New CSEF Welding Supplement in Part 3 of the NBIC and Updated Research by EPRI

George W Galanes, PE
Chair, Part 3 SC R&A

John A. Siefert
Senior Technical Leader

National Board Chief’s Meetings
New CSEF Supplement for 2017 Edition of Part 3 of the NBIC

Supplement 11

WELD AND POST REPAIR INSPECTION OF CREEP STRENGTH ENHANCED FERRITIC STEELS

S11.1 SCOPE

The technical information provided in this supplement pertains to weld repair and post repair inspection of creep strength enhanced ferritic steel (CSEF) pressure retaining items. This Supplement provides guidance for full penetration and partial penetration weld repairs not covered under Welding Method 6 (2.5.3.6).

Creep Strength Enhanced Ferritic alloys (CSEF’s) are a collection of ferritic steels whose creep strength is enhanced by the creation of a precise condition of micro-structure, specifically martensite or bainite, which is stabilized during tempering by controlled precipitation of temper-resistant carbides, carbo-nitrides, or other stable and/or meta-stable phases. Careful consideration shall be given to pressure-retaining items that are fabricated from CSEF’s. The behavior of these materials in low temperature (i.e. fracture toughness and/or fatigue) and in high temperature (i.e. creep and/or creep-fatigue) components can be degraded by not adhering to the welding procedures and improper application of post-weld heat treatment (PWHT). Experienced inspection personnel should oversee weld repairs of this nature for strict compliance with all welding procedure and repair requirements.

Post Construction access and in-service operation may not allow the practicable application of PWHT following original construction fabrication requirements and repair weld joint design. This supplement provides guidelines for weld repair options and post repair inspection using a well-engineered approach for CSEF steels. The user is cautioned to seek technical guidance for welding and selection of heat treating requirements.

Prior to using this guideline an engineering evaluation shall be performed to determine the scope of the repair and impact to safety prior to returning the pressure-retaining item to service for a specified period of time, based on approval by the Inspector, and when required the Jurisdiction. The organization performing the engineering evaluation shall have demonstrated experience with Grade 91 CSEF steels.
S11.2 WELD REPAIR OF GRADE 91 STEEL

S11.2.1 Weld Repair Options

(1) 9Cr-1Mo-VNbN Filler Metal (i.e. matching to Grade 91) + Controlled Fill + Low PWHT (Minimum temperature is 1250°F, 675°C). Acceptable filler materials are referenced in Table 11-1. The minimum time and maximum heat treatment temperature shall be in accordance with the original code of construction. For reference, where the Ni+Mn content of the filler metal is not known, the maximum PWHT temperature shall be 1425°F (775°C). As a general best practice, this maximum shall be enforced to avoid over-tempering or exceeding the absolute maximum PWHT temperature. PWHT hold times at temperature shall be as follows;

a. Minimum holding time at PWHT temperature is specified as 1 hour per 1.0 inch (25 mm) of thickness, 30 minute minimum provided the component < 0.5 inches (12.5 mm) in thickness;

b. Minimum holding time at PWHT temperature is specified as 5 hours plus 15 minutes for each additional 1.0 inch (25 mm) over 5.0 inches (125 mm);

(2) 9Cr-1Mo Filler Metal + Controlled Fill and No PWHT. Acceptable filler materials are detailed in Table 11-1.

(3) Ni-base Filler Metal + Controlled Fill and No PWHT. Acceptable nickel base consumables include selected ASME F No. 43 filler metals as detailed in Table 11-1.

Table 11-1. Alternative Weld Repair Methods, Filler Metals and Welding Processes for Grade 91 Steel.

<table>
<thead>
<tr>
<th>Acceptable Weld Repair Method</th>
<th>Welding Process and Filler Metal AWS Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matching (9Cr-1Mo-VNbN)</td>
<td>• SMAW – E9015-B9, E9016-B9, E9018-B9 or E9015-B91&lt;sup&gt;A&lt;/sup&gt;, E9016-B91&lt;sup&gt;A&lt;/sup&gt; or E9018-B91&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>• FCAW – E91T1-B9 or E91T1-B91&lt;sup&gt;A&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
S11.3 Application of Controlled Fill Welding Procedure

(a) The minimum preheat for the repair procedure shall be 300 °F (150 °C). The preheat temperature shall be checked to ensure the minimum preheat temperature is maintained during all welding and until welding is completed. The maximum interpass temperature shall be 550 °F (290 °C). At the completion of welding, a post weld hydrogen bake-out is not required nor prohibited.

(b) In general To control heat input, it is recommended to weld the repair groove the weld repair shall be performed using a “controlled fill” technique. In this technique, the first layer in contact with the repair groove can be identical or smaller in diameter than the fill passes.

(c) Figures 11-1 through 11-4 illustrate the various types of recommended acceptable weld joint details using the controlled fill technique for full or partial penetration weld repairs.

(d) The bead-to-bead overlap shall be ~50% or greater. The fill passes shall be deposited working from the bevel of the machined excavation towards the center of the excavation with a minimum overlap of 25% and ideally 50%. As a rule of thumb, if the welder aims for the toe of the previously deposited weld bead, an overlap of at least 40% will be achieved.

(e) When the SMAW process is specified with ferrous filler metals, the fill passes are restricted to a maximum electrode diameter of 1/8 in. (3.2 mm). When the SMAW process is specified with nickel-base filler metals, the fill passes in immediate contact with the excavation shall not exceed an electrode diameter of 1/8” (3.2 mm), and for the remaining fill passes to restore the excavated material an increase in the electrode diameter to 5/32 in. (4.0 mm) is permitted. When the
GTAW process is specified, any limits for filler metal size shall be reflected in the qualified PQR and WPS.

Figure 11-1. Schematic of the Controlled Fill Welding Procedure for Grade 91 Steel for a Partial Penetration Weld Repair.
Note 1 – The excavation shall have rounded corners to prevent lack of fusion defects. In these locations it is recommended to use a smaller diameter electrode (such as 3/32 in., 2.4 mm) to ensure acceptable fusion.
Note 2 – The repair cavity width shall extend at least 0.40 in. (10 mm) beyond the fusion line of the original weld.
Note 3 – Where the excavation may pose challenges with electrode access, it is recommended that the fill passes in immediate contact with the machined excavation be restricted in height as the weld repair is performed.
Figure 11-2. Schematic of the Controlled Fill Welding Procedure for Grade 91 Steel for a Full Penetration Weld Repair Using a Compound Bevel. Note 1 – Where the excavation may pose challenges with electrode access, it is recommended that the fill passes in immediate contact with the machined excavation be restricted in height as the weld repair is performed.
Figure 11-3. Schematic of the Controlled Fill Welding Procedure for Grade 91 Steel for Full Penetration Weld Repair Using a Land. 
Note 1 – The excavation shall have rounded corners to prevent lack of fusion defects. In these locations it is recommended to use a smaller diameter electrode (such as 3/32 in., 2.4 mm) to ensure acceptable fusion.
Figure 11-4. Schematic of the Controlled Fill Welding Procedure for Grade 91 Steel for a Full Penetration Weld repair Using a Step Weld Preparation.

Note 1 – The excavation shall have rounded corners to prevent lack of fusion defects. In these locations it is recommended to use a smaller diameter electrode (such as 3/32 in., 2.4 mm) to ensure acceptable fusion.

Note 2 – The repair cavity width shall extend at least 0.40 in. (10 mm) beyond the fusion line of the original weld.

Note 3 – Where the excavation may pose challenges with electrode access, it is recommended that the fill passes in immediate contact with the machined excavation be restricted in height as the weld repair is performed.
S11.4 Qualification of Controlled Fill Welding Procedure

(a) The test material for the welding procedure qualification shall be P-No 15E, Group 1, Grade 91.

(b) Qualification thickness for the test plates and repair groove depths shall be in accordance with ASME Section IX.

(c) The Welding Procedure Specification (WPS) shall be qualified in accordance with requirements of ASME Section IX. If qualifying the WPS with PWHT, the PWHT is to be low temperature PWHT, i.e., a minimum temperature of 1250 deg F (675 deg C) and a maximum temperature of 1445 deg F (785 deg C).

(d) For qualification of weld repair procedures using 9Cr-1Mo filler metal and in the as-welded condition, the requirements for the bend test shall be performed using a bend radius which achieves a minimum of 14% elongation in the outer fibers.

S11.5 POST REPAIR INSPECTION

(a) After the completion of weld repairs to CSEF steels, post inspection requirements shall be developed and implemented based on acceptance from the Inspector, and if applicable, the Jurisdiction.

(b) Post-repair inspection intervals and methods of examination shall be implemented to ensure safe operation and margin to locate and monitor defect growth in the weld repair area. The selected non-destructive examination method shall provide meaningful results and shall follow NBIC Part 3, Section 4.

(c) Post repair inspection shall be on-going until the component reaches end of life or is replaced. A recommended re-inspection interval is every other planned major outage or six years, whichever is less. The Owner/User may revise the re-inspection interval based on inspection results from previous inspections.

For NBIC Committee use only
Outstanding Reservations Regarding the Approval of Alternative Weld Repair Techniques for Grade 91 Steel

- Qualification of procedures
- End-use application to provide reasonable case studies and “weld repair exemplars”
- Comments from an involved NBIC participant and member

<table>
<thead>
<tr>
<th>Alternative Weld Repair Method</th>
<th>Welding Process and AWS Classification for Acceptable Filler Metals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Filler Metal</strong></td>
<td><strong>Procedure</strong></td>
</tr>
<tr>
<td>Matching (9Cr-1Mo-VNbN)</td>
<td>Controlled Fill + Low PWHT</td>
</tr>
<tr>
<td></td>
<td>• SMAW – E9015-B9 or E9015-B9A</td>
</tr>
<tr>
<td></td>
<td>• FCAW – E91T1-B9</td>
</tr>
<tr>
<td></td>
<td>• GTAW – ER90S-B9 or ER90S-B9A</td>
</tr>
<tr>
<td>9Cr-1Mo</td>
<td>Controlled Fill</td>
</tr>
<tr>
<td></td>
<td>• SMAW – E8015-B8</td>
</tr>
<tr>
<td></td>
<td>• FCAW – E81T1-B8</td>
</tr>
<tr>
<td></td>
<td>• GTAW – ER80S-B8</td>
</tr>
<tr>
<td>Ni-base</td>
<td>Controlled Fill</td>
</tr>
<tr>
<td></td>
<td>• SMAW – EPRI P87B, ENiCrFe-2C, ENiCrFe-3D</td>
</tr>
<tr>
<td></td>
<td>• GTAW – EPRI P87E, ERNiCr-3F</td>
</tr>
</tbody>
</table>
A Summary of Recent Group Qualifications for Alternative Weld Repair Procedures in Grade 91 Steel
## Composition of Welding Consumables

<table>
<thead>
<tr>
<th>Material</th>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Si</th>
<th>Ni</th>
<th>Cr</th>
<th>Mo</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>E9015-B9 ER90S-B9</td>
<td>0.090</td>
<td>0.61</td>
<td>0.008</td>
<td>0.005</td>
<td>0.20</td>
<td>0.31</td>
<td>8.50</td>
<td>1.06</td>
<td>N, Nb, N</td>
</tr>
<tr>
<td>E8015-B8 ER80S-B8</td>
<td>0.056</td>
<td>0.77</td>
<td>0.006</td>
<td>0.003</td>
<td>0.35</td>
<td>0.26</td>
<td>9.56</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td>Ni-base¹ (e.g. ENiCrFe-3)</td>
<td>0.053</td>
<td>6.36</td>
<td>0.009</td>
<td>0.004</td>
<td>0.44</td>
<td>66.0</td>
<td>16.4</td>
<td></td>
<td>Fe, Nb, Ti</td>
</tr>
</tbody>
</table>

¹Note: Ni-base may include other filler materials such as ERNiCr-3, ERNiFeCr-4, ENiCrFe-2 or ENiFeCr-4. There are subtle details in the composition for each of these filler materials and they should not always be regarded as “equivalent”
Recent Welding Qualifications

- During the week of October 25\textsuperscript{th} 2015, 40 project members witnessed a total of 20 weld procedures in Grade 91 steel using alternative weld procedures outlined by Welding Method 6 and by the proposed Welding Supplement.

- All procedures were qualified in the as-welded condition.

- There were no defects (bends or tensile tests) which failed a single procedure. Thus, all procedures were qualified to the language in ASME B&PV Code Section IX and the revision for bend testing thick-section coupons manufactured from procedures welded with ER80S-B8 or E8015-B8.

  - In the case of thick-section qualifications for ER80S-B8 and E8015-B8 the bend test radius was reduced to 14\% (from 20\%) and per guidance in the proposed Welding Supplement.
Recently Qualified Procedures – Thin Section (3/8 inch plate and No PWHT)
P15E = Grade 91, P5A = Grade 22, P8 = SS304H

<table>
<thead>
<tr>
<th>PQR No.</th>
<th>Material 1</th>
<th>Material 2</th>
<th>Filler Metal (Process)</th>
<th>Qualified Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQ15-0390</td>
<td>P15E</td>
<td>P15E</td>
<td>ER80S-B8 (GTAW)</td>
<td>1/16 to 3/4 inches</td>
</tr>
<tr>
<td>PQ15-0391</td>
<td>P15E</td>
<td>P5A</td>
<td>E8015-B8 (SMAW)</td>
<td></td>
</tr>
<tr>
<td>PQ15-0392</td>
<td>P15E</td>
<td>P8</td>
<td>ERNiCr-3 (GTAW)</td>
<td></td>
</tr>
<tr>
<td>PQ15-0393</td>
<td>P15E</td>
<td>P15E</td>
<td>ENiCrFe-2 (SMAW)</td>
<td></td>
</tr>
<tr>
<td>PQ15-0394</td>
<td>P15E</td>
<td>P5A</td>
<td>ERNiCr-3 (GTAW)</td>
<td></td>
</tr>
<tr>
<td>PQ15-0395</td>
<td>P15E</td>
<td>P8</td>
<td>ENiCrFe-2 (SMAW)</td>
<td></td>
</tr>
<tr>
<td>PQ15-0400</td>
<td>P15E</td>
<td>P15E</td>
<td>ERNiCr-3 (GTAW)</td>
<td></td>
</tr>
<tr>
<td>PQ15-0401</td>
<td>P15E</td>
<td>P5A</td>
<td>ENiCrFe-2 (SMAW)</td>
<td></td>
</tr>
<tr>
<td>PQ15-0402</td>
<td>P15E</td>
<td>P8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PQ15-0403</td>
<td>P15E</td>
<td>P15E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PQ15-0404</td>
<td>P15E</td>
<td>P5A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PQ15-0405</td>
<td>P15E</td>
<td>P8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Recently Qualified Procedures – Thick Section (2 inch plate and No PWHT)\(^1\)

P15E = Grade 91, P5A = Grade 22, P8 = SS304H

<table>
<thead>
<tr>
<th>PQR No.</th>
<th>Material 1</th>
<th>Material 2</th>
<th>Filler Metal</th>
<th>Process</th>
<th>Qualified Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQ15-0396</td>
<td>P15E</td>
<td>P15E</td>
<td>ERNiCr-3</td>
<td>GTAW</td>
<td>3/16 to 8 inches</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ENiCrFe-2</td>
<td>SMAW</td>
<td></td>
</tr>
<tr>
<td>PQ15-0397</td>
<td>P15E</td>
<td>P5A</td>
<td>ERNiCr-3</td>
<td>GTAW</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ENiCrFe-2</td>
<td>SMAW</td>
<td></td>
</tr>
<tr>
<td>PQ15-0398</td>
<td>P15E</td>
<td>P15E</td>
<td>ER80S-B8</td>
<td>GTAW</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>E8015-B8</td>
<td>SMAW</td>
<td></td>
</tr>
<tr>
<td>PQ15-0399</td>
<td>P15E</td>
<td>P5A</td>
<td>ER80S-B8</td>
<td>GTAW</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>E8015-B8</td>
<td>SMAW</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Note: Thick-section qualifications to stainless were omitted because there is not yet a widespread application of thick-section application of Grade 91 pipe to stainless steel pipe in the power generation industry
Evaluation of Thick-section Qualification
A Summary of Applications of Alternative Weld Repair Procedures for Grade 91 Steel
There is Continuing Support for Well-Engineered, Alternative Weld Repairs in Gr. 91 Steel – One End-User’s Application within the Last 6 Months

- **Thermowell replacement** (1.5 inch); threaded connection; with seal weld using both Ni-base and –B8 (no PWHT)
  - For <1020°F (550°C), -B8 only

- **HRSG drain value** replacements (≤ 2 inch); socket weld connection; repairs using both Ni-base and –B8
  - For <1020°F (550°C), -B8 only

- **Temperature element weld pad attachment**; pad attached to the OD of pipe; fillet weld repair using –B8

- **HRSG superheater stub tube** replacement (2 inch OD); tube to tube and tube to header with Ni-base

- **Drain pot level control** instrument adapter fitting (1.5 inch); socket weld with Ni-base
  - For <1020°F (550°C), -B8 only
A Second Example of a Small Bore Repair (previously discussed)

- An HRSG unit was brought off load shortly before a planned outage as a result of a steam leak from a small diameter HP superheater outlet pressure impulse line (incorrect material). Temporary repairs to three lines were carried out using Ni-base GTAW socket welds to allow rapid return to service.

A Third Example of a Small Bore Repair (previously discussed)

- 24” Reheat valve drain line failure in an HRSG unit (1000°F, 600 psi); 304H drain line welded to Grade 91 valve body

- Specific issues with existing repair approach:
  - Use of a “bullet” PWHT is NOT a good idea
  - PWHT of the valve and/or band around the area can compromise the internals, or more time to remove the internals and hope you don’t fry the seat….
  - PWHT is time consuming, perhaps technically inadvisable, and expensive.

- Approach, local repair with GTAW and ENiCr-3 (Filler Metal 82) using a socket/fillet weld and left in as-welded condition
  - Goal: bridge gap to “permanent fix” in 2016 when all SS lines will be replaced with Grade 91
  - Very similar to RWE approach detailed previously
And a Well-Publicized Through-thickness Repair

- **TVA used EPRI guidelines (3002003833) for alternative weld repairs for Gr. 91 steel**
- Inspection at first outage did not find defects associated with weld repair and the weld continues to operate
  - Eliminated PWHT (risk of over-tempering, mal-PWHT and damage to the valve)
  - Eliminated the cost of PWHT (~$5k USD savings)
  - Reduced outage time (3 days)
  - Estimated cost savings from outage time alone is ~$1 million USD

And the World’s First Documented use of Welding Method 6 (AEP Cardinal Unit 1)

- State of Ohio approved application of WM6 in February 2015
- Initial issues with qualification of welders (added requirements imposed by State included RT and bend tests)
- Specific issues with existing repair approach:
  - Weld with matching filler metal
  - Perform PWHT
  - Perform Radiography
  - Move to next tube
- 7 total applications in SA-213 T91 reheater tube (2.0 inch X 0.165 inch) yielding 14 total WM6 repairs, operating at 550°C (1020°F) and 6.5 MPa (950 psi); all repairs performed in month of May
  - Goal: Bridge the gap to component replacement in Fall 2015
- Days of outage time were avoided
- Tubes at EPRI for analysis
# Weld Repair Tracking Sheet – Page 1

<table>
<thead>
<tr>
<th>Unit Name</th>
<th>(Note: will not be issued in the report – for tracking only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Type/Size</td>
<td></td>
</tr>
<tr>
<td>Unit Operation Details</td>
<td></td>
</tr>
<tr>
<td>Hours (at time of repair)</td>
<td></td>
</tr>
<tr>
<td>Starts (at time of repair)</td>
<td></td>
</tr>
<tr>
<td>Operating Pressure</td>
<td>(nearest measured value)</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>(nearest measured value)</td>
</tr>
<tr>
<td>Component Details</td>
<td></td>
</tr>
<tr>
<td>(specifically the one being repaired)</td>
<td></td>
</tr>
<tr>
<td>Type of Component</td>
<td>(valve, casing, pipe, etc.)</td>
</tr>
<tr>
<td>Approximate metal thickness near damage</td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td></td>
</tr>
<tr>
<td>Specification</td>
<td></td>
</tr>
</tbody>
</table>
## Weld Repair Tracking Sheet – Page 1

<table>
<thead>
<tr>
<th>Damage Details</th>
<th>Welding Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>What type of damage? (image available?)</td>
<td>How was the repair tracked and/or documented?</td>
</tr>
<tr>
<td>Damage detection? (NDE, boat sample, etc.)</td>
<td>Welding Process (SMAW, GTAW, FCAW, etc.)</td>
</tr>
<tr>
<td>Was it decided to excavate and repair the damage?</td>
<td>Filler Material (AWS specification, if known)</td>
</tr>
<tr>
<td>What was the magnitude of the damage? (length, depth)</td>
<td>Preheat/Interpass</td>
</tr>
<tr>
<td>How was damage excavated? (arc-gouging, machining, grinding, etc.)</td>
<td>What Welding Method was used?</td>
</tr>
</tbody>
</table>
| Was the chemistry of the base material verified? (If so, can this be provided?) | }
## Weld Repair Tracking Sheet – Page 2

<table>
<thead>
<tr>
<th>Post Weld Heat Treatment</th>
<th>Was PWHT conducted?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>What standard was invoked?</td>
<td>(AWS D10.10, D10.22 or similar)</td>
</tr>
<tr>
<td>Temperature or Range</td>
<td></td>
</tr>
<tr>
<td>Heating rate</td>
<td></td>
</tr>
<tr>
<td>Cooling Rate</td>
<td></td>
</tr>
<tr>
<td>NDE and Acceptance</td>
<td>Was NDE conducted during Welding? (What methods and after which layer(s) or thickness(es))?</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>What method was utilized for final NDE inspection?</td>
<td></td>
</tr>
</tbody>
</table>
Weld Repair Tracking Sheet – Page 2

Describe any issues reported during or following the weld repair and other pertinent information:

<table>
<thead>
<tr>
<th>Post Repair</th>
<th>Did re-cracking occur in the weld repair?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>If re-cracking did occur, after how many hours of operation?</td>
</tr>
<tr>
<td></td>
<td>How was (or is) re-cracking being addressed?</td>
</tr>
<tr>
<td></td>
<td>Were any operational changes made, such as a decrease in the operating temperature?</td>
</tr>
</tbody>
</table>
Tracking of Innovative Repairs once Implemented is a Key, on-going Exercise

- The importance of databases and sharing information cannot be understated
- There have been ~dozen known applications of Alternative Weld Repair of Grade 91 Steel and these end-users are being asked to track and fill out the database form
- EPRI will then monitor and track these repairs for the foreseeable future and when opportunity arises examine ex-service repairs
A Summary of Comments for Negative Ballot on the Welding Supplemental – Examples of Continued Feedback
EPRI Response to Comment 1

“*When is it not possible to perform PWHT?*”

**EPRI Response:**

- **There are practical limitations;** complex components, thick to thin transitions; inability to use a preferred vendor
- **There are commercial limitations;** unexpected identification of damage late in an outage, a forced outage in peak season, etc.

To the second part of the question generally questioning the integrity of the approach, **EPRI Response:**

- The use of alternative weld repair procedures is not a mandatory requirement. Thus, there are cases where end-users or vendors may elect to not use these procedures.
- In cases where end-users do elect to perform alternative weld repair:
  - Well-engineered approach (i.e. familiarity with 3002003833)
  - Case by case, component-specific
  - Recognition of the importance to database repairs
EPRI Response to Comment 1

“Allowing these repairs in pressure parts that are external to the boiler enclosure moves them to where subsequent leakage and failure present a personnel hazard and thus a heightened safety concern compared to the repair Method 6… Does NBIC really want to take on that risk?”

EPRI Response:

– The commenter has raised a concern regarding “Damage Tolerance”
– **Damage tolerance is not a function of PWHT.** In fact, PWHT does not “magically” induce damage tolerance in a component
– Damage tolerance is function of:
  – Base metal risk factors
  – Design of the component (i.e. mechanical notches)
  – Design of the weldment (i.e. aligned metallurgical notch in the form of a HAZ)
– As detailed in 3002003833, a well-engineered repair can actually promote a degree of damage tolerance in the repair that is not inherent to as-fabricated welds and regardless of the applied PWHT
Comment 2 (Structure of Supplement)

- “The proposal should be incorporated as an Alternative Welding Method. The title of paragraph 2.5.3 would need to be modified since it states “Without Postweld Heat Treatment” and SX.2.1 of this proposal requires a low temperature PWHT. These should this be split into two separate Methods. Or best only allow the low PWHT method as the less risky of the two.”

- **EPRI Response:** Again, PWHT has nothing to do with “risk.” Risk, as defined by the susceptibility to catastrophic failure in operation, is a function of factors which contribute to the “damage tolerance” of the structure.
Comparison of Conventional Weld Geometry and Welding Procedures

- As shown in the series of cross-weld tests to the left, failure occurred through a rapid linking of micro-damage in the Grade 91 HAZ and independent of whether PWHT was applied. This is because a susceptible region is created in the Grade 91 HAZ by the welding thermal cycle. This region is relatively unaffected by a subsequent PWHT resulting in identical behavior for each of the provided examples. This series of images presents an example for potential safety risk because each examples possesses a weld geometry which does NOT have inherent damage tolerance.
Comparison of Repair Weld Geometry and Welding Procedures

- **E9015-B9 Filler**
  - PWHT = 1250°F/2h
  - Defect in HAZ being propagated through parent material

- **E8015-B8 Filler**
  - PWHT = None
  - Defect in HAZ being propagated through parent material

- **Ni-base Filler**
  - PWHT = None
  - Defect in HAZ being propagated through parent material

As shown in the series of cross-weld tests to the left, an initial macro-defect has formed in the HAZ of the repair. However, and unlike the previous examples this defect is being forced to propagate through stronger, more ductile and undamaged parent material. This series of examples provides an inherent level of safety and promotes the potential for leak-before-break (i.e. damage tolerance).
Example of Damage Intolerant versus Damage Tolerant Weld Geometries; *Independent of the Applied PWHT*

Conventional Weld Geometries; Not Damage Tolerant

Repair Weld Geometry with better approach for accommodating Damage Tolerance
"For temporary repairs, two different procedures are used – one with an Inconel electrode and another with a low-alloy electrode. These procedures do not include stress-relief. At some later date, we will remove that temporary repair and put in a permanent repair when we have time, when it is economical and feasible, and other conditions are met. But temporary repairs sometimes run for 15 years, and permanent repairs sometimes crack again after three years. So one cannot call either one permanent or temporary – the quality of the repair seems to be a function of the stress and the thermal cycles for that particular part of the casing."

In reality, the integrity of the repair is not solely a function of PWHT, but of design, damage and procedure.
EPRI Response to Comment 3

- “Consider limiting repairs w/o PWHT to circumferential welds only….”

**EPRI Response:**

- This is not a practical consideration of the issues that present power plant owner/operators. Where a well-engineered approach is engineered, enforced and utilized there are many components, geometries and material combinations that can be repaired. However, it is imperative that the application of an alternative weld repair approach be addressed on a case-by-case basis and on a component basis.

- Thus, it is NOT the EPRI position to disallow specific applications until sufficient evidence is present which supports this position (see previous, successful applications of alternative weld repairs in a variety of components/geometries/etc.)
EPRI Response to Comment 3

- “…This should certainly prohibit repairs w/o PWHT on longitudinal seam welds.”

- **EPRI Response:**
  - Where end-users have subcritically PWHT longitudinal seam-welds or welded fittings like laterals/wyes/tees/branches the EPRI position is that these should be replaced
  - However, lead time for replacement components is often on the order of 2 or 4 years. It is not practical to force a shutdown of the plant for this timeframe. Thus, a “temporary” repair and/or using a “minor” repair approach should be allowed
EPRI Response to Comment 3

“XS.2.1 – Local PWHT at a low temperature of 1250°F with TC’s on the pipe O.D. will yield an I.D. temperature of only ~1100°F for thick sections. This isn’t an adequate tempering temperature for Gr. 91 PWHT. What is the basis for selecting 1250°F?”

EPRI Response:

– Please see position paper which explains this and other points:
  

  ▪ And also this report:

EPRI Response to Comment 3

“How much of the original weld must remain after excavating the damage? Can the proposed repairs be completely through wall? Does this apply to tubes that are larger or thicker than permitted in Method 6?”

EPRI Response:

– The proposed NBIC Welding Supplement should cover all excavations – full, partial or minor. The ultimate excavation needs to be left to owner/operator to engineer and/or address considerations which may or may not facilitate a particular excavation.
– See TVA example of two full penetration repairs using E8015-B8 and no PWHT
– To be addressed in more detail in Comment 4 response
EPRI Response to Comment 4

“Consider adding a requirement to remove the HAZ on both sides of the weld for the depth of the repair. EPRI work supports that will be beneficial to remaining weldment life.”

EPRI Response:
- While in principle we agree, there are realistic and practical limitations to this blanket requirement, such as a pipe to valve girth weld repair (and indeed others)
- There are scenarios where “minor” repairs can be expected to operate safely and under a reasonable expectation that these types of welds are replaced at some definite point in the future or are routinely inspected
EPRI to Initiate a series of 2.5 Day Workshops Limited to Members and Invited Individuals

- EPRI is committed to educating its membership and the public to meet its mission statement:
  - See position papers
  - Series of workshops in 2016 (1X) and 2017 (2X) to provide cradle to grave training on life management of 9Cr CSEF steels
  - Aim is to have ~4 workshops on a regional basis (Midwest, Southeast, Texas, United Kingdom)

- First workshop to be hosted by American Electric Power on August 9 to 11 in Columbus, OH;
  - Key invitations to state chief inspectors, insurance agencies and other relevant individuals and limited to ~100 attendees
  - EPRI partnering with industry leaders with regard to inspection guidance and PWHT guidance
  - It must be emphasized that weld repair is but one part of the life management strategy for CSEF steels
Component Life Management Strategy for Grade 91 Steel (and others)

The overall EPRI recommended approach to Life Management of Complex Components involves:

1. Facilitating Root Cause Analysis when problems are encountered and accurate Technology Transfer
2. Developing and applying Purchase Specifications, which are based on sound science and engineering
3. Guidance on Quality Assurance during Component Manufacture and System Fabrication
4. Supporting Life Management Plan – when to look, where to look, how to look
5. Approved procedures for Repair and Replacement
Conclusions

- EPRI supports well-engineered, alternative weld repair scenarios that address application on a case-by-case, component-specific basis for 9Cr steels and where PWHT is not mandated.
- There is always risk in making welds in high energy piping, regardless of whether PWHT is applied and regardless of the chosen repair process. The goal is always to reduce this risk.
Conclusions – for the Inspector

- Reducing risk – from an inspector standpoint – can include the following guidance/questions:
  - Is the end-user/vendor familiar with Welding Method 6, the proposed NBIC Welding Supplement and EPRI Report 3002003833?
  - Has the end-user/vendor provided a reasonable approach to repair to address identified risks?
  - Is the end-user providing a filled out datasheet to help database the initial set of repairs to EPRI?
  - How has the repair vendor selected welders? And what did the welder procedure qualification entail? And especially for limited access repairs?
  - How is post-repair inspection being handled? Is 100% volumetric inspection being performed? When is the next planned inspection following operation of the repair?