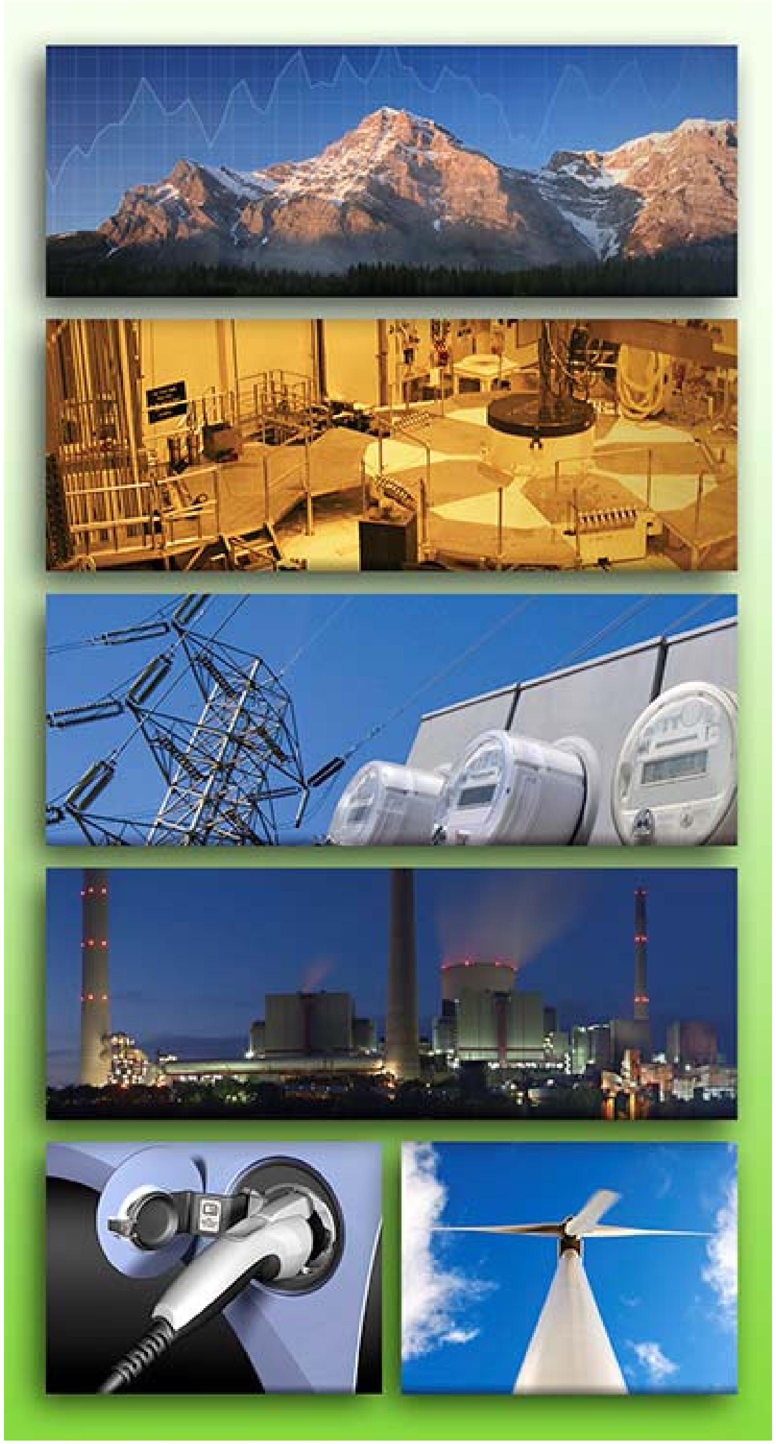


ELECTRIC POWER RESEARCH INSTITUTE

Excavate and Weld Repair (EWR) Concept

April, 2010

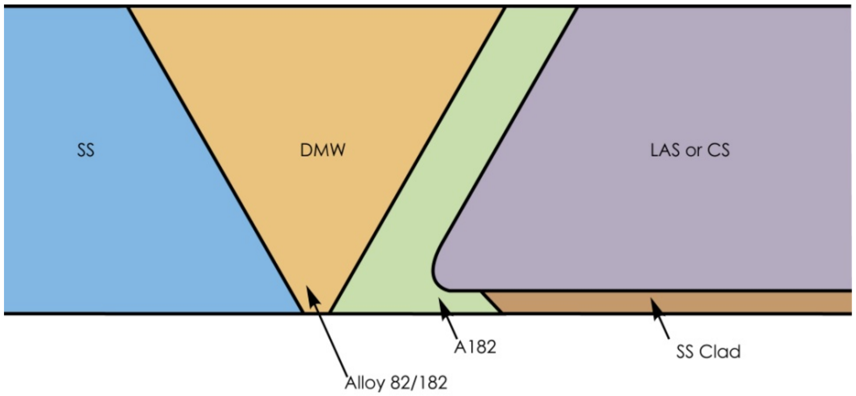
William Sims
Chairman MRP Assessment ITG
Eric Willis, Craig Harrington
EPRI
Pete Riccardella, Richard Smith
Structural Integrity Associates

Presentation Topics

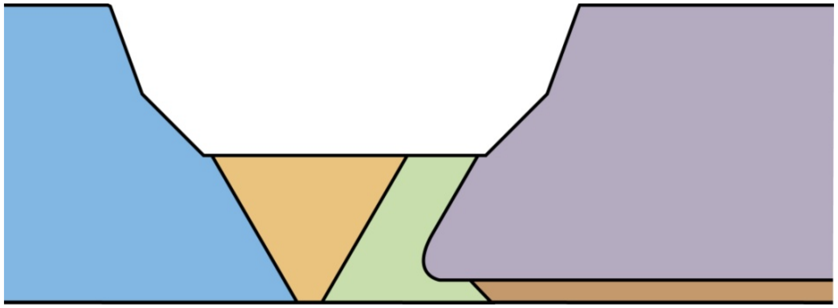
- Introduction
- Development of Design Requirements
- Materials and Welding Considerations
- Examination Requirements
- Future planned work

Introduction of Basic EWR Concept

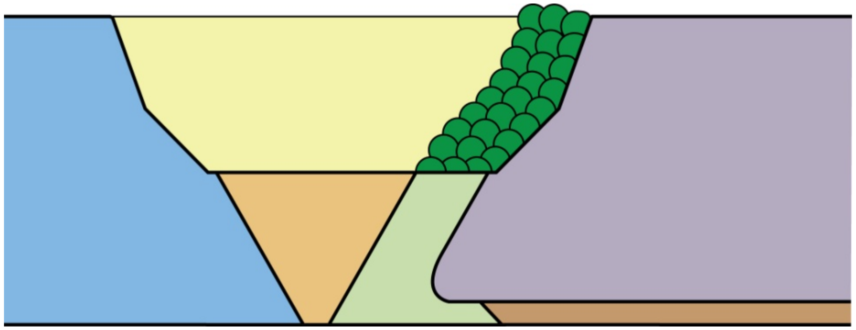
As Constructed



Excavation Complete



Weld 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

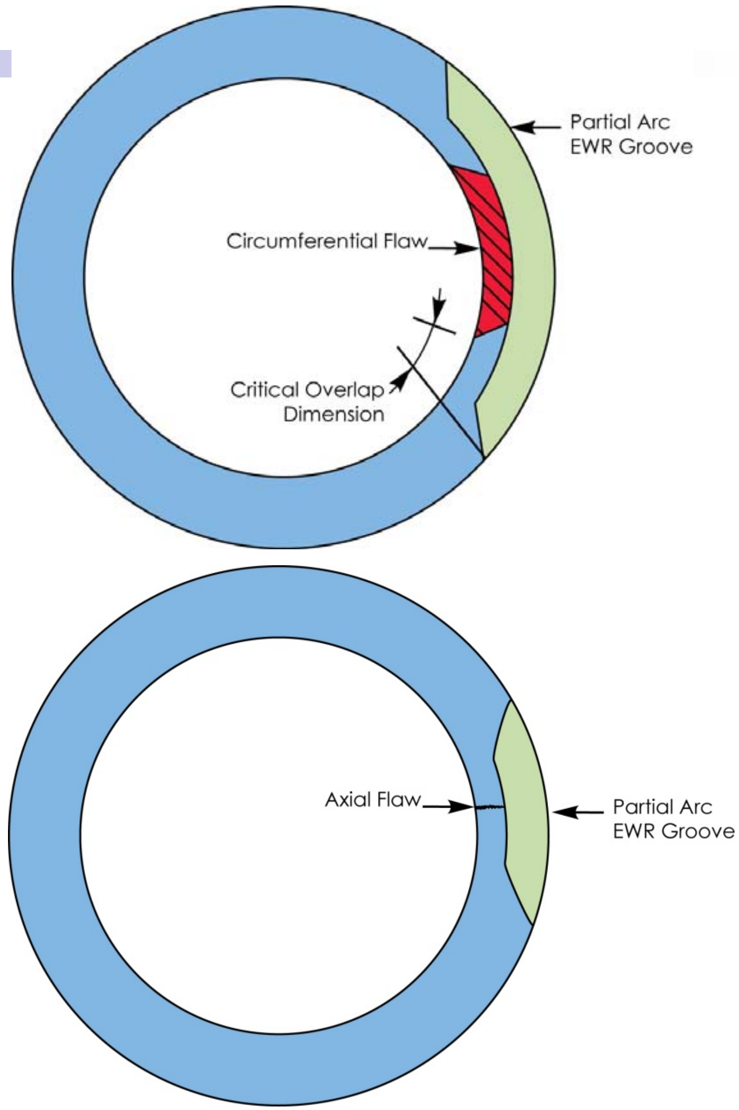
- Excavation depth depends on applied loadings (Service Levels A, B, C, D)
  - 50% of original wall thickness will be sufficient to meet Code limits for most locations
  - Minimum excavation depth must also allow for fatigue crack and PWSCC growth over the life of the repair assuming that an ID surface 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

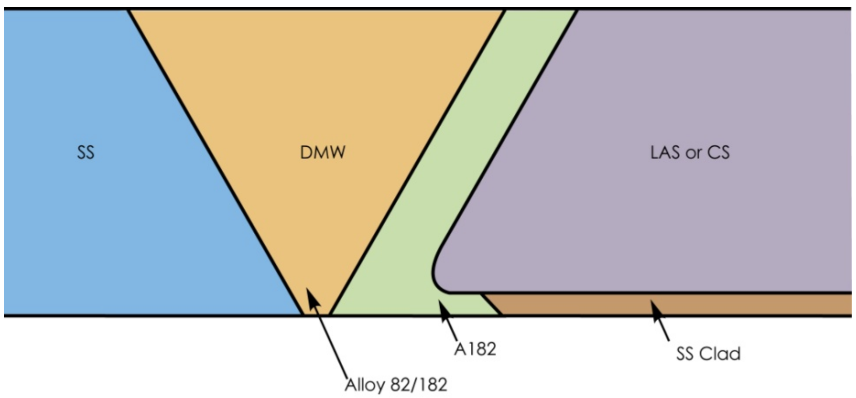


EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Materials and Welding Considerations

Materials and Welding Considerations

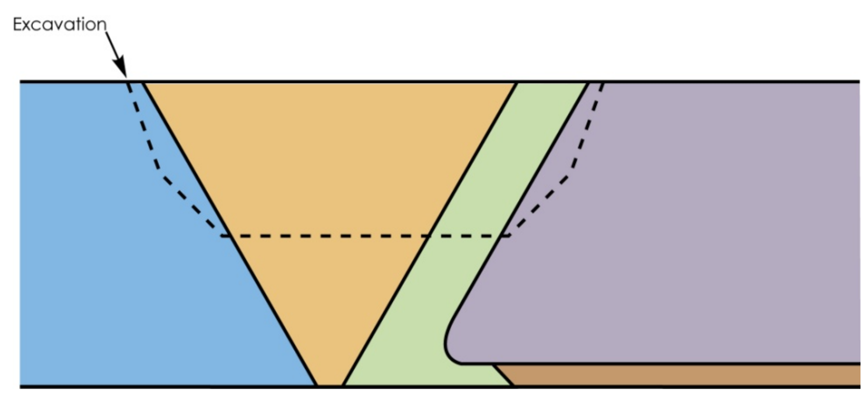
- Original weld is a composite of materials
  - Low alloy steel or CS
  - Alloy 82/182 butter
  - Alloy 82/182 butt weld
  - Stainless steel (wrought or cast) component
    - Pipe
    - Safe-end
    - Pump casing/nozzle



ELECTRIC POWER RESEARCH INSTITUTE

Materials and Welding Considerations

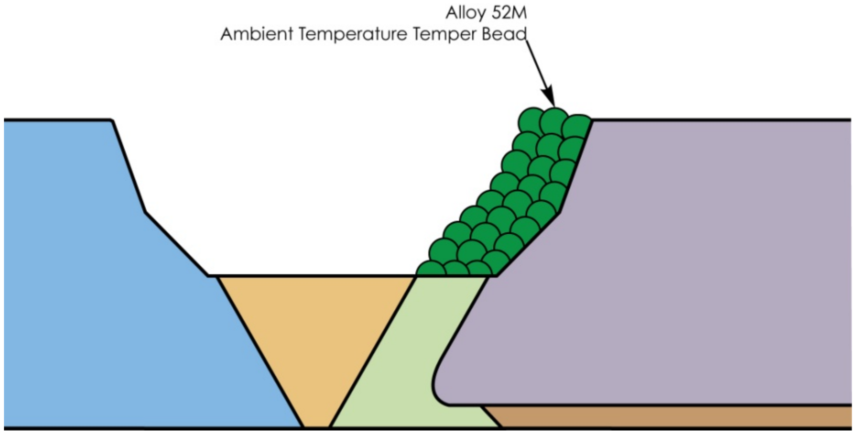
- Excavation removes buttering from LAS or CS material
  - Any new HAZ requires tempering
  - Replace original A82/182 with PWSCC resistant material
    - Alloy 52M (30% Cr)
  - Other potential issues associated with temperbead welding
    - To be addressed in project (review in future meetings w/ NRC)



EPRI ELECTRIC POWER RESEARCH INSTITUTE

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

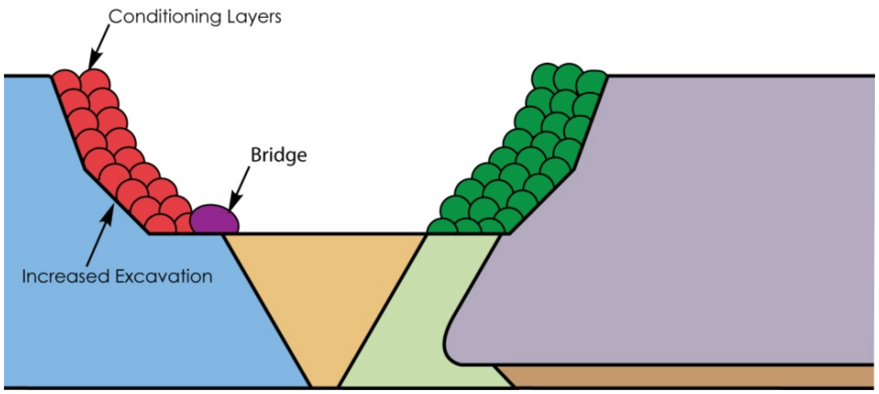


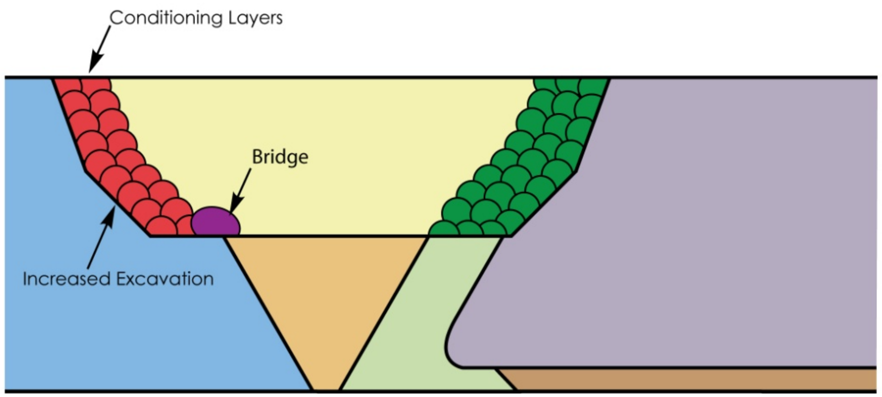
Materials and Welding Considerations
Stainless Steel

- 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. 360º 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. 360º 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

ELECTRIC POWER RESEARCH INSTITUTE

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