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WRTC / Welding Code Issues

Industry/U.S. NRC Materials Program Technical Information Exchange Meeting

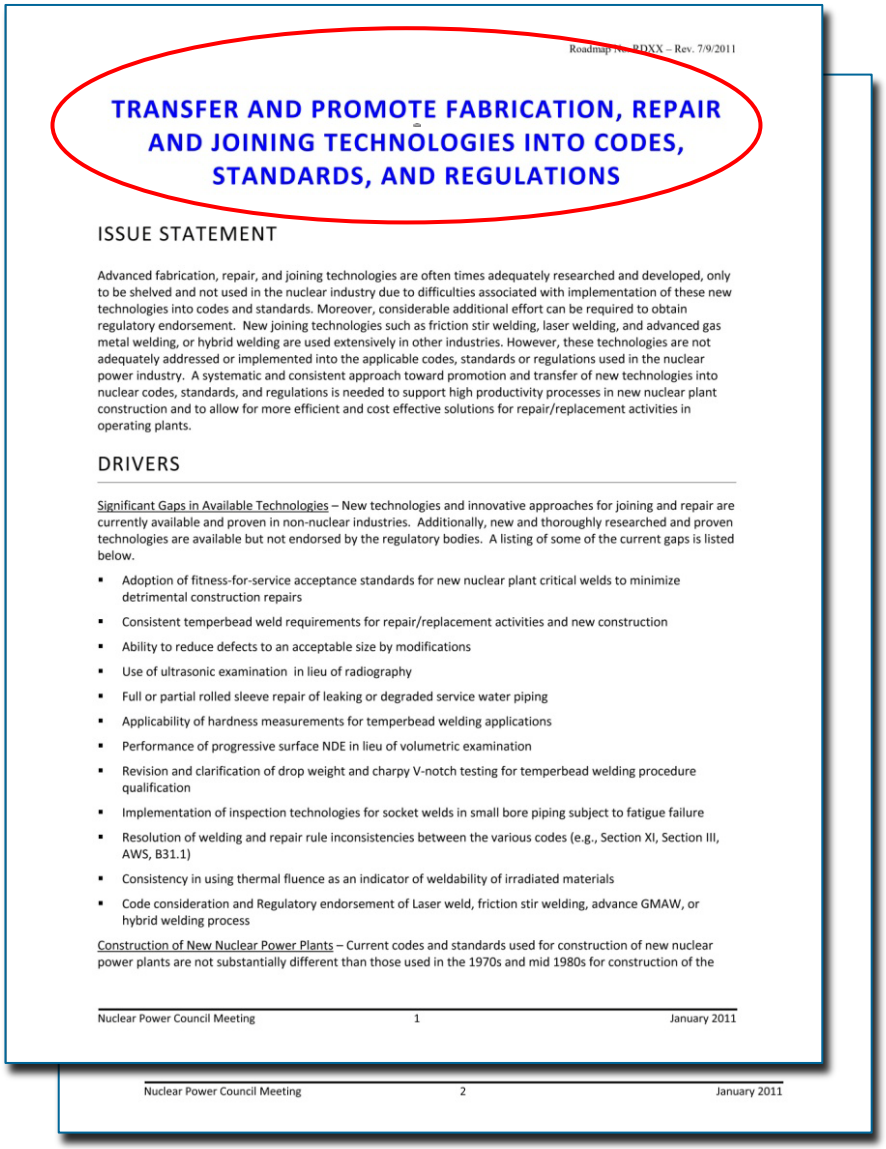
Rockville, MD
Wednesday June 4, 2014

Steve McCracken
EPRI Welding & Repair Technology Center

Presentation Outline

- **WRTC Code Issues Road Map**
- WRTC Code Issues Report
- SMAW Temper Bead Code Case
- HDPE Electrofusion Repair
- N-740-3 FSWOL Code Case
- Summary/Status of XI Code Cases

WRTC Code Issues Roadmap



Roadmap No. PDXX – Rev. 7/9/2011

TRANSFER AND PROMOTE FABRICATION, REPAIR AND JOINING TECHNOLOGIES INTO CODES, STANDARDS, AND REGULATIONS

ISSUE STATEMENT

Advanced fabrication, repair, and joining technologies are often times adequately researched and developed, only to be shelved and not used in the nuclear industry due to difficulties associated with implementation of these new technologies into codes and standards. Moreover, considerable additional effort can be required to obtain regulatory endorsement. New joining technologies such as friction stir welding, laser welding, and advanced gas metal welding, or hybrid welding are used extensively in other industries. However, these technologies are not adequately addressed or implemented into the applicable codes, standards or regulations used in the nuclear power industry. A systematic and consistent approach toward promotion and transfer of new technologies into nuclear codes, standards, and regulations is needed to support high productivity processes in new nuclear plant construction and to allow for more efficient and cost effective solutions for repair/replacement activities in operating plants.

DRIVERS

Significant Gaps in Available Technologies – New technologies and innovative approaches for joining and repair are currently available and proven in non-nuclear industries. Additionally, new and thoroughly researched and proven technologies are available but not endorsed by the regulatory bodies. A listing of some of the current gaps is listed below.

- Adoption of fitness-for-service acceptance standards for new nuclear plant critical welds to minimize detrimental construction repairs
- Consistent temperbead weld requirements for repair/replacement activities and new construction
- Ability to reduce defects to an acceptable size by modifications
- Use of ultrasonic examination in lieu of radiography
- Full or partial rolled sleeve repair of leaking or degraded service water piping
- Applicability of hardness measurements for temperbead welding applications
- Performance of progressive surface NDE in lieu of volumetric examination
- Revision and clarification of drop weight and charpy V-notch testing for temperbead welding procedure qualification
- Implementation of inspection technologies for socket welds in small bore piping subject to fatigue failure
- Resolution of welding and repair rule inconsistencies between the various codes (e.g., Section XI, Section III, AWS, B31.1)
- Consistency in using thermal fluence as an indicator of weldability of irradiated materials
- Code consideration and Regulatory endorsement of Laser weld, friction stir welding, advance GMAW, or hybrid welding process

Construction of New Nuclear Power Plants – Current codes and standards used for construction of new nuclear power plants are not substantially different than those used in the 1970s and mid 1980s for construction of the

Nuclear Power Council Meeting 1 January 2011

Nuclear Power Council Meeting 2 January 2011

- **Current WRTC focus areas:**
  - *Temper bead welding issues*
  - *SMAW temper bead*
  - *Excavate & Weld Repair*
  - *Fitness-for-service acceptance*
  - *Hardness criteria for temper bead*
  - *HDPE issues*
  - *Section IX revisions*
  - *Etc.*

Purpose of code issues roadmap is to provide long term focus and direction to WRTC projects that address code and regulatory issues

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2013 Tech Report – ASME Section XI Issues

- **Welding & Repair Technical Issues in ASME Section XI**
  - Single reference for WRTC members to review status of recent Section XI changes and initiatives
  - Updated on a yearly basis
  - Includes significant Section XI issues and revisions
  - Provides status of on-going activities

Key Contributors to 2013 Report:
Dick Smith & Nick Mohr, SIA
Jim O'Sullivan, Procon1
Darren Barborak, AZZ WSI
Steve McCracken, WRTC

EPRI Report 3002000600

2013 - Report 3002000600 Table of Contents

- Validity of Hardness as a Measure for Temper Bead HAZ Toughness
- PWR Weldability Assessments for Austenitic Materials in High Fluence Areas
- Code Case Underwater Cladding Repair by Nickel Plating
- Code Case N-839 SMAW Ambient Temperature Temper Bead
- Code Case N-818 Fitness for Service (ASME Section III)
- Code Case for PWSCC Mitigation by Peening
- Excavate and Weld Repair (EWR) Code Case
- ASME Section IX 2013 Edition Changes
- Upcoming Code Activities
- Status of Code Cases: N-504-4, N-638-7, N-666-1, N-740-2, N-754, N-766, N-770-3, N-786, N-789-1, N-808, N-818

1025170 WRTC: Rolled Plate and Pad Repair Guide Update (N-786 and N-789

2012 - Report 1025169 Table of Contents

- Validity of Hardness as a Measure for Temper Bead HAZ Toughness
- Simulated PWHT for Temper Bead Qualifications
- Alternate Impact Test Rules for Temperbead Qualifications
- Elimination of Hydrogen Bakeout for SMAW Temper Bead
- Methods to Validate Chromium Recovery
- Interpass Temperature Controls for Temper Bead and Weld Overlays
- Excavate and Weld Repair Code Case
- Status of Code Cases
  - N-638-7, N-666-1, N-740-2, N-786, N-789, N-818

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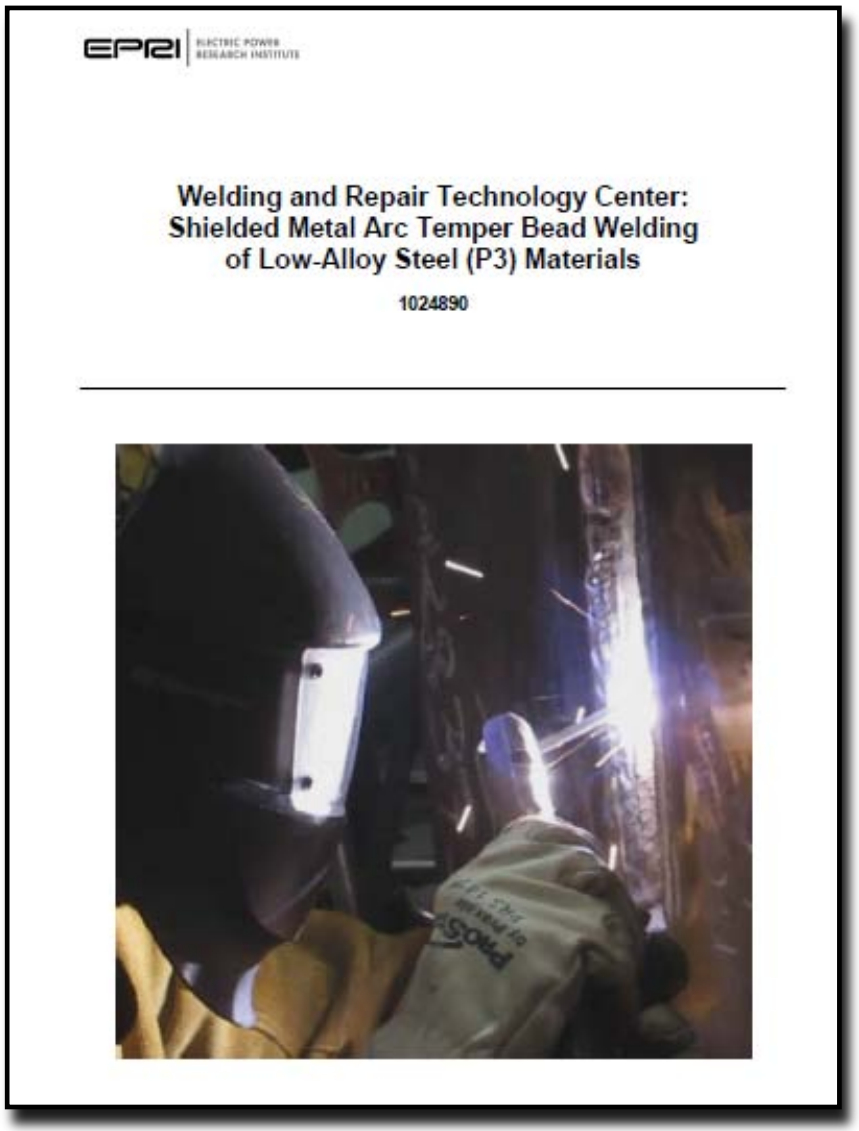
SMAW Ambient Temperature Temper Bead

New Code Case N-839

- Ambient temperature temper bead is currently limited to the machine GTAW process (N-638-7)
- Industry needs a code case similar to N-638-7 that permits ambient temperature temper bead with the SMAW (manual stick electrode) process
- New Code Case N-839 "*Similar And Dissimilar Metal Welding Using Ambient Temperature SMAW Temper Bead Technique, Section XI, Division 1*"
- Special consideration for the SMAW process
  - Understand hydrogen delayed cracking susceptibility and influence of SMAW electrode flux coating
- WRTC performed four point bend strain testing and diffusible hydrogen testing to support N-839

WRTC Activities to Support N-839

Results of Diffusible Hydrogen and Strain Testing



- Modern low moisture / low hydrogen electrodes have extremely low hydrogen content
- Extremely low probability of hydrogen induced cracking with H4 low hydrogen electrodes
- Austenitic and ferritic electrodes verified to have less than 4ml/100g diffusible hydrogen
- Post weld hydrogen bake unnecessary (similar to GTAW)
- 48 hr hold unnecessary (no potential for H_2 cracking)
- Code Case N-839 technical bases in EPRI Report 1024890

Code Case N-839

Overview

- N-839 was written in same format as machine GTAW ambient temperature temper bead code case N-638
- N-839 includes recent changes found in N-638-7
  - Alternate Charpy-V notch test temperatures
  - Simulated PWHT changes
- R.G. 1.147 conditions for N-638-4 are resolved in N-839
  - Indirect interpass temperature determination methods are removed
  - UT examination demonstration with representative samples containing construction type flaws is required
- Minimum preheat of 50°F is not required
- Post weld hydrogen bakeout is not required

Code Case N-839

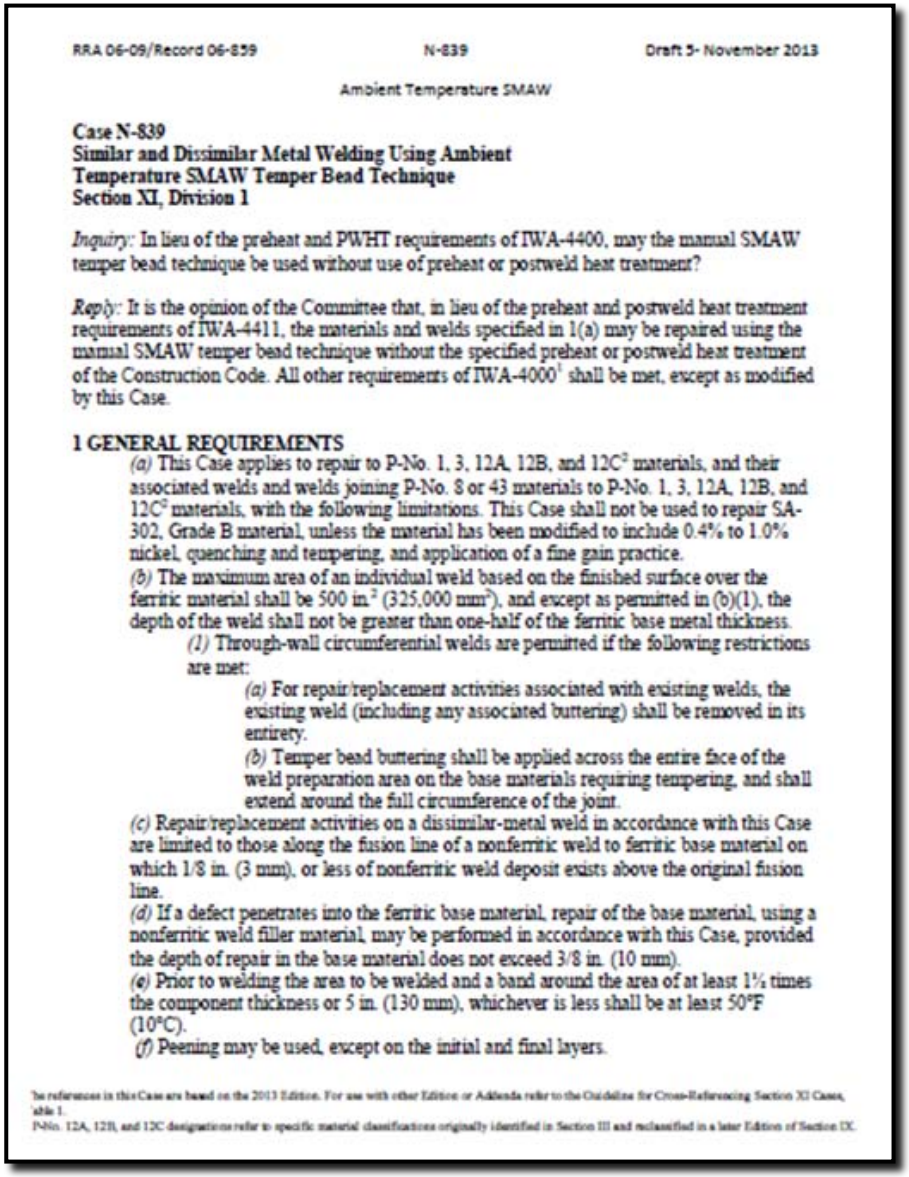
Restrictions and Conservatisms

- H4R (≤ 4ml/100g diffusible hydrogen & moisture resistant) electrodes are required for ferritic filler materials
- Electrode re-baking is not permitted
- Electrode exposure times are conservatively limited
  - Exposure of “H4” electrodes up to 72hr at 80% relative moisture and 80°F had diffusible hydrogen values of no greater than 6ml/100g (3 out of 4 below 4ml/100g) (reference EPRI 1024890)
  - E70XX-H4R exposure up to 8hr
  - E80XX-H4R / E90XX-H4R exposure up to 4hr
  - Austenitic filler materials exposure up to 8hr

Code Case N-839

Status and Progress

- Status of WRTC activities
  - Additional diffusible hydrogen testing of E9018-B3 H4R electrodes at extreme conditions will be performed this summer
- Progress in ASME code
  - Passed WG W&SRP 11-1-0
  - Passed SG RRA 13-1-0
  - Unanimous vote for 2nd consideration at SC XI
  - NRC will maintain negative until testing is complete



RRA 06-09/Record 06-859 N-839 Draft 3- November 2013

Ambient Temperature SMAW

Case N-839
Similar and Dissimilar Metal Welding Using Ambient Temperature SMAW Temper Bead Technique
Section XI, Division 1

Inquiry: In lieu of the preheat and PWHT requirements of IWA-4400, may the manual SMAW temper bead technique be used without use of preheat or postweld heat treatment?

Reply: It is the opinion of the Committee that, in lieu of the preheat and postweld heat treatment requirements of IWA-4411, the materials and welds specified in 1(a) may be repaired using the manual SMAW temper bead technique without the specified preheat or postweld heat treatment of the Construction Code. All other requirements of IWA-4000[1] shall be met, except as modified by this Case.

1 GENERAL REQUIREMENTS

(a) This Case applies to repair to P-No. 1, 3, 12A, 12B, and 12C[2] materials, and their associated welds and welds joining P-No. 8 or 43 materials to P-No. 1, 3, 12A, 12B, and 12C[2] materials, with the following limitations. This Case shall not be used to repair SA-302, Grade B material, unless the material has been modified to include 0.4% to 1.0% nickel, quenching and tempering, and application of a fine grain practice.

(b) The maximum area of an individual weld based on the finished surface over the ferritic material shall be 500 in.[2] (325,000 mm[2]), and except as permitted in (b)(1), the depth of the weld shall not be greater than one-half of the ferritic base metal thickness.

(1) Through-wall circumferential welds are permitted if the following restrictions are met:

(a) For repair/replacement activities associated with existing welds, the existing weld (including any associated buttering) shall be removed in its entirety.

(b) Temper bead buttering shall be applied across the entire face of the weld preparation area on the base materials requiring tempering, and shall extend around the full circumference of the joint.

(c) Repair/replacement activities on a dissimilar-metal weld in accordance with this Case are limited to those along the fusion line of a nonferritic weld to ferritic base material on which 1/8 in. (3 mm), or less of nonferritic weld deposit exists above the original fusion line.

(d) If a defect penetrates into the ferritic base material, repair of the base material, using a nonferritic weld filler material, may be performed in accordance with this Case, provided the depth of repair in the base material does not exceed 3/8 in. (10 mm).

(e) Prior to welding the area to be welded and a band around the area of at least 1½ times the component thickness or 5 in. (130 mm), whichever is less shall be at least 50°F (10°C).

(f) Peening may be used, except on the initial and final layers.

[1] References in this Case are based on the 2013 Edition. For use with other Editions or Addenda refer to the Guidelines for Cross-Referencing Section XI Cases, Table 1.
[2] P-No. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and reclassified in a later Edition of Section IX.

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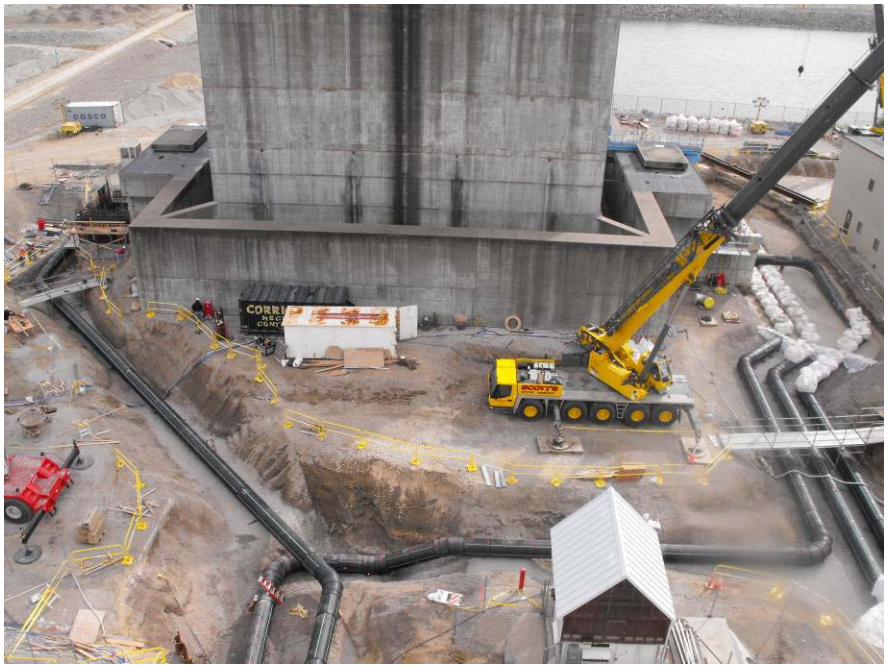
HDPE Piping for Nuclear Service

HDPE is installed in safety related ESW systems and other raw water systems at operating nuclear plants



Currently there is no code sanctioned feasible means to repair or modify buried HDPE piping in nuclear systems

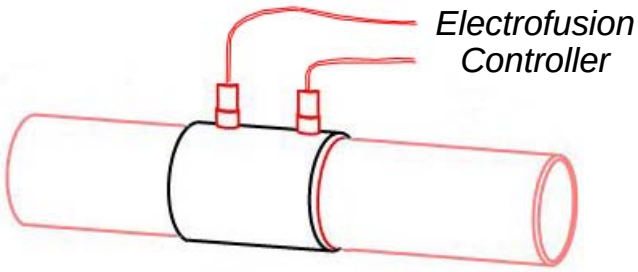
Electrofusion for HDPE

Nuclear Applications

- Problem: There is no feasible code sanctioned methods for repair or modification of buried HDPE piping in nuclear systems
- Solution: Develop rules for use of HDPE electrofusion couplings and fittings for nuclear applications
- Approach:
  - Develop ASME B&PV Section IX Code rules for electrofusion
  - Develop enhanced ASME Section XI Code Case for repair/ replacement of HDPE piping in nuclear applications using electrofusion
  - Incorporate the enhanced ASME Section XI rules for electrofusion into the ASME Section III Appendix for HDPE piping

What is Electrofusion?

- A method of joining HDPE and other plastic pipe using special fittings that have built-in electric heating elements which are used to fuse (weld) the joint
- The pipes to be joined are cleaned, inserted into the electrofusion fitting (with temporary clamp if required) and a voltage (typically 40V) is applied for a fixed time depending on the fitting size and design
- The heating coils built into the electrofusion fitting melt the inside of the fitting wall and outside of the pipe wall to make a very strong homogeneous joint



Electrofusion for HDPE

ASME Section IX

- ASME Section IX Rules for Electrofusion
  - Based on existing ASTM, Regulatory (49 CFR 192), and Industry Standards (PPI).
  - Include socket-type and saddle-type electrofusion fittings
  - Integrate into ASME Section IX, 2013 Edition, Part QF on Plastic Fusing with similar requirements:
    - Data acquisition devices and records
    - Visual inspection and data verification
    - Destructive qualification testing
    - Qualification testing by specific fitting manufacturer or by user
    - Enhanced essential variables for procedure & performance qualification

Electrofusion for HDPE

ASME Section III and XI

- ASME Section XI Code Case for Electrofusion
  - Expand Section IX requirements to address nuclear applications
    - Owner involvement in procurement and testing
    - Performance demonstration requirements
    - Mandatory training for electrofusion operators & inspectors
    - Special repair rules
    - Special qualification requirements for NDE personnel
    - Visual inspection & Volumetric NDE
    - Hydrostatic testing
    - Inservice inspection
- ASME Section III, Division 1, Appendix on Buried HDPE
  - Incorporate Section XI Code Case provisions into Div. 1 requirements

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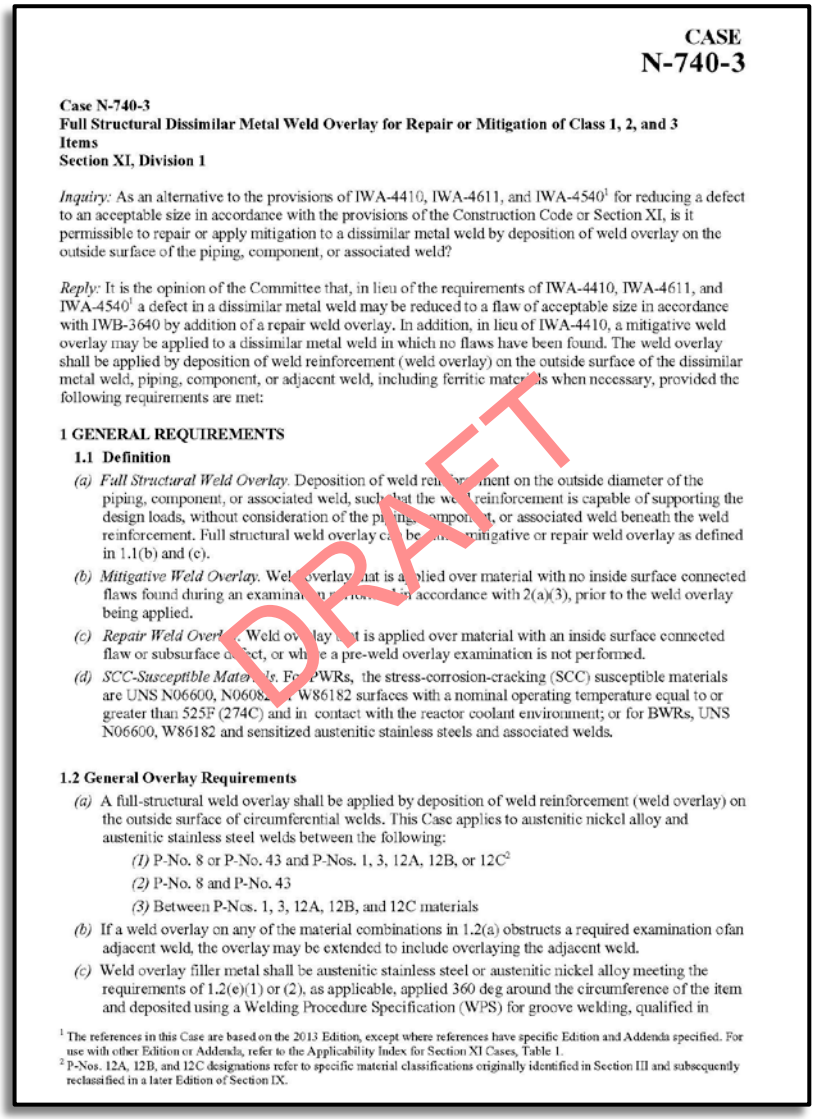
Full Structural Weld Overlay N-740 Changes



CASE
N-740-3

Case N-740-3
Full Structural Dissimilar Metal Weld Overlay for Repair or Mitigation of Class 1, 2, and 3 Items
Section XI, Division 1

Inquiry: As an alternative to the provisions of IWA-4410, IWA-4611, and IWA-4540[1] for reducing a defect to an acceptable size in accordance with the provisions of the Construction Code or Section XI, is it permissible to repair or apply mitigation to a dissimilar metal weld by deposition of weld overlay on the outside surface of the piping, component, or associated weld?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4410, IWA-4611, and IWA-4540[1] a defect in a dissimilar metal weld may be reduced to a flaw of acceptable size in accordance with IWB-3640 by addition of a repair weld overlay. In addition, in lieu of IWA-4410, a mitigative weld overlay may be applied to a dissimilar metal weld in which no flaws have been found. The weld overlay shall be applied by deposition of weld reinforcement (weld overlay) on the outside surface of the dissimilar metal weld, piping, component, or adjacent weld, including ferritic materials when necessary, provided the following requirements are met:

1 GENERAL REQUIREMENTS

1.1 Definition

(a) *Full Structural Weld Overlay.* Deposition of weld reinforcement on the outside diameter of the piping, component, or associated weld, such that the weld reinforcement is capable of supporting the design loads, without consideration of the piping, component, or associated weld beneath the weld reinforcement. Full structural weld overlay can be a mitigative or repair weld overlay as defined in 1.1(b) and (c).

(b) *Mitigative Weld Overlay.* Weld overlay that is applied over material with no inside surface connected flaws found during an examination performed in accordance with 2(a)(3), prior to the weld overlay being applied.

(c) *Repair Weld Overlay.* Weld overlay that is applied over material with an inside surface connected flaw or subsurface defect, or where a pre-weld overlay examination is not performed.

(d) *SCC-Susceptible Materials.* For PWRs, the stress-corrosion-cracking (SCC) susceptible materials are UNS N06600, N06082, W86182 surfaces with a nominal operating temperature equal to or greater than 525F (274C) and in contact with the reactor coolant environment; or for BWRs, UNS N06600, W86182 and sensitized austenitic stainless steels and associated welds.

1.2 General Overlay Requirements

(a) A full-structural weld overlay shall be applied by deposition of weld reinforcement (weld overlay) on the outside surface of circumferential welds. This Case applies to austenitic nickel alloy and austenitic stainless steel welds between the following:

(1) P-No. 8 or P-No. 43 and P-Nos. 1, 3, 12A, 12B, or 12C[2]

(2) P-No. 8 and P-No. 43

(3) Between P-Nos. 1, 3, 12A, 12B, and 12C materials

(b) If a weld overlay on any of the material combinations in 1.2(a) obstructs a required examination of an adjacent weld, the overlay may be extended to include overlaying the adjacent weld.

(c) Weld overlay filler metal shall be austenitic stainless steel or austenitic nickel alloy meeting the requirements of 1.2(e)(1) or (2), as applicable, applied 360 deg around the circumference of the item and deposited using a Welding Procedure Specification (WPS) for groove welding, qualified in

[1] The references in this Case are based on the 2013 Edition, except where references have specific Edition and Addenda specified. For use with other Edition or Addenda, refer to the Applicability Index for Section XI Cases, Table 1.
[2] P-Nos. 12A, 12B, and 12C designations refer to specific material classifications originally identified in Section III and subsequently reclassified in a later Edition of Section IX.

- N-740-3 Revisions
  - Revised to resolve NRC conditions and Stds Committee XI negatives
  - PSI/ISI requirements for PWRs moved to N-770
  - Specifications other than ERNiCrFe-7A (52M) permitted
  - Weld wire Cr minimum reduced to 26% minimum
  - Fatigue crack growth laws of 2010 Section XI Appendix C specified
  - Revised to clarify that proximity rules are not required when evaluating laminar indications that obstruct PSI examination volume

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Status of Code Cases

Code Case N-504-5 (ASME PM: Shane Findlan)

Title/Description

Alternative Rules for Repair of Classes 1, 2, and 3 Austenitic Stainless Steel Piping (Section XI, Division I) [ASME Record:04-264, RRA 13-04]

ASME Status

Code Case N-504-4 was approved for use by ASME on July 14, 2006. Code Case N-504-5 is currently still in progress with the revision to address the current approach of N-740 and NRC limitations for N-504-4.

Regulatory Status

The latest revision of Regulatory Guide 1.147 “Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1” is Revision 16 and was published October 2010. Revision 16 conditionally accepts N-504-4.

Draft Revision 17 to Regulatory Guide 1.147 dated June 2013 continues to list N-504-4 as conditionally accepted with the same limitations as Revision 16.

Status of Code Cases

Code Case N-638-7 (ASME PM: Steve McCracken)

Title/Description

Similar and dissimilar metal welding using ambient temperature machine GTAW temper bead technique (Section XI, Division 1). [ASME Record 10-550, RRA 13-13]

ASME Status

Code Case N-638-7 was approved by ASME on June 21, 2013

Regulatory Status

Regulatory Guide 1.147 Revision 16 lists Code Case N-638-4 as “Conditionally Acceptable”

Newer revisions of Code Case N-638 (-5,-6, or -7) are not addressed in Draft Revision 17 of Reg. Guide 1.147 dated June 2013 . Code case N-638-4 is still listed as conditionally accepted with the same limitations.

Status of Code Cases

Code Case N-740-3 (ASME PM: Steve McCracken)

Title/Description

Full structural dissimilar metal weld overlay for repair or mitigation of class 1, 2, and 3 items (Section XI, Division 1). [ASME Records: 07-1243, 09-822, 12-1640]

ASME Status

Code Case N-740-2 was approved by ASME on November 10, 2008. A revision to Code Case N-740-2 is currently being drafted in ASME Section XI Working Group Welding and Special Repair Process. To be ready for comment at Feb 2014 meeting.

Regulatory Status

As specified in Regulatory Guide 1.193 “ASME Code Case N-740 “Not Approved For Use” Revision 3 published October 2010

Draft Reg. Guide 1.193 Rev. 4 dated June 2013 now lists N-740, N-740-1, and N-740-2 as “Not Approved For Use”

Status of Code Cases

Code Case N-754-2 (ASME PM: Steve McCracken)

Title/Description

Optimized Structural Dissimilar Metal Weld Overlay for Mitigation of PWR Class 1, 2, and 3 Items (Section XI, Division 1). [ASME Records: 06-500, 12-1330, RRA 13-04]

ASME Status

Code Case N-754-1 was approved by ASME on February 15, 2013. A revision to Code Case N-754-1 is currently being drafted, among other items, Code Case N-754-2 will incorporate new simulated PWHT and alternate Charpy testing rules approved in N-638-7.

Regulatory Status

Code Case N-754 is not addressed in draft Regulatory Guide 1.147 Revision 17 and was also not addressed in draft Regulatory Guide 1.193 Revision 4 both dated June 2013.

Status of Code Cases

Code Case N-766 (ASME PM: Joe Weicks)

Title/Description

Nickel Alloy Reactor Coolant Inlay and Onlay for Mitigation of PWR Full Penetration Circumferential Nickel Alloy Dissimilar Metal Welds in Class 1 Items Section XI, Division 1). [ASME Record: 11-835]

ASME Status

Code Case N-766 was approved by ASME on December 20, 2010

Code Case N-766-1 was approved by ASME on February 15, 2013

Regulatory Status

Code Case N-766 is not addressed in draft Regulatory Guide 1.147 Revision 17 and was also not addressed in draft Regulatory Guide 1.193 Revision 4 both dated June 2013.

Status of Code Cases

Code Case N-786 (ASME PM: Jim O'Sullivan)

Title/Description

Alternative requirements for sleeve reinforcement of class 2 and 3 moderate energy carbon steel piping (Section XI, Division 1). [ASME Record: 09-1691]

ASME Status

Code Case N-786 was approved for use by ASME on March 24, 2011.

Regulatory Status

On February 27, 2013 Exelon submitted a request for alternative to use N-786 at multiple facilities. The NRC has Request for Additional Information (RAI) related to the submitted request for alternative and Exelon is currently working through the RAIs

Draft Revision 17 to Reg. Guide 1.147 dated June 2013 does not address N-786.

Status of Code Cases

Code Case N-789 (ASME PM: Jim O'Sullivan)

Title/Description

Alternative requirements for pad reinforcement of class 2 and 3 moderate energy carbon steel piping (Section XI, Division 1). [ASME Records: 10-1105, 12-1621]

ASME Status

Code Case N-789 was approved for use by ASME on June 25, 2011.

Code Case N-789-1 is in progress to incorporate clarifications resulting from Relief Request RAI's, and to add monthly monitoring of pressure pads as result of Relief Request condition of approval.

Regulatory Status

Request for Alternative was sent on November 10, 2011 to the NRC by Exelon using the methodology of N-789 for repairs to moderate energy piping systems.

Draft Revision 17 to Reg. Guide 1.147 dated June 2013 does not address N-789

Status of Code Cases

Code Case N-808 (ASME PM: Jim O'Sullivan)

Title/Description

Code Case N-808, Use of Polyethylene Class 3 Plastic Pipe (ASME Section XI). [ASME Records: 11-1103, 12-1479]

ASME Status

This code case is still in progress. However, a revision is also being worked on to allow electro-fusion of coupling to repair HDPE piping.

Regulatory Status

Due to the similarities between N-755 and N-808 it would be expected that the NRC would have similar concerns for N-808. However, Callaway and Catawba have successfully installed HDPE piping their facilities and the associated operating experience could be used to assist a utility interested in installing HDPE piping.

Status of Code Cases

Code Case N-818 (ASME PM: Jim O'Sullivan)

Title/Description

Use of Analytical Evaluation Approach for Acceptance of Full Penetration Butt Welds in Lieu of Weld Repair (Section III, Division 1). [ASME Records: 11-424, 12-1688]

ASME Status

Code Case N-818 was approved by ASME on December 06, 2011. Revision to N-818 is in progress

Regulatory Status

The latest revision of Regulatory Guide 1.84 "Design, Fabrication, and Materials Code Case Acceptability, ASME Section III" is Revision 35 and was published October 2010. Revision 35 does not address Code Case N-818. Current use of Code Case N-818 would require utilities to submit a Request for Alternative/Relief Requests

Questions or Comments?

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Welding and Repair Technology Center

Together…Shaping the Future of Electricity