NBIC Alternative Welding Method 6

John A. Siefert and Jonathan D. Parker
EPRI, Program 87 Fossil Materials and Repair
National Board Chief Inspectors Technical Program
October 8-9, 2014
Together…Shaping the Future of Electricity

EPRI’s Mission

To conduct research, development and demonstration on key issues facing the electricity sector on behalf of our members, energy stakeholders, and society.
EPRI Laboratory Resources for Materials Testing and Characterization (Charlotte, NC)

- Welding
- Specialist Machining
- Heat-treatment & Field Simulations
- Unique Characterization Facilities
- High-temperature mechanical testing
Putting our Research in Alternative Well-Engineered Weld Repairs of Grade 91 Steel into Perspective

• Research has been conducted through two, key conduits:
  – Program 87 Fossil Materials and Repair
    • $3.5 million funding, ~40 funders (including international), research guided by key meetings 3X/year
  – Grade 91 Weld Repair Supplemental Project
    • $1.6 million funding, ~30 funders (from 8 countries), research guided by key meetings 4X/year
    • Expert working groups included for additional guidance
• Research has been presented to NBIC since January 2013 and to ASME in August 2014
Today’s Only “Accepted” Approach to Weld Repair in Grade 91 Steel

- There is not a single document, paper, review article, etc. that supports weld repair in Grade 91 steel using a matching filler metal and applying a traditional PWHT as the most acceptable engineering position.
  - EPRI maintains that well-engineered weld repairs are NOT a one-size-fits-all solution.

- It has *not been shown* that an “accepted” repair using matching filler metal and a traditional PWHT in Grade 91 steel actually meets the standard set by new construction.
  - This accepted weld repair assumes that a field PWHT is properly executed.
  - NBIC has no jurisdiction or additional controls regarding application of PWHT.
Motivations for Alternative Weld Repairs in Grade 91 Steel

• Field PWHT is complex, inconsistent and unappreciated
• Weld repair should never be managed with a one-size-fits-all approach
  – Reality is that we fully expect Grade 91 steel to be around for the next 50 years in the minimum
  – Grades 11/22 utilized >65 years
    • Hence, Welding Methods 2 – 5
• EPRI Goal: provide supporting data for alternative welding repair methods for Grade 91 steel
  – Thin section approach (Proposed Welding Method 6)
  – Thick section approach (to be NBIC Supplement, proposed in January 2015)
Welding Method 6, Paragraph 2.5.3.6 (Paraphrased, still in public comment period)

• This welding method provides guidance for welding Grade 91 tube material which cannot be locally post weld heat treated (PWHT) within a boiler setting. This repair method utilizes a controlled fill technique.

• When using this welding method, the following is required:
  – This method is limited to butt welds in tubing 5” NPS or less in diameter and ½” or less in wall thickness
  – Application shall be limited to a location internal to the boiler setting.
  – Upon the completion of weld repair, the repair region shall be kept dry until return to service.
Welding Method 6, Paragraph 2.5.3.6  
(Paraphrased, still in public comment period)

• The material shall be limited to P-No 15E, Group 1, Grade 91 for the repair.

• The welding shall be limited to the SMAW or GTAW processes, manual or automatic, using suitably controlled maintenance procedures to avoid contamination by hydrogen producing sources.

• The surface of the metal shall be free of contaminants and kept dry.

• The test material for the welding procedure qualification shall be of the same P-No and Group No and Grade as the original specification for the repair.

• Qualification thickness for the test plates and repair groove depths shall be in accordance with ASME Section IX, QW-451.
Welding Method 6, Paragraph 2.5.3.6  
(Paraphrased, still in public comment period)

- The WPS shall be qualified in accordance with the requirements of ASME Section IX, except that no postweld heat treatment shall be applied to the test coupon. Additionally:
  - The minimum preheat for the GTAW process shall be 200 deg F (93 deg C).
  - The minimum preheat for the SMAW process shall be 300 deg F (150 deg C).
  - The maximum interpass temperature shall be 400 deg F (200 deg C).
  - The filler metal shall be limited to an austenitic, nickel-base filler metal having a designation F-No. 43 and limited to:
    - ERNiCr-3 (Filler Metal 82), ENiCrFe-3 (INCONEL Welding Electrode 182), ENiCrFe-2 (INCO-WELD A), ASME B&PV Code Cases 2733 and 2734 (EPRI P87).
USA Expert Working Group – Agenda

- Questions/comments/concerns provided to EPRI prior to the meeting. Several presentations were prepared to address these specific areas.
- USA
  - May 28th, 2014
- European
  - June 3rd, 2014

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<th>TOPIC</th>
<th>PRESENTER</th>
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<td>8:30 – 9:00am</td>
<td>Welcome and Safety</td>
<td>J. Parker</td>
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<td>9:00 – 10:30am</td>
<td>Introduction</td>
<td>J. Parker</td>
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<td>10:30 – 11:00am</td>
<td><strong>BREAK</strong></td>
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<td>11:00am – 3:00pm</td>
<td>EPRId data on specific topics regarding the weld repair of Grade 91 steel: Working Lunch</td>
<td>J. Parker, J. Siefert</td>
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<td>BREAK ~1:30 to 2:00 pm</td>
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<td>• Controlled fill weld repair approach</td>
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<td>• Recommended preheat and interpass temperatures</td>
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<td>• Controlling the composition of E8015-B8</td>
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<td>• Analysis of low temperature fracture toughness on hydro testing</td>
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<td>• Analysis of weld repair performance and ductility</td>
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<td>• Characterization of failures in Grade 91 repair welds</td>
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<td>3:00 – 3:30pm</td>
<td>On-going activities related to Weld Repair of Grade 91 Steel and Technology Transfer</td>
<td>J. Parker</td>
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<td>3:30 – 5:00pm</td>
<td>Review of issues and agreement on path forward for future adoption of well-engineered weld repair methods</td>
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Expert Working Group Representation Included Key Components in the Power Generation Supply Chain

• In the USA Expert Working Group:
  – End users (utilities), OEMs, Filler Metal Supplier, Consultants, Independent research organization
  – ASME, AWS, NBIC

• In the European Expert Working Group:
  – End users (utilities), Filler Metal Suppliers, Insurance regulator, Consultants, Independent research organizations
  – EN code, ECCC, PED

• Between the two groups, >700 years of engineering expertise in fossil-fired generation
Common Questions

• What is a controlled fill welding technique?
  – For tubing, limitation to ≤1/8” diameter electrode (or ≤3/32” diameter solid wire) and when possible, one bead per layer
  – For thick-section tubing, one bead per layer not always possible, such as:
    • Thick-section tubing ➔ generally >0.30 inches

• Clarification regarding qualification to ASME B&PV Code?
  – Proposed welding method does NOT need to meet requirements in ASME B&PV Code Section IX QW-290

• Other restrictions?
  – Application to steam service only
  – Language regarding “the repair region shall be kept dry” inserted to reduce any risk to stress corrosion cracking
What Welding Method 6 Will NOT Cover

- Stub to header welds
- Attachment welds
- Excavated damage in thick-section components
- Thick-section welds (generally defined as >0.50 inch in thickness), such as repairs to:
  - Girth welds
  - Seam-welds
  - Elbows
  - Welded wyes, branches, tees
  - Drain to valve body connections

An NBIC Part 3 Supplement is currently being reviewed for proposal to cover these additional scenarios
EPRI Research does NOT End with Incorporation of Welding Method 6 into NBIC Part 3

• Every weld repair made by EPRI membership using Welding Method 6 will be tracked and monitored
  – Unexpected failures will be examined
  – The integrity of “good repairs” will be evaluated (systematic removal of repair welds)
• Any perceived issue of the proposed Welding Method 6 will be immediately reported to the NBIC for potential action

It must be noted that EPRI’s single greatest obligation is not to its membership, but to the greater public good and therefore the safety of those implementing this procedure
Future Weld Repair Research in Grade 91 Steel and its Implications to Thick Section Component Weld Repair
The Consequence of Poor Damage Tolerance, Contrasted with a Well-Engineered Repair Weld

- Typical Grade 91, low ductility HAZ failure
  - No damage tolerance
- Failure behavior may lead to “break before leak”, i.e. catastrophic failure
  - See end cap failures

- Repair weld exhibits damage tolerance
- Failure behavior may lead to “leak before break” AND provide an opportunity to “find’ the damage via routine inspection
The Potential for Damage Tolerant Weld Designs in Thick Section Repairs is Real and has been Demonstrated

Step weld repair promotes crack propagation in the ductile base metal
The Future Proposal for Thick-section Weld Repair

• Recommendations and guidance for weld repair of complex components to be addressed in:
  – *Best Practice Guideline for Well-Engineered Weld Repair of Grade 91 Steel*
  – EPRI Report 3002003833
• Available for comment ➔ if received by October 31, 2014 to be incorporated into final draft document and future NBIC Supplement covering weld repair of Grade 91 steel
• If you would like to review, please contact:
  – John Siefert
  – 1-704-595-2885
  – jsiefert@epri.com
Conclusions

• Alternative Welding Method 6 for weld repair of P15E Grade 91 steel has been validated for a range of destructive evaluation including:
  – Hardness mapping
  – Charpy impact toughness testing
  – Qualification to ASME Section IX
  – High temperature performance (creep)
  – No red flags have been raised

The application of Welding Method 6 within EPRI member utilities will be tracked and monitored to ensure that this method is safe, reliable and better define the acceptable performance window (if necessary)
Together...Shaping the Future of Electricity
Expert Working Group Attendees

**USA**
- Jeff Henry, Alstom Power
  - Chairman of ASME Section II
  - Chairman of ASME Task Group on CSEF Steels
- Bill Newell, Euroweld LTD
  - Chairman of ASME Section II/IX Subgroup
  - Strength of Weldments
  - Member of ASME Section IX
- Dick Smith, Structural Integrity
  - Member of ASME Section XI Working Group
  - Welding and Special Processes
- Jude Foulds, Clarus Consulting
  - Chairman of ASME Section II Task Group on Data Analysis
  - Member of ASME Section II
  - Member of ASME Section II/IX Subgroup Strength of Weldments
- George Galanes, Diamond Technical Services
  - Chairman of NBIC Part 3 Repairs and Alterations Subcommittee
  - NBIC main committee member
  - Chairman of ASME Section I Subgroup Materials
  - Member of ASME Section I
- Joel Feldstein, Foster Wheeler
  - Chairman of ASME Pressure Technology Standards
- Tim Bacha, We Energies ➔ End-user/Utility/Member Representation
- Mike Crichton, AEP ➔ End-user/Utility/Member Representation
- Kent Coleman, Dr. Jonathan Parker, John Siefert, EPRI

**European**
- Dr. Kenneth Mitchell, RWE Generation
  - Senior Welding Engineer
- Dr. Steve Brett, Steve Brett Consultancy Ltd.
  - Consultant
  - Honorary Professor Nottingham University
- Peter Bates, EON Technologies
  - Supplier Quality Engineer
- Dr. Birendra Nath, GDF Suez Energy
  - Chief Metallurgist
- Frederic Vanderlinden, Laborelec GDF Suez
  - Expert Power Plant Materials
- Craig Degnan, EON Technologies
  - Materials Engineer
- Stephen Thomson, EON Technologies
  - Welding Engineer
- Ronny Krein, Vostalpine Bohler Welding
  - Application Engineer
- Dr. Kwan-Gyu Tak, Voestalpine Bohler Welding
  - Global Industry Segment Manager – Power Generation
- Dr. David Allen, Impact PowerTech
  - Chairman ECCC
- Graham Holloway, I. A. Barnes & Co. Ltd.
  - Technical Director
- Steve Jones, RSA (Royal Son Alliance)
  - Consultant
- Dr. Jonathan Parker, Electric Power Research Institute
  - Fellow Institute of Mechanical Engineers
  - Fellow Institution of Materials
  - Chartered Engineer
- John Siefert, Electric Power Research Institute