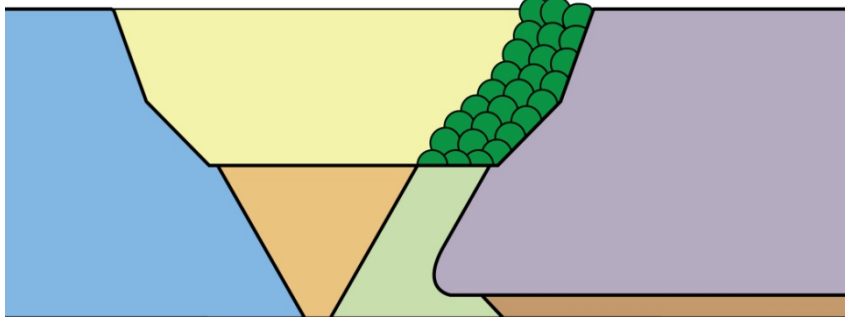
- Introduction
- Development of Design Requirements
- Materials and Welding Considerations
- Examination Requirements
- Future planned work

Introduction of Basic EWR Concept

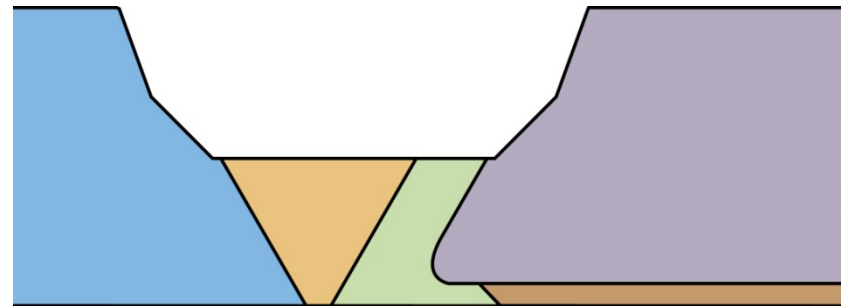
As Constructed



Weld Complete



Excavation Complete



Why EWR is Needed for the PWR Fleet

- In some un-mitigated DMW locations substantial interferences can make it very difficult if not impossible to install current mitigation approaches (WOL and MSIP)
- An alternative mitigation and emergent repair strategy is needed for these locations
- Mitigation and repair of large diameter components has significant outage impact
 - Advantages of the EWR process on large diameter components
 - Much less time to implement than overlay (8 days for full circ. EWR vs. 11-16 days for equivalent overlay)
 - Partial arc EWRs can be used for timely localized emergent repairs of as-found flaws (3-5 days to implement)
 - Fewer limitations due to interferences

Introduction to EWR Concept

- Fundamental Concept
 - Excavate a portion of original butt weld thickness and replace with PWSCC resistant, Alloy 52M weld metal
- Alternative to weld overlays for:
 - Large bore welds(>24 in. NPS) to reduce welding time
 - Locations with significant physical interferences
 - May also be applied to smaller diameter components
- Similar to FSWOL (i.e. all design loads carried exclusively by newly applied, PWSCC resistant material) for fully circumferential 360° repair but without the residual stress benefit
- Three options are possible:
 - Preemptive mitigation (full 360° EWR)
 - Full 360° EWR repair
 - Partial arc repair (axial or limited circumferential flaw)



Development of Design Requirements

Design Requirements – ASME Code

- Technical basis for EWR design is existing ASME Code, Section XI rules:
 - IWA-4420 provides specific guidance for defect removal as part of an ASME Code, Section XI repair program
 - Defect removal area and any remaining portion of defect may be evaluated and accepted in accordance with appropriate Section XI flaw evaluation provisions
 - IWB-3640 provides applicable flaw evaluation procedures and acceptance criteria for types of defects that would remain in service following an EWR
 - Meeting IWB-3640 automatically satisfies ASME Section III primary stress limits
- Owner would also need to reconcile material change in repaired weld region in applicable ASME Code, Section III Stress Report, but no need to update Section III Secondary Stress / Fatigue analyses because no change in configuration

Design Requirements - Excavation

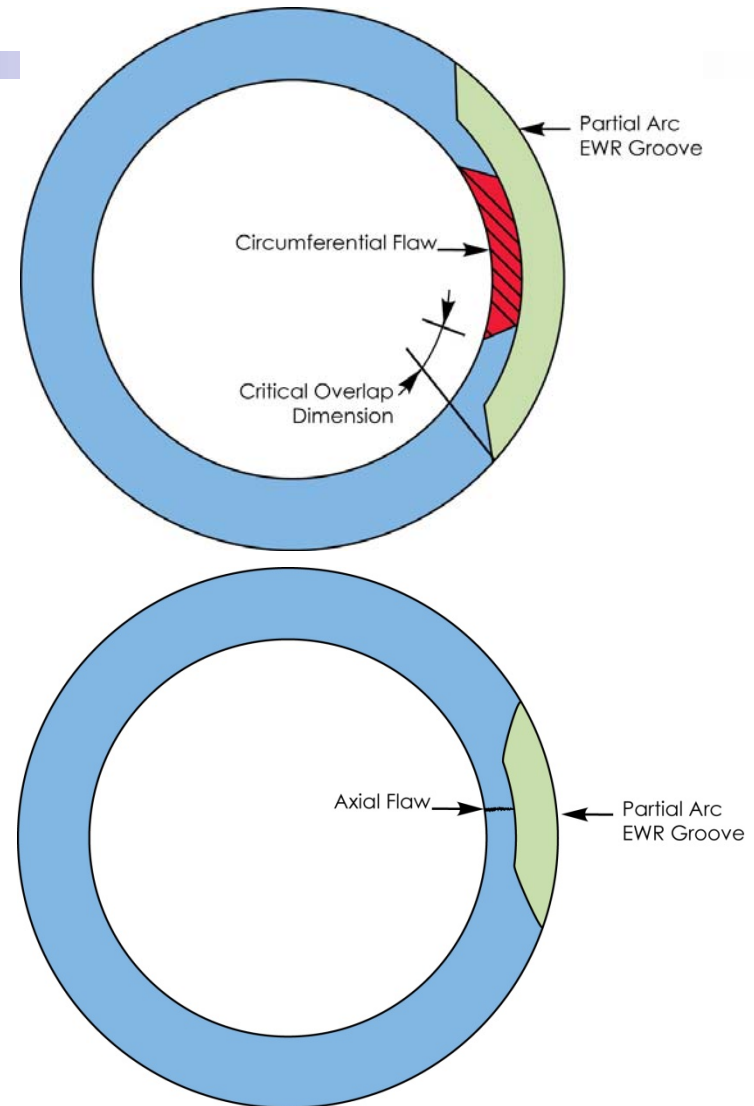
- Excavation depth depends on applied loadings (Service Levels A, B, C, D)
 - 50% of original wall thickness will be sufficient to meet Code limits for most locations
 - Minimum excavation depth must also allow for fatigue crack and PWSCC growth over the life of the repair assuming that an ID surface connected flaw exists
- Excavation and repair length may be:
 - 360° of circumference (repair or mitigation)
 - Partial arc repair (axial or limited circumferential flaw)

Design Requirements – Analysis Details

- Perform PWSCC and Fatigue crack growth rate analyses for the maximum pre-existing flaw:
 - Flaw depth assumed equal to maximum depth in original weldment (up to the repair cavity)
 - Pressure, Thermal, Mechanical and Residual stresses to be considered
- For full 360° EWR, crack growth will be in Alloy 52M (PWSCC Resistant) material
 - Fatigue growth computed using standard industry curves for PWR environment (NUREG/CR-6907)
 - PWSCC growth computed using K-independent curves for Alloy 52M material (therefore residual stresses not needed)

Design Requirements – Analysis Details (cont'd)

- For partial arc excavation, a key design parameter will be overlap length required to ensure that finite length circumferential flaw doesn't grow beyond EWR during repair life
 - Thru-wall growth is bounded by PWSCC resistant material
 - Circumferential growth will be in susceptible material (Alloy 82/182) and residual stresses will thus be needed
 - For axial flaws, overlap length will likely be governed by welding and tooling considerations

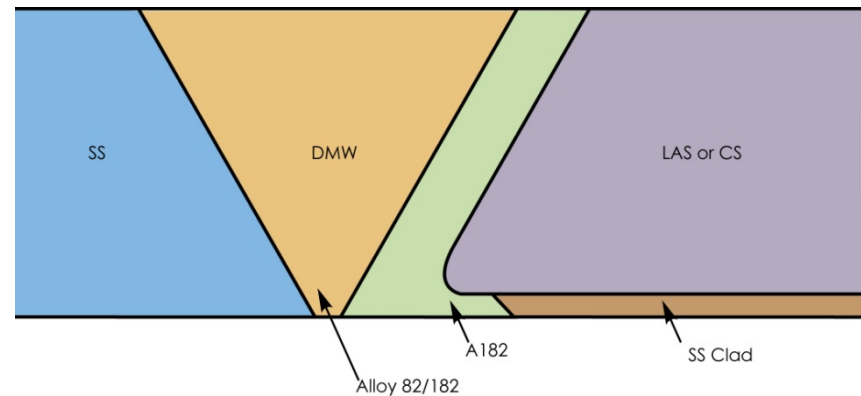




Materials and Welding Considerations

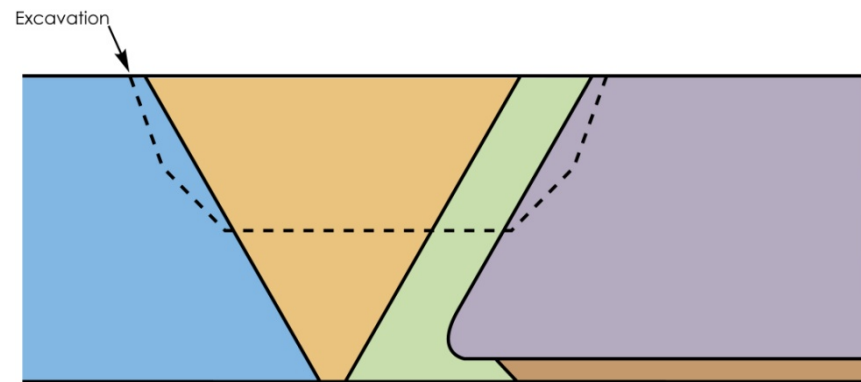
Materials and Welding Considerations

- Original weld is a composite of materials
 - Low alloy steel or CS
 - Alloy 82/182 butter
 - Alloy 82/182 butt weld
 - Stainless steel (wrought or cast) component
 - Pipe
 - Safe-end
 - Pump casing/nozzle



Materials and Welding Considerations

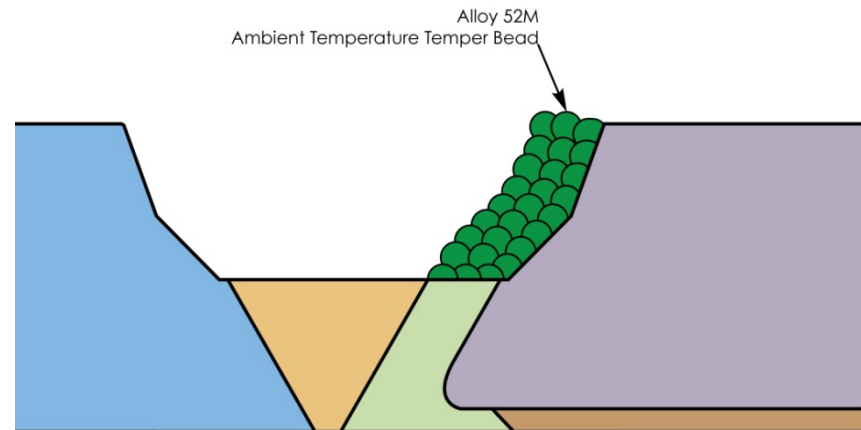
- Excavation removes buttering from LAS or CS material
 - Any new HAZ requires tempering
 - Replace original A82/182 with PWSCC resistant material
 - Alloy 52M (30% Cr)
 - Other potential issues associated with temperbead welding
 - To be addressed in project (review in future meetings w/ NRC)



Materials and Welding Considerations

Carbon / Low Alloy Steel

- Component is typically filled with water
- PWHT is not practical and would result in excessive radiation to workers if component is drained
- Ambient temperature temperbead techniques available for machine GTAW and have been used extensively
- Nuclear ASME CC N-638-2



Materials and Welding Considerations

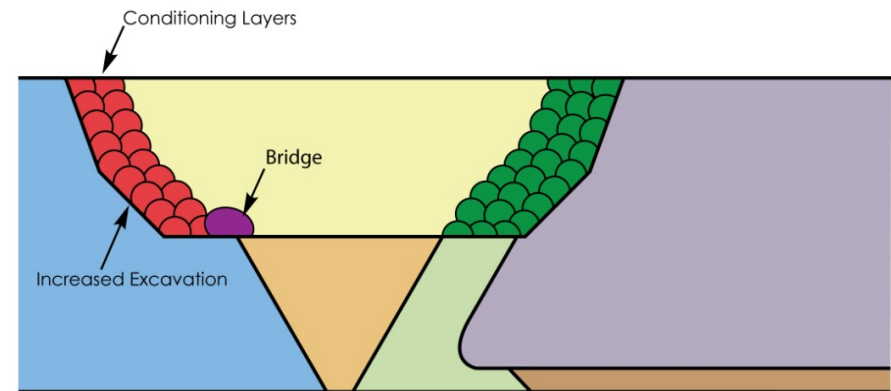
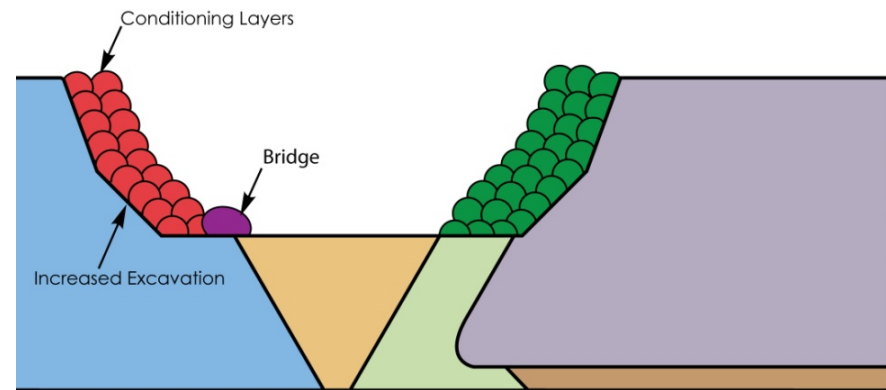
Stainless Steel

- Alloy 52M is susceptible to solidification cracking
- Chemistry of stainless steel is important to assessing risk of solidification cracking in Alloy 52M
- Weld dilution control is essential to control deposit chemistry
- Use of SS conditioning layer(s) or buffer layer(s)
 - Proven for overlays
 - Adapt techniques to groove side walls
- Welding considerations for 2G (component vertical) and 5G (component horizontal)
- Bridge bead(s) – Alloy 82 lowers chance for bridge bead cracking

Materials and Welding Considerations

Stainless Steel

- Alloy 52M susceptible to Ductility Dip Cracking (DDC)
 - Influenced by degree of remelting and restraint
 - Technique development and demonstration required
- Intended approach involves use of efficient weld beads and precision weld bead stacking to minimize weld shrinkage in final closure



Process Demonstration Needs

- Process Demonstrations recommended as follows
 - Techniques to identify fusion interfaces (etching)
 - Temperbead applied to groove sidewall
 - SS conditioning layers applied to castings to minimize risk of solidification cracks in Alloy 52M fill (welding parameter development)
 - Bridge bead used to tie-in conditioning layers to existing Alloy 182
 - Groove filling techniques that minimize risk of DDC
- Considerations for component orientation (vertical or horizontal welding)
- Circumferential arc segment mockups designed for water-backed groove simulation



Examination Requirements

Examination Requirements - Timing

- Prior to excavation
- After excavation is completed
- Acceptance examinations of weld repair
- Preservice inspection
- Future inservice inspections

Examination Prior To Excavation

- Detect and Size Defects
 - ASME Code, Section XI, PDI qualified UT (qualified for detection and sizing)
 - Purpose of exam is to detect, characterize, locate and size crack-like defects that will be mitigated by this repair approach
 - Dimensioning is important to define key repair process parameters (excavation location, size, shape, depth, etc.)

Examination of Excavation

- Two scenarios identified with implications on examination:
 1. SS surface conditioning not required
 - **PT examination shall be performed prior to welding to verify surface suitable for welding (ASME III, NB-4450).**
 2. Chemistry of stainless steel base material is such that surface conditioning deposit needed
 - **PT examination conducted after last layer of conditioning weld deposit**
- Acceptance criteria for both cases is NB-5350

Examination for Acceptance of Weld Repair

- Per NB-4450, if repair excavation is greater than 3/8" or 10% of component thickness, radiographic examination (RT) is required
 - Existing flaw will be present in repair applications
- Alternative UT exam will be utilized under provisions of Code Case N-659
 - Demonstration needs to be performed on mock-up coupon built in accordance with Code Case N-659 (containing fabrication defects)
 - Approach will be consistent with recent PDI qualifications approved by the NRC
 - Personnel performing examinations will be qualified by demonstration on test coupon(s) developed by EPRI.
 - Relief Request is required for this alternative

Preservice Inspection

- Per ASME XI, IWB-2200, volumetric PDI UT examination required with procedure and personnel qualified in accordance with Section XI, Appendix VIII.
 - Procedure and qualifications currently exist
 - Primary focus to identify original flaw being repaired and determine if there has been any growth during repair process
 - Examination result will become baseline for future Inservice Inspections (ISI).

Future Inservice Inspection Requirements

- EWR currently not addressed in Code Case N-770 or MRP-139. ISI requirements to be established similar to N-770, with industry and regulatory participation:
- Three options identified:
 1. 360° EWR with no PWSCC identified in pre-excavation exam
 - Repair is treated as a Code repair and normal Code rules apply (similar to N-770 Category C)
 2. 360° EWR with existing flaw bounded by the bottom of the excavated groove
 - Perform volumetric in-service inspection once during the first or second refueling outage following application.
 - If no indication of crack growth or new cracking, place into population to be examined on a sample basis (similar to N-770 Cat F)
 3. Partial arc EWR (TBD)



Future Planned Project Phases

Future Planned Project Phases

- Phase 2
 - Analytical Evaluation
- Phase 3
 - Task 1-Implementation and Examination Mock-up Validation/Demonstration
 - Task 2-Production of a Topical Report Similar to MRP-169

Phase 2 Project Details

- Analytical Evaluation (Full Circumference and Partial Arc EWRs)
 - Sub-task 1 – Sizing, simplified fatigue, and PWSCC crack growth evaluation methodology to support emergent repair
 - Sizing calculation (primary stress criteria)
 - Fatigue and PWSCC crack growth (establish minimum Alloy 52M thickness required to accommodate post repair growth)
 - Sub-task 2 - Detailed analysis of specific geometry example
 - Repair sizing and design
 - Loads and finite element development
 - Thermal/mechanical and residual stress analysis
 - Crack growth evaluation (PWSCC and Fatigue)
 - ASME Code Section III reconciliation
 - Sub-task 3 - Report update on Phase 2 analyses
 - Sub-task 4 - Meeting to update NRC on Phase 2

Phase 3 Project Details

- Task 1 - Implementation and Examination Mockup Validation/Demonstration
 - Sub-task 1 - Demonstration scope for EWR Process
 - Development of WPSs/PQRs (including review of existing ones for applicability)
 - Development of joint geometry requirements
 - Tooling considerations
 - Base material considerations; e.g., potential need for conditioning layers on cast SS
 - Demonstration of etching technique
 - Sub-task 2 - Demonstration scope for EWR Process (*Continued*)
 - Two Mock-ups
 - Fabricated from CASS and P3 materials
 - Demonstration Weld (one welded in each of two plate welding positions) (Ref. ASME IX QW461.1 and 461.3)
 - 1G/2G (Flat-to-Horizontal)
 - 3G/4G (Vertical-to-Overhead)
 - In-process PT and follow-up UT examinations
 - Follow-up destructive metallurgical examinations of weld repair

Phase 3 Project Details

- Task 2-Production of Topical Report and review and approval
 - Sub-task 1-Produce Topical Report
 - Utility review and comment
 - Submit to the NRC with request for SER
 - Interface with NRC on review of Topical Report