THE NATIONAL BOARD OF BOILER AND PRESSURE VESSEL INSPECTORS

SUBGROUP ON REPAIRS and ALTERATIONS SPECIFIC

MINUTES

Meeting of July 17, 2012
Columbus, Ohio

The National Board of Boiler & Pressure Vessel Inspectors
1055 Crupper Avenue
Columbus, Ohio 43229-1183
Phone: (614)888-8320
FAX: (614)847-1828

1. **Call to Order**

The meeting was called to order at 8:00 a.m. by Subgroup Chairman Paul Edwards.

2. **Announcements**

Wednesday's evening outing will leave from the Crowne Plaza Hotel at 5:30 p.m.
Lunch will be served each day at 12 noon and breakfast will be served at 7 a.m.
on Thursday.

3. **Adoption of the Agenda**

There was a motion to approve the Agenda. The motion was unanimously approved.

4. **Approval of Minutes of January 17, 2012 meeting**

There was a motion to approve the Minutes of January 17, 2012. The motion was unanimously approved.

5. **Review of the Roster (Attachment 1)**

6. **Action Items (Attachment 2)**

NB11-1001 ***Part 3, 3.3.4.9 SG R/A Specific*** **-** Tube plugging for fire tube boilers.

A progress report and proposed language was provided by Mr. Bramucci. (Attachment 2, pp. 1)

NB12-0801 ***Part 3, SG R/A Specific*** **-** Repair and alteration of Gasketed PHEs in the field.

A progress report was provided by Mr.Cauthon. (Attachment 2, pp. 2-18)

NB12-2101 ***Part 3, 4.2 SG R/A Specific*** – A recommendation to change the reference in this section from 2001 to 2006. (Attachment 2, pp.19-24)

Mr. Jim Pillow presented proposed revisions. There was a motion made to approve the proposed revisions. The motion was unanimously approved.

7. **New Business**

NB12-0403- CSEF Weld Repair Options using temper bead.

Mr. George Galanes gave a presentation on NB12-0403 to the Subgroup. (Attachment 2, pp. 25-69)

8. **Future Meetings**

January 14-18, 2013, Mobile, Alabama
July 15-19, 2013, Columbus. OH

9. **Adjournment**

The meeting was adjourned at 2:15 p.m.

Respectfully Submitted,
James McGimpsey
Secretary
:rh

H:\ROBIN-Active Documents\NBIC Secretarial Documents\Committees\SC on Repairs and Alterations\SG on RA Specific\Agendas\Agenda RA Specific 0112.doc

Attendance List Repairs Alterations-Specific Subgroup

Meeting Date: July 17, 2012

James T. Pillow Common Arc Corporation 67 Wyndemere Lane Windsor, CT 06035 Ph: 860-688-2531 Fax: 860-688-2531 E-mail: Jpillow@commonarc.com	Attended: Yes ☒ No ☐ [illegible] *Initial*	**George W. Galanes, PE** Manager, Metallurgy and QA Edison Mission Group/Midwest Generation 235 Remington Blvd. Boilingbrook, IL 60440 Ph: 630-771-7927 Fax: 312-788-5218 E-mail: ggalanes@MWGen.com	Attended: Yes ☒ No ☐ [illegible] *Initial*
Angelo Brammucci Alstom Power Inc. 2000 Day Hill Road Windsor, CT 06095 Ph: 860-285-9176 Fax:860-285-3840 Email: angelo.c.bramucci@power.alstom.com	Attended: Yes ☒ No ☐ [illegible] *Initial*	**James Sekely** Welding Services, Inc. 716 Vanderbilt Drive Monroeville, PA 15146 Ph: 412-389-5567 Fax: 724-327-7381 E-mail: jsekely@comcast.net	Attended: Yes ☐ No ☒ [illegible] *Initial*
Frank Pavlovicz The Babcock & Wilcox Company 20 S. Van Buren Ave. Barberton, Ohio 44133 Ph: 440-237-9481 Fax: 330-860-8932 E-mail: fjpavlovi@gmail.com	Attended: Yes ☐ No ☐ RETIRED *Initial*	**Jim McGimpsey** The National Board 1055 Crupper Ave. Columbus, OH 43229 Ph: 614-888-8320 Fax: 614-847-1828 E-mail: jmcgimps@nationalboard.org	Attended: Yes ☒ No ☐ [illegible] *Initial*
Wayne Jones Arise Boiler Inspection and Insurance Company 705 East 4th Street Bay Minette, AL 36507 Ph: 251-937-6225 Fax: E-mail: wayne.jones@ariseinc.com	Attended: Yes ☐ No ☒ [illegible] *Initial*	**Brian Boseo** Graycor Services LLC Two Mid America Plaza, Suite 400 Oakbrook Terrace, IL 60181 Ph: 630-684-~~3016~~ 7300 Fax: 630-684-7116 E-mail: brian_boseo@graycor.com	Attended: Yes ☒ No ☐ [illegible] *Initial*

ALTERNATE:

RAY MILETTI
74 ROBINSON AVE.
BARBERTON, OH. 44203
BWCC
PH.: 330-860-2589
RLMILETTI@BABCOCK.COM

Attendance List Repairs Alterations-Specific Subgroup

Meeting Date: July 17, 2012

Walt Sperko Sperko Engineering 4803 Archwood Drive Greensboro. NC 27406 Ph: 336-674-0608 Fax: E-mail: sperko@asme.org	Attended: Yes ☐ No ☒ JRM *Initial*	**Stuart Cameron** Doosan Babcock Porterfield Road Renfrew PA 4 8DJ Ph: 44-141-885-3310 Fax: scameron@doosanbabcock.com Resigned	Attended: Yes ☐ No ☒ JRM *Initial*
Benjamin Schaefer BGH American Electric Power (AEP) Manager Fossil Plant Quality Control American Electric Power 1 Riverside Plaza, 18th Floor Columbus, Ohio 43211 P: 614-716-1843 F: 614-716-3204 Email: bschaefer@aep.com	Attended: Yes ☒ No ☐ B *Initial*	**Edward Ortman** Alstom Power 175 Addison Road Windsor, CT 06095 Ph: 860-285-2437 Fax: 860-285-3436. E-mail: Edward.m.ortman@power.alstom.com RANDY CAUTHON (SUB) SEE BELOW	Attended: Yes ☐ No ☒ JRM *Initial*
Zyad Jabal Tampa Electric P.O. Box 111 Tamapa, FL 33601 Ph: 813-228-4111 Fax: 813-228-4560 Email: zxjabal@tecoenergy.com	Attended: Yes ☐ No ☒ JRM *Initial*	**Rick Valdez** ARB Corporate Quality Control Manager 2600 Commercentre Drive Lake Forest, CA 92630 Ph; 661-331-6024 Fax: 661-833-4409 Email:	Attended: Yes ☒ No ☐ RV
Name: WILLIAM VALLANCE — Yes Company: STATE OF MICHIGAN Address: PO BOX 30254 City/State/Zip: LANSING MI 48909 Ph: 517 241 9359 Ext. Fax: 517 241 6301 E-mail: VallanceW@michigan.gov		Name: RANDY CAUTHON Company: APCOMPOWER INC. / ALSTOM Address: 200 GREAT POND DR City/State/Zip: WINDSOR, CT 06095 Ph: 860-285-3481 Ext. Fax: 860-285-4377 E-mail: randal.t.cauthon@power.alstom.com	

Attendance List Repairs Alterations-Specific Subgroup

Meeting Date: July 17, 2012

Name: PAUL EDWARDS Company: SHAW STONE + WEBSTER Address: City/State/Zip: Ph: Ext. Fax: E-mail: PAUL.EDWARDS@SHAWGRP.COM	Name: Walter Beach Company: Beach Technical Code Services Address: 574 Fieldstone dr. City/State/Zip: Amherst, ohio 44001 Ph: 440 864-7800 Ext. Fax: E-mail: wgbeach@gmail.com
Name: RON PULLIAM Company: BABCOCK & WILCOX Address: City/State/Zip: Ph: Ext. Fax: E-mail: RLPULLIAM@BABCOCK.COM	Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:
Name: Larry McManamon Company: Boilermakers UNION Address: 5666 W 95 St City/State/Zip: Oak Lawn Ill 60453 Ph: 708.267 9850 Ext. Fax: 708-636-6696 E-mail: LMac@glabaP.com	Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:
Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:	Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:

Attendance List Repairs Alterations-Specific Subgroup

Meeting Date: July 17, 2012

Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:	Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:
Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:	Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:
Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:	Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:
Name: Company: Address: City/State/Zip: Ph: Ext. Fax:	Name: Company: Address: City/State/Zip: Ph: Ext. Fax: E-mail:

Proposed Changes
NB11-1001

1) Engineering evaluation of the defect in the pressure-retaining item shall be conducted using one or more fitness-for-service condition assessment method(s) as described in NBIC, Part 2, 4.4. Engineering evaluation of the condition assessment results shall be performed by an organization that has demonstrated industry experience in evaluating pressure-retaining items as referenced in NBIC, Part 2, S5.3.

2) If engineering evaluation indicates a defect can remain in the pressure-retaining item, a risk-based inspection program shall be developed and implemented based on review and acceptance by the Inspector and, when required, the Jurisdiction. The risk-based inspection program shall be in accordance with the requirements in NBIC, Part 2, 4.4.

3) The fitness-for-service condition assessment and risk-based inspection programs shall remain in effect for the pressure-retaining item until such time that the defect can be completely removed and the item repaired. The fitness-for-service condition assessment method, results of assessment, and method of weld repair shall be

based inspection program developed and implemented as required by Paragraph 3.3.4.8. The inspection interval shall not exceed the remaining life of the item, and shall be documented on the FFSA Form and in the remarks section of the Form R-1. The FFSA Form shall be affixed to the Form R-1 when weld repairs are performed in 3.3.4.8. A07

6) A copy of the completed Form R-1 with the completed FFSA Form attached may be registered with the National Board, and when required, filed with the Jurisdiction where the item was installed.

Insert New Para. Here

3.3.5 REPAIR OF ASME SECTION VIII, DIVISION 2 OR 3, PRESSURE VESSELS

3.3.5.1 SCOPE

The following requirements shall apply for the repair of pressure vessels constructed to the requirements of Section VIII, Division 2 or 3, of the ASME Code.

3.3.5.2 REPAIR PLAN

Rational: In an effort to address many jurisdictions and repair organizations concerns with the tube plugging type of procedure that is performed on a continuous basis and to assist in unifying basic requirements following guidelines of the NBIC. Tube plugging is presently being performed using various processes such as welding, and mechanical methods such as driving, expanding or explosive bonding to existing tubes (sleeved or un-sleeved) or tube sheet holes when tubes are removed.
The scope of the NBIC should only address the repairs that pertain to replacement of tubing or when tubing involves welding in its repair method. The task group felt that the plugging of a tube or tubes in a boiler or heat exchanger is a deviation from its original operating parameters and the manufacturer's original design. The NBIC should not address mechanical repair methods, and could not safely determine a repair procedure or process when the various effects on the pressure boundaries, heat transfer and byproducts of combustion are unknown.

Section 3.3.4.9 TUBE PLUGGING

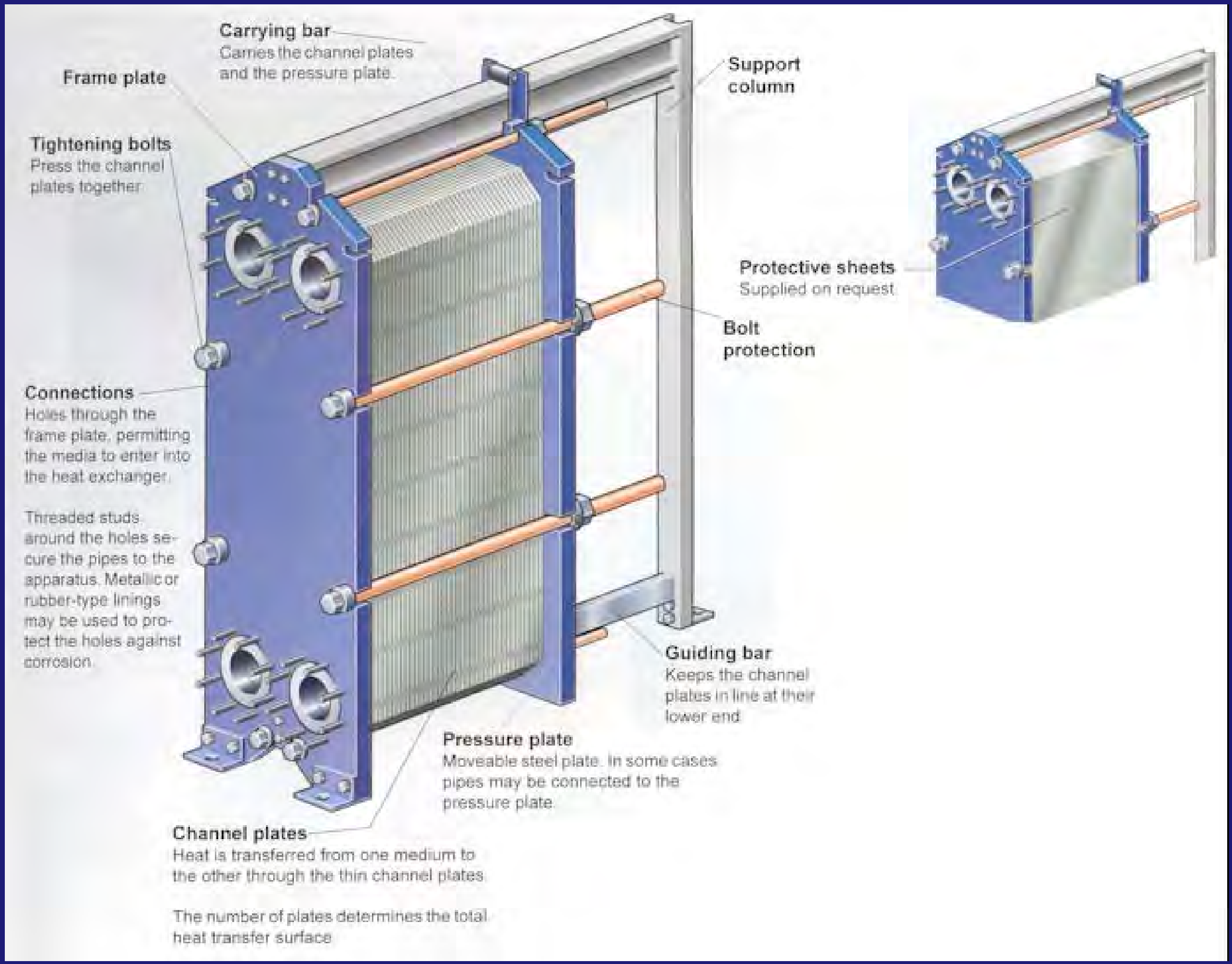
When tube plugging is performed, the following requirements should be met:

If tube replacement is not practical at the time the defect is found, plugging of tubes in a boiler or heat exchanger may be considered temporary and only conducted after notification of an inspector or the jurisdiction.

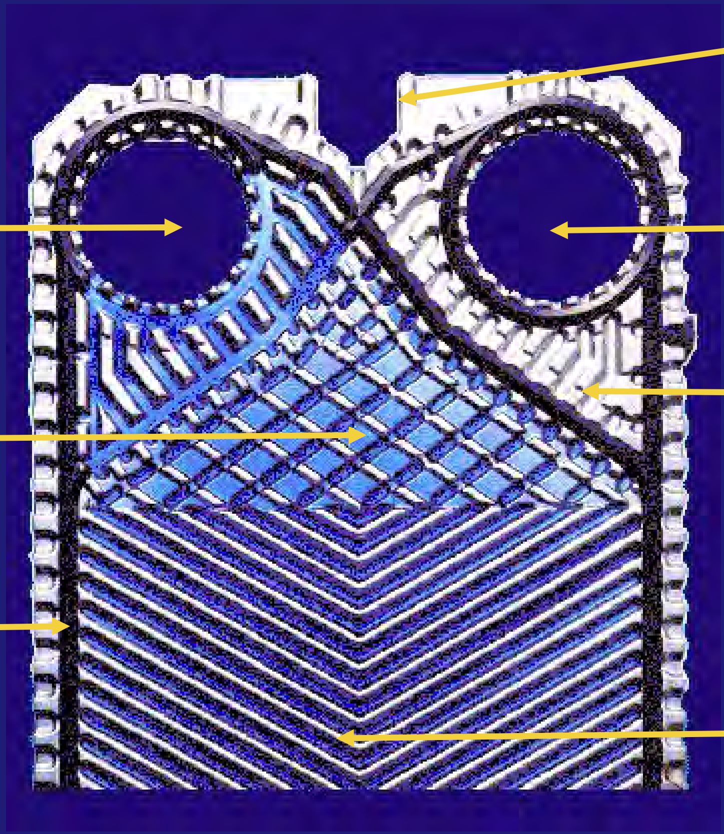
The manufacturer should be consulted and repair procedure evaluated to determine the scope of repair and address operating or safety concerns.

If welded repairs or replacement of pressure retaining parts are conducted, all welding and material shall be in accordance to the original code of construction or as noted in the applicable sections of the NBIC.

Basic PHE Design



Heat Plate Transfer Plates



Hanger

Flow Inlet / outlet

Flow Passing through

Leak chamber

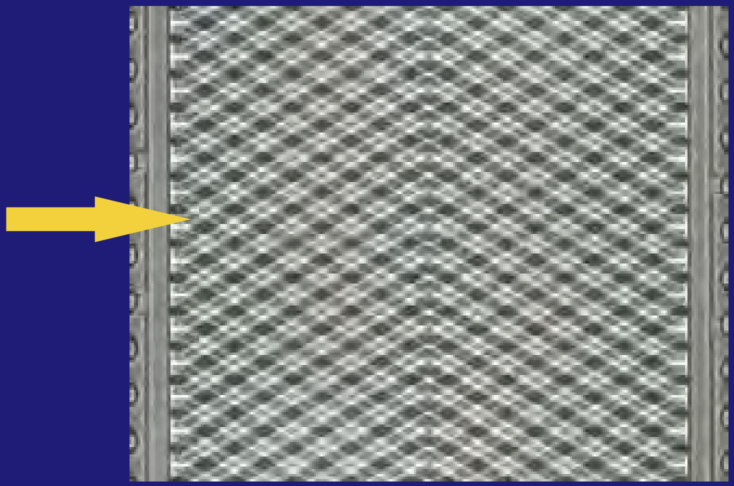
Distribution area

Gasket in
gasket groove

Main heat transfer
area

Plate - Corrugation Function

- Mechanical
  - Provide contact points
  - Allows thin material
- Increases Area
- Flow dynamic
  - Creates high turbulence
  - High efficiency
  - Minimize fouling
  - Cork-screw flow



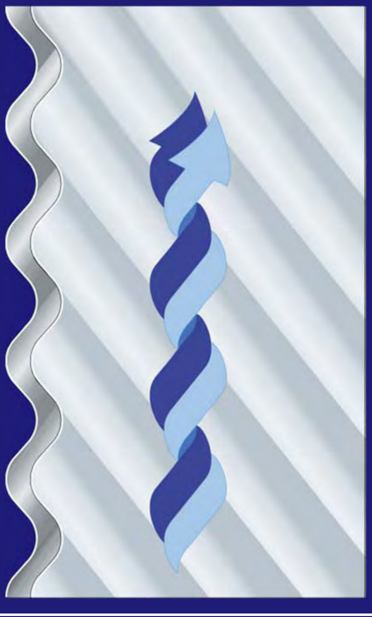


Plate - Corrugation and Channels

- We have two plate corrugations (L and H)
- These form three different channels (L, M and H)

L: Low theta

H: High theta

L + L = L channels

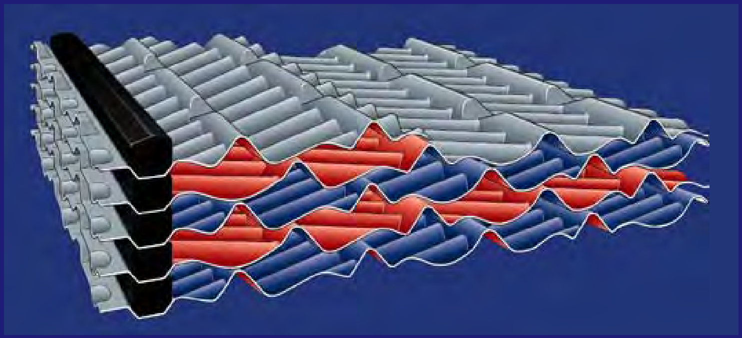
L + H = M channels

H + H = H channels

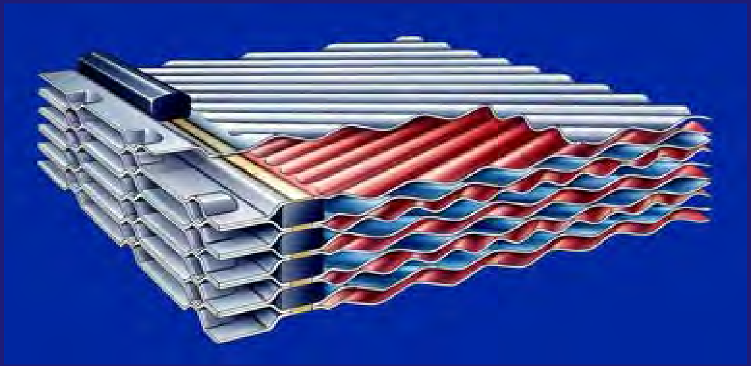
- L, M and H channels available
- Minimize surface area for given Pd and heat transfer

PHE Sealing Systems

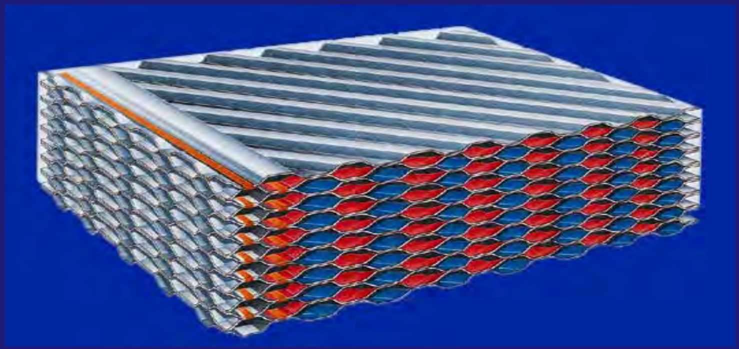
- Gasketed



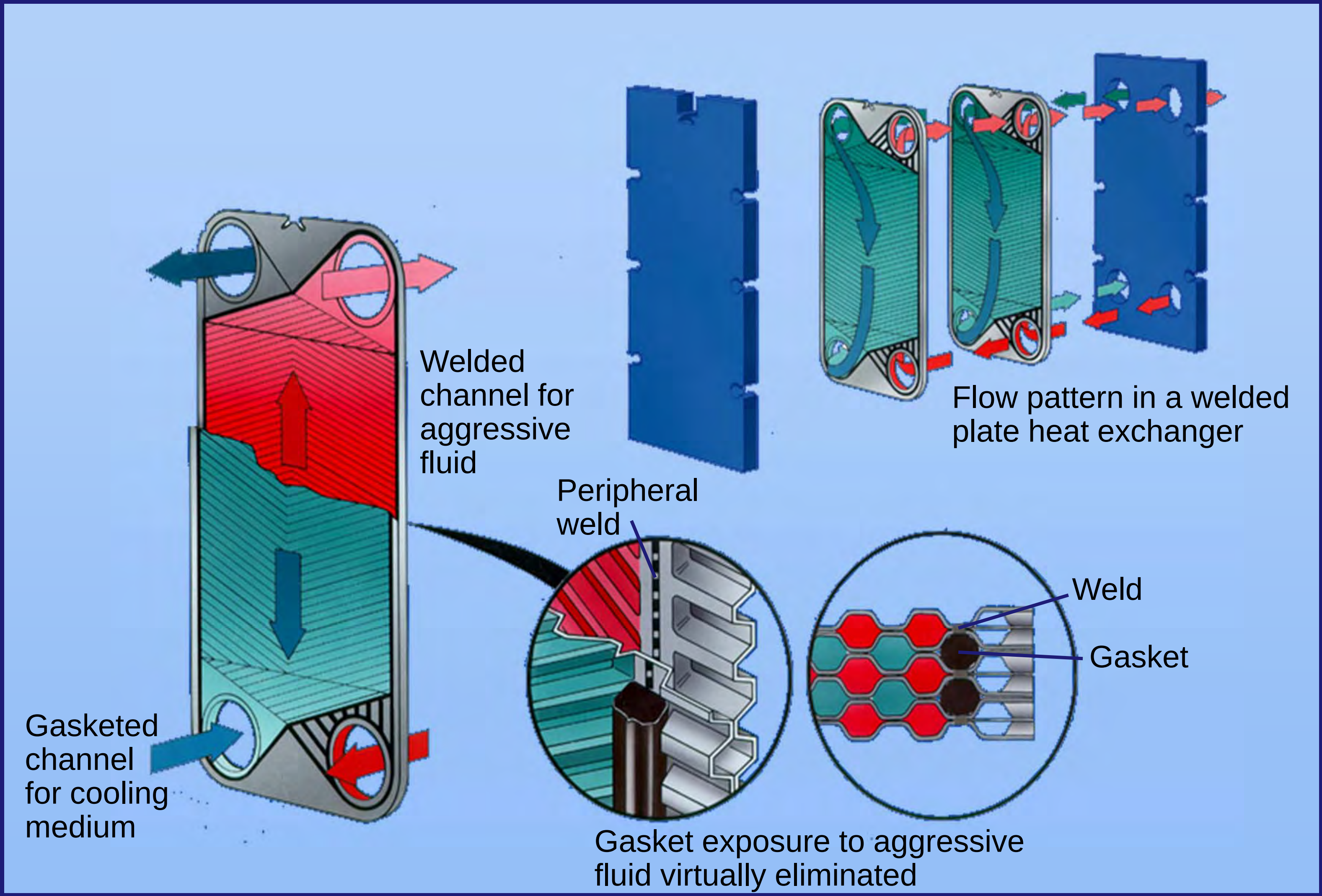
- Semi-Welded



- 100%Welded

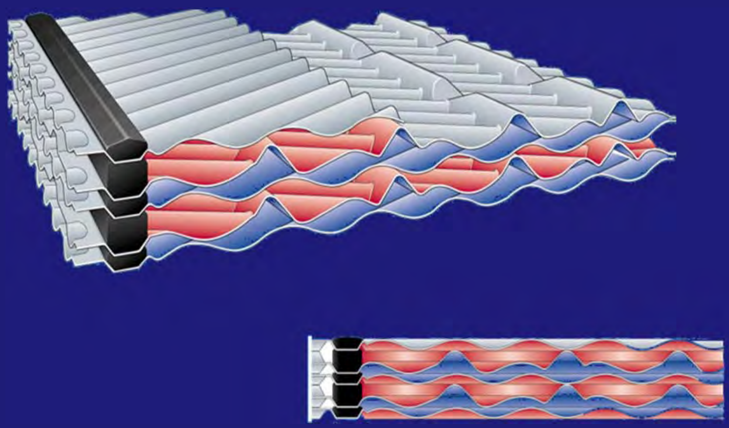


The Semi-Welded PHE

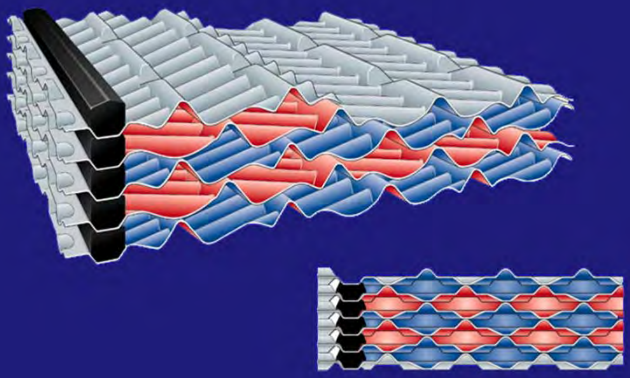


The Wide-Gap Plate Heat Exchanger

Single side Wide-gap



Double side Wide-gap



Used when

- Fibrous liquid
- Liquids with particles
- High viscosity liquids

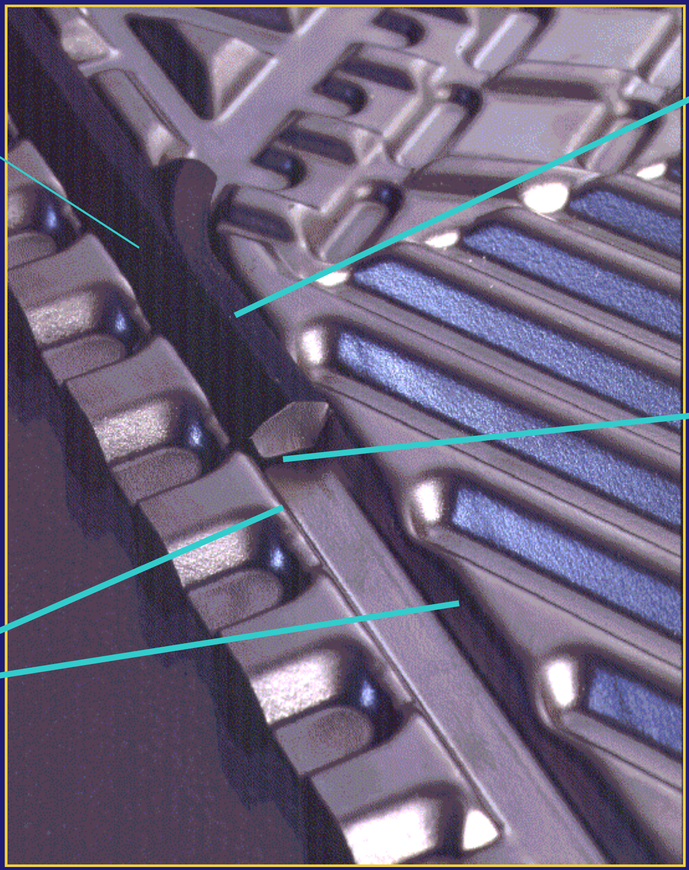
Typical applications

- Sugar industry
- Distillery
- Pulp and paper
- General chemical industry

Common Elastomer Gaskets

- Nitrile (NBR)
- EDPM
- FKM
- Silicone
- Neoprene
- Chloroprene

Gasket Sealing System



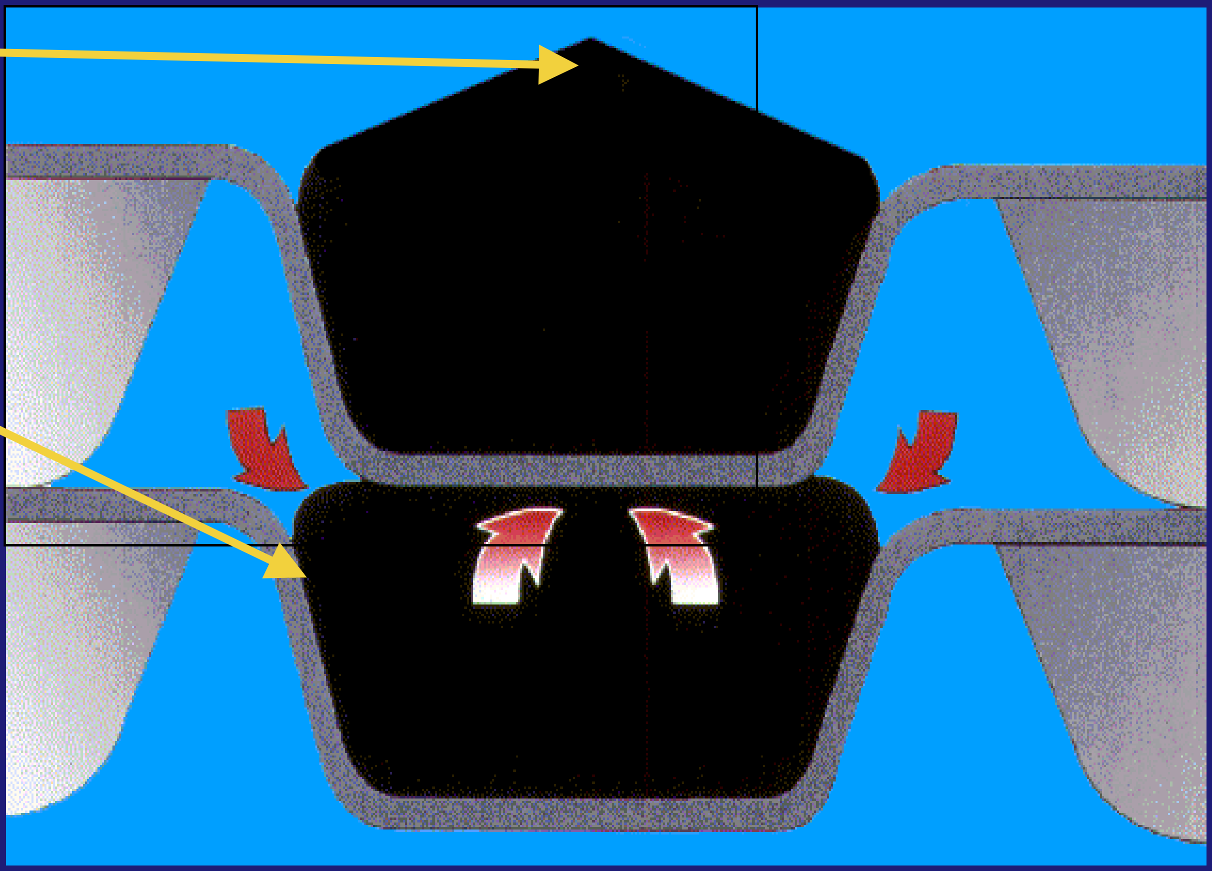
Gasket - Profile and Groove

Profile

Provides
Sealing
Forces

Groove

Supports
Gasket



Gasket Sealing/Leakage Variables

- Plate Pack Tightening Dimension
- Gasket Material – Hardness
- Gasket Material – Surface Condition (Oily, Dry, Rough, Smooth, etc.)
- Gasket Groove Design and Deformation
- Gasket Groove (Heat Transfer Plate) Surface
- Gasket Gluing

Leaks During Operation

- Plate Pack Loosened
- Shifting Plate Pack or Floating Nozzles
- Extreme Over-Pressurization or Water Hammer
- Gasket Decomposition

MANDATORY APPENDIX XX
PLATE HEAT EXCHANGERS

XX-1 SCOPE

Types of PHE's and constructions covered by this Appendix.

XX-2 MATERIALS AND METHODS OF FABRICATION

(Heat transfer plate materials and forming. Mechanical assembly.)

XX-3 TERMINOLOGY

(Terms: Definitions)

XX-4 CONDITIONS OF APPLICABILITY

(Overall Configuration and uses.)

XX-5 NOMENCLATURE

(Calculation nomenclature)

XX-6 DESIGN CONSIDERATIONS

(Frame and Bolt design methodology. Plate pack design methodology.)

XX-7 CALCULATION PROCEDURE

(Frame and Bolt calculation strategy. Plate Pack Proof test factors.)

XX-8 PRESSURE TEST REQUIREMENTS

(Incorporate Code Case Testing Requirements)

XX-9 DATA REPORTS

(Listed fields to complete.)

XX-10 EXAMPLE

(Application of design rules.)

TG Meeting Minutes - Plate Heat Exchangers in Section VIII-1&2

Time: May 15, 2012 – 3:00pm to 5:00pm
Location: Gaylord Opryland, Nashville, TN

1. **Call to Order – 3:00pm**
   a. **Announcements –** Members Bob Lerch, Djordje Smic, Dave Morris, and Bob Flynn were unable to attend.
   b. **Attendance**

Name	Company	M/V
Mike Pischke	Alfa Laval Inc.	M TG Chair
Pete Matkovics	SPX(APV)	M
Robert Zerbe	GEA	M
John Grubb	ATI Alleghany Ludlum	M
Ramsey Mahadeen	Atlas Ind Mfg	M Ex-Officio
Clyde Neely	Becht Engineering	M
Cesar Romero	Trantor	M
Sandy Babka	HSB Global	M
Brian Deeb	Trantor	V
Ed Soltow	SGL Carbon	V
Pam Gum	Nooter/Eriksen	V
Jason Coon	Nooter/Eriksen	V
Charles Keuler	Paul Mueller Co.	V

2. **Acceptance of Agenda – Unanimously Accepted**

3. **Approval of the Minutes from February , 2012 – Unanimously Approved**

4. **New Business**
   No new business

5. **Old Business**
   a. **Proposed Code Case (Item 11-1636)**

   The TG discussed the negatives and comments received from the BPV VIII Committee on the proposed Code Case. Suggestion were made to add verbiage to control the plate compression dimension and allow for AI review of design methodology. It was agreed to initiate discussion at BPV VIII first, then based upon the Committee's feedback, add or change the Code Case verbiage to address the Committee's feedback.

6. Scope of Work

- General Strategy – *Mike P. to report.*
  - The strategy will be to develop a mandatory Appendix based on the format used in Appendix 41. A copy of this template will be attached to the item record in C&S Connect.
  - Applicable elements of the initial Code Case will be incorporated into this Appendix.
  - Members were identified who will begin drafting the individual sections of the Appendix. (See attached Appendix.)
- Definitions - *Pete M. to report.*
  - **Action:** Pete Matkovics will distribute the latest revision in MSWord to the TG for review.
- Design Aspects – *Mike P. to report*
  - **Action:** This will be developed, collectively, by the TG.
    - Leak before catastrophic failure of Gasketed PHE's – Leak Pressure?
    - Code versus Non-Code Components.
    - Specific rules for the different types: Gasketed, Semi-welded, Welded, Brazed, and Diffusion Bonded.
    - Number of heat transfer plates specified on the MDR.
    - Use of UG-11
- Materials – *John G. to report.*
  The template for submitting Code Cases for non-ASME materials has been identified. See attached.
- Welding - *Not covered*
  - Some topics that will need to be discussed are the welds within the Code boundary: Nozzle Welds, LBW Cassettes, liners, hangers, etc.
- Incorporation of Interpretations and Code Cases – *Mike P. to report.*
  - **Action:** No new actions.
- Recommendations to the National Board for Post Construction – *Mike P. to report:* ***no new changes.***
  - **Action:** Mike Pischke contacted the National Board regarding developing Post Construction rules. The NB has opened an item. A proposal will be submitted to the TG.

7. **Adjournment –** Next Meeting will be held on August 14, 2012 at the Hyatt Capital Hill in Washington, DC

Membership Roster

Name	Interest	Company	Phone Number	e-mail
Mike Pischke	AK	Alfa Laval Inc.	804-236-1249	mike.pischke@alfalaval.com
Sandy Babka	AH	HSB -CT	860-722-5197	Sandy_Babka@HSBCT.com
Pete Matkovics	AK	SPX(APV)	919-581-1105	pete.matkovics@spx.com
Robert Zerbe	AK	GEA	717-268-6301	robert.zerbe@geagroup.com
John Grubb	AM	ATI Alleghany Ludlum	724-226-6230	John.Grubb@ ATImetals.com
Bob Lerch	AW	Colorado Springs Utilities	719-668-8941	blerch@csu.org
Dave Morris	AK	Heatric Corporation	+44(0) 1202 627 000	morrisd@asme.org
Bob Flynn	AK	Taco Corporation	508-675-7300	rhflynn@taco-hvac.com
Clyde Neely	AF	Becht Engineering Co.	304-722-1294	cneely@becht.com
Djordje Srnic	AT	ABSA	780-433-0281 x3333	srnic@absa.ca
Ramsey Mahadeen	Ex-Officio	Atlas Ind Mfg	973-779-3970	ramsey@atlasindustrial.com

Code Case XXXX
Determination of the MAWP for the Heat Transfer Plates in
Plate Heat Exchangers containing Gasketed Plate Packs
Section VIII, Divisions 1 &2

Inquiry: For plate heat exchangers that contain gaskets between each heat transfer plate or between each welded pair of heat transfer plates (gasketed plate packs), may the MAWP of the heat transfer plates be determined by performing a hydrostatic test on the plate heat exchanger assembly in accordance with UG-99 using a test pressure of at least 1.3 times the design pressure and a stress ratio of 1.0?

Reply: It is the opinion of the Committee that, for plate heat exchangers that contain gasketed plate packs, the MAWP of the heat transfer plates may be determined by performing a hydrostatic test on the plate heat exchanger assembly in accordance with UG-99 using a test pressure of at least 1.3 times the design pressure and a stress ratio of 1.0, provided that the following requirements are met:

- *a)* Water at ambient temperature shall be used for the hydrostatic test.
- *b)* The application of this Code Case is limited to plate heat exchangers containing gasketed plate packs and shall not be applied to plate heat exchangers containing fully welded or brazed plate packs.
- *c)* The MAWP of the heat transfer plates within the gasketed plate pack is the design pressure used for the hydrostatic test.
- *d)* The MAWP and construction of the other pressure retaining components within the plate heat exchanger shall be in accordance with existing Code rules.
- *e)* The Manufacturer's model number, and the material, thickness and number of plates shall be shown on the Manufacturer's Data Report.
- *f)* The gasketed plate heat exchanger shall not be used in "Lethal Service".
- *g)* This Case number shall be shown on the Manufacturer's Data Report.

NB12-2101

Toledo
Refining Company

May 30, 2012

Shawn Tiedeken
Inspection Superintendent
Toledo Refining Company, LLC
1819 Woodville Road
Oregon, OH 43616

Secretary, NBIC Committee
The National Board of Boiler and Pressure Vessel Inspectors
1055 Crupper Avenue
Columbus, OH 43229
NBICinquiry@nationalboard.org

Re: Revision inquiry to 2011 National Board Inspection Code (NBIC), Part 3, Section 4, Subsection 4.2, Nondestructive Examination

Dear NBIC Committee Secretary,

National Board Inspection Code (NBIC), 2011 edition, Part 3, Section 4, Repairs and Alterations – Examination and Testing, Subsection 4.2 Nondestructive Examination, paragraph (b) states, " NDE personnel shall be qualified and certified in accordance with the requirements of the original code of construction. When this is not possible or practicable, NDE personnel may be qualified and certified in accordance with their employer's written practice. ASNT SNT-TC-1A, Recommended Practice Non-destructive Testing Personnel Qualification and Certification (~~2001~~ 2006 edition), or ASNT CP-189, Standard for Qualification and Certification of Nondestructive Testing Personnel (~~2001~~ 2006 edition), shall be used as a guideline for employers to establish their written practice."

It is recommended to revise the "2001 edition" requirements to state "2006 edition" requirements. (See Attachment 1)

This revision is being requested such that there will be consistency between the NBIC required editions of ASNT SNT TC-1A and those specified in the latest versions of ASME Section VIII, ASME Section V, B31.1 codes of construction. The following provides background requirements from the applicable codes of construction. The numbering of each code reference is consistent the attached references.

1. Within the 2010 with 2011 Addenda, ASME Boiler and Pressure Vessel Code, Section VIII, Rules for the Construction of Pressure Vessels, Table U-3, the 2006 edition is specified for both ASNT CP-189 and SNT-TC-1A.
2. In 2010 ed., ASME B31.1, Power Piping, Chapter VI, Inspection, Examination, and Testing, paragraph 136.3.2, NDE personnel are qualified and certified per a developed program consisting of training, on the job training, oral or written examination, vision acuity examination, and documented certification. As an alternative, Section V, ASME Boiler and Pressure Vessel Code, Section V, Article 1 can be used for the qualification of NDE personnel.

Toledo
Refining Company

3. 2010 with 2011 addenda, ASME Boiler and Pressure Vessel Code, Section V, Nondestructive Examination, Subsection A, Nondestructive Methods of Examination, Article 1, General Requirements, Paragraph T-120, General, sub paragraph (e) requires that NDE personnel are qualified and certified per their employer's written practice, which shall be in accordance with one of the following: (1), SNT-TC-1A (footnote 3) Personnel Qualification and Certification in Nondestructive Testing or (2) ANSI/ASNT CP-189 (footnote 3), ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel. Footnote 3 states that the 2006 edition is required for both SNT-TC-1A and ANSI/ASNT CP-189.
4. ASME B31.3, Process Piping Code, Section 342, Examination Personnel, Paragraph 342.1, it states that NDE personnel or "examiners" shall have training and experience commensurate with the needs of the examination type or method. The footnote reference specifies that SNT-TC-1A may be used as a guide to develop the training and respective experience requirements in performing the examination type or method. No year is specified.

In all the referenced code paragraphs, it is clear that the latest versions of the codes applicable to NBIC specify the 2006 edition of SNT-TC-1A and ANSI/ASNTCP-189.

Should there be any question, please do not hesitate to contact the undersigned at (419) 698-7445.

Sincerely,

Shawn J Tiedeken

Shawn J. Tiedeken
Inspection Superintendent
Toledo Refining Company, LLC

Attachment 1

PART 3, SECTION 4
REPAIRS AND ALTERATIONS — EXAMINATION AND TESTING

4.1 SCOPE

This section provides requirements and guidelines for performing examinations and tests for repairs and alterations to pressure-retaining items.

4.2 NONDESTRUCTIVE EXAMINATION

a) The nondestructive examination (NDE) requirements, including technique, extent of coverage, procedures, personnel qualification, and acceptance criteria, shall be in accordance with the original code of construction for the pressure-retaining item. Weld repairs and alterations shall be subjected to the same nondestructive examination requirements as the original welds. Where this is not possible or practicable, alternative NDE methods acceptable to the Inspector and the Jurisdiction where the pressure-retaining item is installed, where required, may be used.

2006 2006

b) NDE personnel shall be qualified and certified in accordance with the requirements of the original code of construction. When this is not possible or practicable, NDE personnel may be qualified and certified in accordance with their employer's written practice. ASNT SNT-TC-1A, *Recommended Practice Nondestructive Testing Personnel Qualification and Certification* (2001 edition), or ASNT CP-189, *Standard for Qualification and Certification of Nondestructive Testing Personnel* (2001 edition), shall be used as a guideline for employers to establish their written practice. The ASNT Central Certification Program (ACCP, Rev. 3, Nov. 1997) may be used to fulfill the examination and demonstration requirements of the employer's written practice. Provisions for training, experience, qualification, and certification of NDE personnel shall be described in the "R" Certificate Holder's written quality system.

4.3 PRESSURE GAGES, MEASUREMENT, EXAMINATION, AND TEST EQUIPMENT

The calibration of pressure gages, measurement, examination, and test equipment, and documentation of calibration shall be performed, as required, by the applicable standard used for construction.

4.4 EXAMINATION AND TEST FOR REPAIRS AND ALTERATIONS

The following requirements shall apply to all repairs and alterations to pressure-retaining items:

a) The integrity of repairs, alterations, and replacement parts used in repairs and alterations shall be verified by examination or test;

b) Testing methods used shall be suitable for providing meaningful results to verify the integrity of the repair or alteration. Any insulation, coatings, or coverings that may inhibit or compromise a meaningful test method shall be removed, to the extent identified by the Inspector;

c) The "R" Certificate Holder is responsible for all activities relating to examination and test of repairs and alterations;

d) Examinations and tests to be used shall be subject to acceptance of the Inspector and, where required, acceptance of the Jurisdiction.

Reference 1

(10)
(a)

TABLE U-3
YEAR OF ACCEPTABLE EDITION OF REFERENCED STANDARDS IN THIS DIVISION

Title	Number	Year
Seat Tightness of Pressure Relief Valves	API Std. 527	1991 (R2007)(1)
Unified Inch Screw Threads (UN and UNR Thread Form)	ASME B1.1	Latest edition
Pipe Threads, General Purpose (Inch)	ANSI/ASME B1.20.1	Latest edition
Cast Iron Pipe Flanges and Flanged Fittings, Classes 25, 125, and 250	ASME B16.1	2005
Pipe Flanges and Flanged Fittings	ASME B16.5	2009(2)
Factory-Made Wrought Buttwelding Fittings	ASME B16.9	Latest edition
Forged Fittings, Socket-Welding and Threaded	ASME B16.11	Latest edition
Cast Bronze Threaded Fittings, Classes 125 and 250	ASME B16.15	Latest edition
Metallic Gaskets for Pipe Flanges — Ring-Joint, Spiral-Wound, and Jacketed	ASME B16.20	Latest edition
Cast Copper Alloy Pipe Flanges and Flanged Fittings, Class 150, 300, 400, 600, 900, 1500, and 2500	ASME B16.24	2006
Ductile Iron Pipe Flanges and Flanged Fittings, Class 150 and 300	ASME B16.42	1998 (R2006)
Large Diameter Steel Flanges, NPS 26 Through NPS 60	ASME B16.47	2006
Square and Hex Nuts (Inch Series)	ASME B18.2.2	Latest edition
Welded and Seamless Wrought Steel Pipe	ASME B36.10M	Latest edition
Guidelines for Pressure Boundary Bolted Flange Joint Assembly	ASME PCC-1	2010
Repair of Pressure Equipment and Piping	ASME PCC-2	2008
Pressure Relief Devices	ASME PTC 25	2008
Qualifications for Authorized Inspection	ASME QAI-1	Latest edition (3)
ASNT Central Certification Program	ACCP	Rev 7
ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel	ANSI/ASNT CP-189	2006
Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing	SNT TC 1A	2006
Standard Test Methods for Flash Point by Tag Closed Tester	ASTM D 56	Latest edition
Standard Test Methods for Flash Point by Pensky-Martens Closed Tester	ASTM D 93	Latest edition
Standard Guide for Preparation of Metallographic Specimens	ASTM E 3	2001 (R2007)
Pressure Relieving and Depressuring Systems	ANSI/API Std. 521	5th Ed., January 2007
Reference Photographs for Magnetic Particle Indications on Ferrous Castings	ASTM E 125	1963 (R2008)(1)
Hardness Conversion Tables for Metals	ASTM E 140	Latest edition
Standard Reference Radiographs for Heavy-Walled [2 to 4½-in. (51 to 114-mm)] Steel Castings	ASTM E 186	1998 (R2004)
Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels	ASTM E 208	2006
Standard Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings	ASTM E 280	2010
Standard Reference Radiographs for Steel Castings up to 2 in. (51 mm) in Thickness	ASTM E 446	2010
Marking and Labeling Systems	ANSI/UL-969	1995

Reference 2

Chapter VI
Inspection, Examination, and Testing

136 INSPECTION AND EXAMINATION

136.1 Inspection

136.1.1 General. This Code distinguishes between "examination" and "inspection." Inspection is the responsibility of the Owner and may be performed by employees of the Owner or a party authorized by the Owner, except for the inspections required by para. 136.2. Prior to initial operation, a piping installation shall be inspected to ensure compliance with the engineering design and with the material, fabrication, assembly, examination, and test requirements of this Code.

136.1.2 Verification of Compliance. Compliance with the requirements of this Code shall be verified by an Authorized Inspector when a Code stamp is required by Section I of the ASME Boiler and Pressure Vessel Code. The rules of this Code and the quality control system requirements of Appendix A-300 of Section I of the ASME Boiler and Pressure Vessel Code shall apply. The quality control system requirements are shown in Appendix J of this Code. The duty of the Inspector shall be as defined in PG-90, Section I, of the ASME Boiler and Pressure Vessel Code. Data Report Forms are included in the Appendix of ASME Section I for use in developing the necessary inspection records. The Inspector shall assure himself/herself that the piping has been constructed in accordance with the applicable requirements of this Code.

136.1.3 Rights of Inspectors. Inspectors shall have access to any place where work concerned with the piping is being performed. This includes manufacture, fabrication, heat treatment, assembly, erection, examination, and testing of the piping. They shall have the right to audit any examination, to inspect the piping using any appropriate examination method required by the engineering design or this Code, and to review all certifications and records necessary to satisfy the Owner's responsibility as stated in para. 136.1.1.

136.1.4 Qualifications of the Owner's Inspector

(A) The Owner's Inspector shall be designated by the Owner and shall be an employee of the Owner, an employee of an engineering or scientific organization, or of a recognized insurance or inspection company acting as the Owner's agent. The Owner's Inspector shall not represent nor be an employee of the piping manufacturer, fabricator, or erector unless the Owner is also the manufacturer, fabricator, or erector.

(B) The Owner's Inspector shall have not less than 10 years of experience in the design, manufacture, erection, fabrication, or inspection of power piping. Each year of satisfactorily completed work toward an engineering degree recognized by the Accreditation Board for Engineering and Technology shall be considered equivalent to 1 year of experience, up to 5 years total.

(C) In delegating the performance of inspections, the Owner is responsible for determining that a person to whom an inspection function is delegated is qualified to perform that function.

136.2 Inspection and Qualification of Authorized Inspector for Boiler External Piping

136.2.1 Piping for which inspection and stamping is required as determined in accordance with para. 100.1.2(A) shall be inspected during construction and after completion and at the option of the Authorized Inspector at such stages of the work as he/she may designate. For specific requirements see the applicable parts of Section I of the ASME Boiler and Pressure Vessel Code, PG-104 through PG-113. Each manufacturer, fabricator, or assembler is required to arrange for the services of Authorized Inspectors.

136.2.1.1 The inspections required by this Section shall be performed by an Inspector employed by an ASME accredited Authorized Inspection Agency.

136.2.2 Certification by stamping and Data Reports, where required, shall be as per PG-104, PG-105, PG-109, PG-110, PG-111, and PG-112 of Section I of the ASME Boiler and Pressure Vessel Code.

136.3 Examination

136.3.1 General. Examination denotes the functions performed by the manufacturer, fabricator, erector, or a party authorized by the Owner that include nondestructive examinations (NDE), such as visual, radiography, ultrasonic, eddy current, liquid penetrant, and magnetic particle methods. The degree of examination and the acceptance standards beyond the requirements of this Code shall be a matter of prior agreement between the manufacturer, fabricator, or erector and the Owner.

136.3.2 Qualification of NDE Personnel. Personnel who perform nondestructive examination of welds shall be qualified and certified for each examination method in accordance with a program established by the

Reference 2

employer of the personnel being certified, which shall be based on the following minimum requirements:

(A) instruction in the fundamentals of the nondestructive examination method.

(B) on-the-job training to familiarize the NDE personnel with the appearance and interpretation of indications of weld defects. The length of time for such training shall be sufficient to ensure adequate assimilation of the knowledge required.

(C) an eye examination performed at least once each year to determine optical capability of NDE personnel to perform the required examinations.

(D) upon completion of (A) and (B) above, the NDE personnel shall be given an oral or written examination and performance examination by the employer to determine if the NDE personnel are qualified to perform the required examinations and interpretation of results.

(E) certified NDE personnel whose work has not included performance of a specific examination method for a period of 1 yr or more shall be recertified by successfully completing the examination of (D) above and also passing the visual examination of (C) above. Substantial changes in procedures or equipment shall require recertification of the NDE personnel.

As an alternative to the preceding program, the requirements of the ASME Boiler and Pressure Vessel Code, Section V, Article 1 may be used for the qualification of NDE personnel. Personnel qualified to AWS QC1 may be used for the visual examination of welds.

136.4 Examination Methods of Welds

136.4.1 Nondestructive Examination. Nondestructive examinations shall be performed in accordance with the requirements of this Chapter. The types and extent of mandatory examinations for pressure welds and welds to pressure retaining components are specified in Table 136.4. For welds other than those covered by Table 136.4, only visual examination is required. Welds requiring nondestructive examination shall comply with the applicable acceptance standards for indications as specified in paras. 136.4.2 through 136.4.6. As a guide, the detection capabilities for the examination method are shown in Table 136.4.1. Welds not requiring examination (i.e., RT, UT, MT, or PT) by this Code or the engineering design shall be judged acceptable if they meet the examination requirements of para. 136.4.2 and the pressure test requirements specified in para. 137. NDE for P-Nos. 3, 4, 5A, 5B, and 15E material welds shall be performed after postweld heat treatment unless directed otherwise by engineering design. Required NDE for welds in all other materials may be performed before or after postweld heat treatment.

136.4.2 Visual Examination. Visual examination as defined in para. 100.2 shall be performed in accordance with the methods described in Section V, Article 9, of the ASME Boiler and Pressure Vessel Code. Visual examinations may be conducted, as necessary, during the fabrication and erection of piping components to provide verification that the design and WPS requirements are being met. In addition, visual examination shall be performed to verify that all completed welds in pipe and piping components comply with the acceptance standards specified in (A) below or with the limitations on imperfections specified in the material specification under which the pipe or component was furnished.

(A) Acceptance Standards. The following indications are unacceptable:

(A.1) cracks — external surface.

(A.2) undercut on surface that is greater than $\frac{1}{32}$ in. (1.0 mm) deep.

(A.3) weld reinforcement greater than specified in Table 127.4.2.

(A.4) lack of fusion on surface.

(A.5) incomplete penetration (applies only when inside surface is readily accessible).

(A.6) any other linear indications greater than $\frac{3}{16}$ in. (5.0 mm) long.

(A.7) surface porosity with rounded indications having dimensions greater than $\frac{3}{16}$ in. (5.0 mm) or four or more rounded indications separated by $\frac{1}{16}$ in. (2.0 mm) or less edge to edge in any direction. Rounded indications are indications that are circular or elliptical with their length less than three times their width.

136.4.3 Magnetic Particle Examination. Whenever required by this Chapter (see Table 136.4), magnetic particle examination shall be performed in accordance with the methods of Article 7, Section V, of the ASME Boiler and Pressure Vessel Code.

(A) Evaluation of Indications

(A.1) Mechanical discontinuities at the surface will be indicated by the retention of the examination medium. All indications are not necessarily defects; however, certain metallurgical discontinuities and magnetic permeability variations may produce similar indications that are not relevant to the detection of unacceptable discontinuities.

(A.2) Any indication that is believed to be nonrelevant shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications that would mask indications of defects are unacceptable.

(A.3) Relevant indications are those that result from unacceptable mechanical discontinuities. Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications that are circular or elliptical with the length less than three times the width.

(A.4) An indication of a discontinuity may be larger than the discontinuity that causes it; however, the size of the indication and not the size of the discontinuity is the basis of acceptance or rejection.

NBIC Subcommittee R&A Action Block

Subject Alternative Repair Option for CSEF Steel, Grade 91

File Number NB12-0403 **Prop. on Pg.**

Proposal Develop code text to address use of temper bead weld repair for Grade 91 tube material

Explanation

EPRI has been working on temper bead weld repair initiatives for Grade 91 tubing since development of a new Ni-base filler metal. This project will provide test results on weld procedure qualification and elevated temperature testing of weld coupons.

Project Manager Galanes/EPRI

Task Group Negatives **TG Meeting Date**

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Temper Bead Repair of T91 Using EPRI P87 Filler Metal

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Abstract

Tube failures in grade 91 (9Cr-1Mo-V steel) occur in fossil-fired power plants and heat recovery steam generators. Due to the hardenability of grade 91, post-weld heat-treatment (PWHT) after welding is required. In this work, thin section Grade 91 was welded utilizing a nickel-based filler metal, EPRI P87, the gas tungsten arc welding (GTAW) process, and various temper bead techniques. The goal of this study was to establish whether it may be possible to forgo PWHT after welding of grade 91 and still provide satisfactory material performance in cases where shortening the repair duration is advantageous. For example if a sudden outage occurs and it is critical for a plant to get back online as quickly as possible, it may be difficult to organize all of the necessary requirements of the material (such as PWHT). Limited studies and industry experience have suggested that a temper bead repair may be possible. For this research, weldments were analyzed using hardness and metallography to screen the two different approaches to the temper bead technique, and to ultimately determine if there is promise in continuing to pursue such a radical repair technique for Grade 91.

Introduction

Temper bead procedures have been utilized since the 1960s. The advantages of these methods lies in the avoidance of a potentially complicated and costly post weld heat treatment (PWHT) and the potential increase in life over a comparable PWHT condition. Success of a temper bead technique lies in the application of a carefully controlled procedure with a compatible material. Through the 1980s and 1990s, EPRI and others demonstrated a wide range of temper bead techniques across a wide range of materials, including nuclear pressure vessel steels and low alloy power generations steels [1,2].

The use of newly developed creep strength enhanced ferritic (CSEF) steels has increased greatly over the last two decades. Such increase has displaced some of the use of low alloy Chromium-Molybdenum (CrMo) steels like Grades 11, 12 and 22. Because temper bead procedures have been successfully applied to these low alloy steels, inquiries have arisen regarding the applicability of a temper bead procedure to the more complicated CSEF family of materials - especially Grade 91. Because Grade 91 components have been employed since the early 1990s, there is sufficient interest in rapid nonconventional (radical) welding procedures for replacement and repair, even if such welding procedures were only regarded as temporary. Additionally, because Grade 91 requires PWHT regardless of thickness, it is often difficult to coordinate both the welding and the PWHT procedure in situations where access is difficult and/or in situations where an unplanned outage was the result of a Grade 91 material failure.

The set of experiments detailed in this paper focus on the development of two different welding techniques for tubing applications. The majority of unplanned outages can be attributed to tube failures. Furthermore, access to a failed tube can be extremely limited, preventing the use of a half-bead technique or buttering the ends of the tubing prior to welding the fill passes. Because of this, two temper bead procedures were selected that would ideally temper the HAZ through the thickness of the weldment. The automated gas tungsten arc welding (GTAW) process was selected for use; if successful, the documented techniques and parameters may be extrapolated to manual processes like GTAW or SMAW. The two temper bead approaches are described below [3,4]:

1. **Consistent Layer.** The consistent layer technique requires that each subsequent weld layer penetrate the underlying layer to develop overlapping temperature profiles while preventing additional transformation of the underlying HAZ. This procedure utilizes controlled heat energy dissipation to develop a tempered martensitic microstructure in the first few millimeters of the HAZ [3]. It can be applied with the SMAW or GTAW process and uses identical heat inputs and/or electrode diameters for each layer.
2. **Controlled Deposition.** In this temper bead process, the heat input is increased in each layer by 30-80%. Because this temper bead technique is normally implemented with the SMAW process, the increase in heat input is typically achieved by increased the electrode diameter one sequential size (i.e. 3/32” to 1/8” to 5/32”, 2.5mm to 3.2mm to 4.0mm). In each layer, the adjacent weld pass overlaps the previously deposited bead by 50%.

The filler metal selected for this demonstration was the nickel-base filler material EPRI P87; its development is detailed elsewhere [6]. Because this filler metal matches Grade 91 in Cr, C and carbide formers, the development of detrimental Type I carbides in service is severely retarded. Additionally, nickel-base filler metals have the added advantage of good toughness and low susceptibility to hydrogen-induced cracking during welding. EPRI P87 has several unique attributes over conventional nickel-base (i.e. ERNiFe-2 or ERNiCr-3) and ferritic filler materials (i.e. –B91 or –B23) that may increase the success of a temper bead procedure in repair and replacement scenarios for Grade 91:

1. Excellent thermal stability with respect to carbide formation, Figure 1;
2. Excellent stability with respect to hardness, Figure 2;
3. Excellent creep ductility, Figure 3;
4. Thermal expansion comparable to Grade 91, Figure 4.

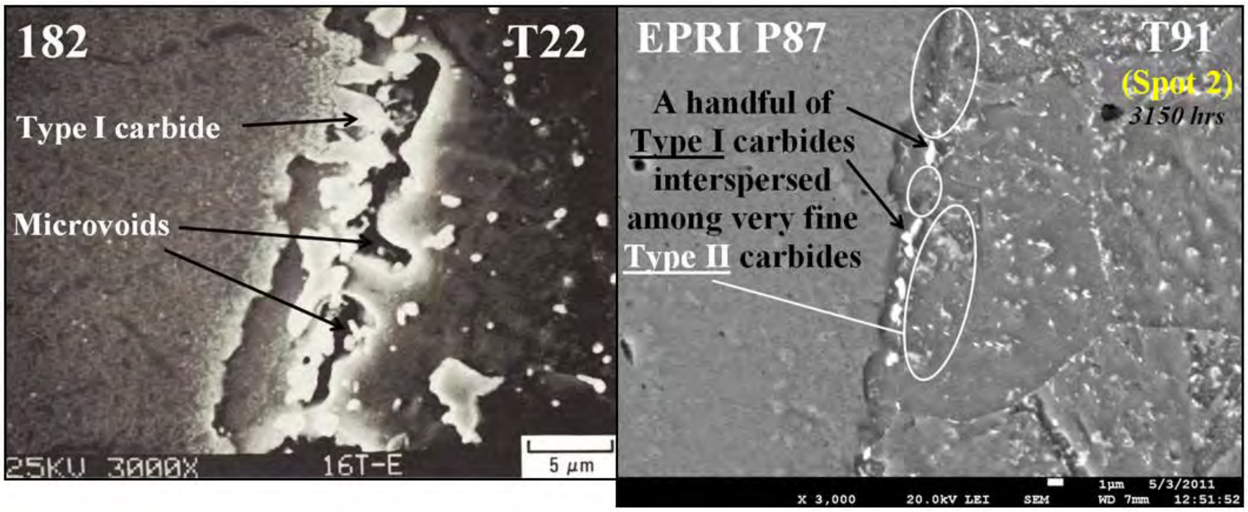

Figure 1
IN182 and EPRI P87 Thermal Stability Comparison
IN182 was exposed for 77,000hrs between 1100-1155F, LMP = 21560-22320 (as determined by oxide scale measurements) [5]. EPRI P87 was exposed for 3,150hrs at 1200F, LMP = 21665 [6].
Note: Figures were sized to match the micron bars for comparison.

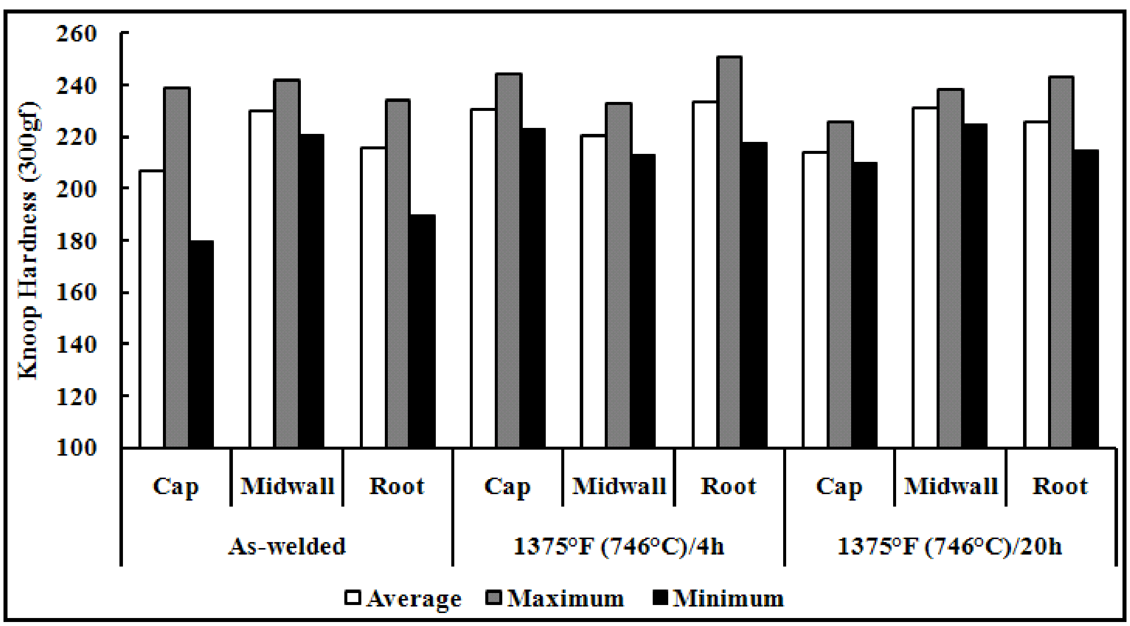

Figure 2
EPRI P87 Weld Metal Hardness Comparison [6]

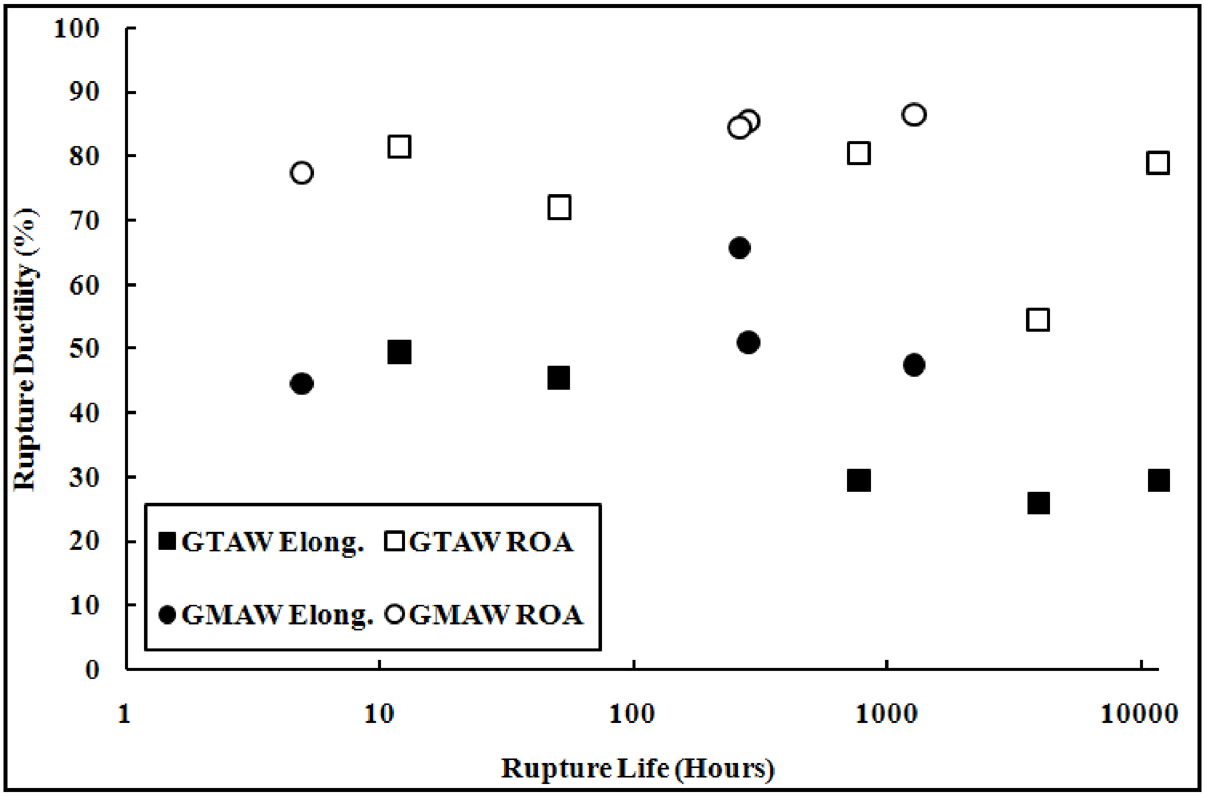

Figure 3
Creep Ductility, GTAW and GMAW All Weld Metal Creep Tests [6]

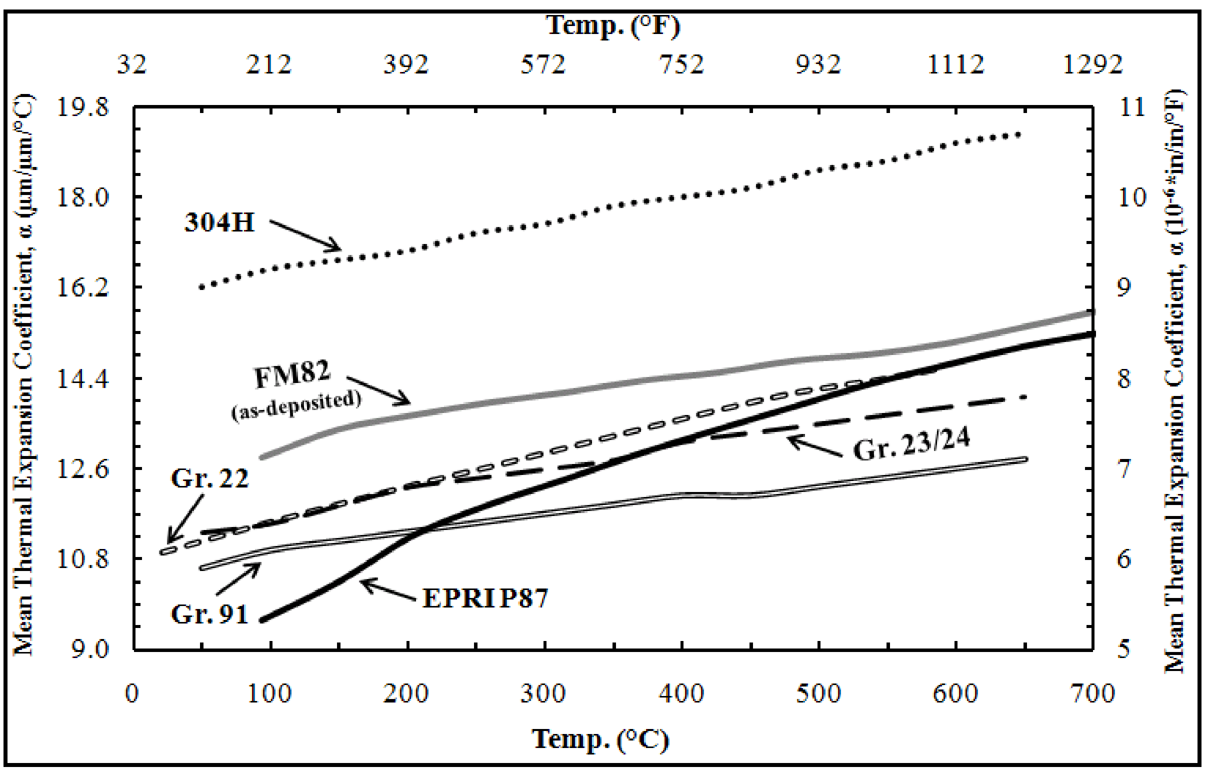

Figure 4
Mean Thermal Expansion Coefficient Comparison [6]

A low preheat (200°F, 93°C) and interpass (250°F, 121°C) was utilized to ensure complete transformation of the deposited weld metal prior to performing the next fill pass. If too high a preheat and interpass were utilized in welding Grade 91, incomplete transformation to martensite on cooling would ensure that fresh martensite would be present in the as-welded microstructure following the completion of the weld. The fresh martensite would not only increase hardness, but reduce toughness and potentially increase susceptibility to cracking phenomena like stress corrosion cracking. M_F temperatures for Grade 91 are given in Figure 5. The $M_{F,OSU}$ band represents a compilation of Grade 91 base material data at a range of cooling rates [7].

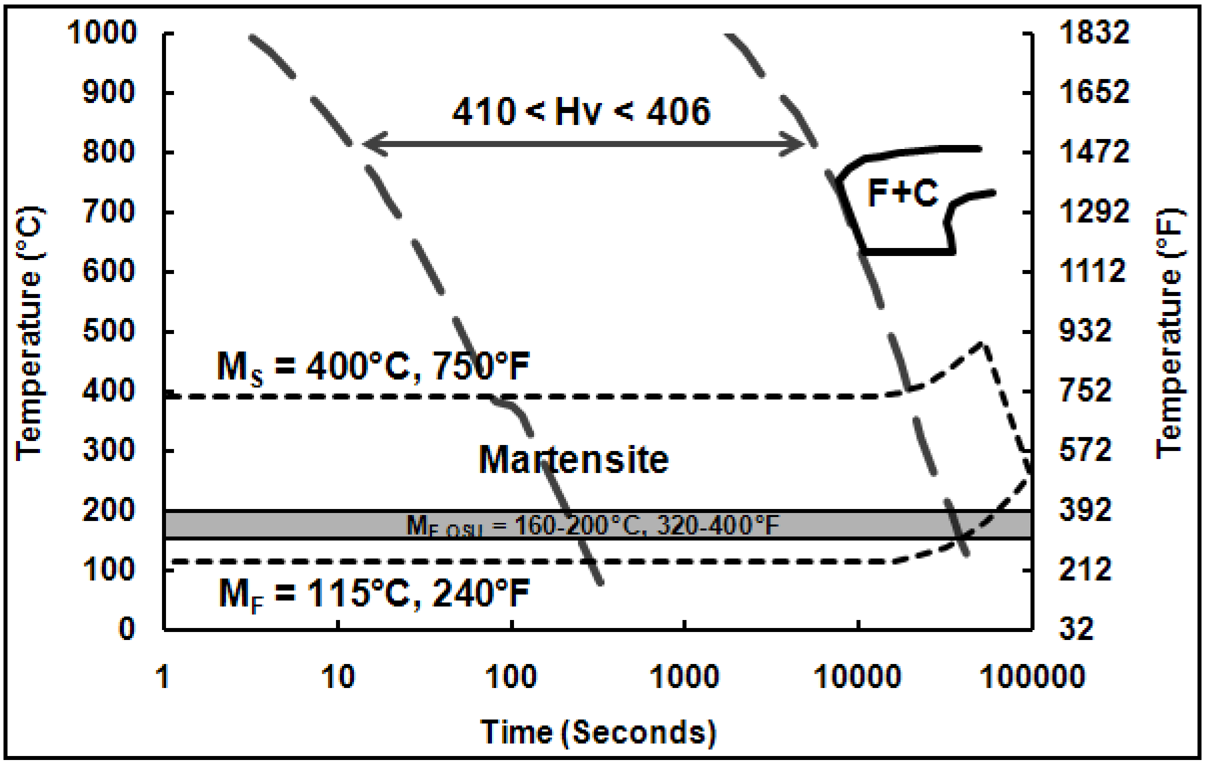

Figure 5
CCT Curve for Grade 91 Adapted from [7,8]

Because the two previously mentioned temper bead techniques were applied in this paper to *T91* material, it was critical to ensure as few weld passes and as simple a welding procedure as possible. Additionally, the development of a temper bead technique for tube to tube butt welds necessitates the consideration of the application. Tube to tube butt welds can be oriented in virtually any position and difficult to access; these two facts complicate the success of *any* welding procedure, let alone a temper bead technique. Because of this, it was decided that grinding (as in half-bead) and buttering of either side of the tube to tube butt weld (as typically done in thick-section temper bead procedures) prior to performing fill passes would be avoided. This paper details the welding development of the consistent layer and controlled deposition temper bead techniques on thin plate material representative of T91 material. Analysis was completed utilizing light microscopy and extensive hardness mapping for screening the success of the two procedures.

Experimental Procedure

Two weldments were made in Grade 91 plate using 0.035” diameter EPRI P87 filler metal. The chemical composition for the base material and filler metal are given in Table 1; these compositions are as reported from the material certifications. The semi-automated gas tungsten arc welding (GTAW) process was used to complete two weldments; one labeled “consistent layer” and the other “controlled deposition.” The shielding gas was 100% Argon. Each weldment was machined to identical dimensions, Figure 6. The mismatch in the groove geometry in Figure 6 was intentional for two purposes:

1. To determine the importance of the bevel on the through-thickness tempering behavior of the HAZ;
2. To determine more accurate impact results in future mechanical testing. The 0° bevel should, theoretically, force crack propagation through the HAZ and not into the weld metal or base material.

Table 1
Chemical Composition of Grade 91 Base Material and EPRI P87 Filler Metal

Element	Grade 91		EPRI P87	
	EPRI Spec. [9]	*Plate R1976*	*Spec. [6]*	*WO35419*
C	0.08-0.12	0.080	0.09-0.14	0.11
Mn	0.30-0.60	0.46	1.2-1.8	1.55
P	0.020 max	0.009	0.01	0.008
S	0.010 max	0.004	0.01	0.003
Cu	0.25 max	0.06		
Si	0.20-0.50	0.35	0.05-0.25	0.16
Ni	0.20 max	0.09	54 max	Bal.
Cr	8.00-9.50	8.59	8.5-9.5	8.52
Mo	0.85-1.05	0.89	1.8-2.2	2.02
V	0.18-0.25	0.207		
Ti	0.010 max	0.002		
Al	0.020 max	0.009		
Zr	0.010 max	0.001		
Cb	0.06-0.10	0.078	0.90-1.40	1.09
N	0.035-0.070	0.0476		
Others	As: 0.012 max Sn: 0.010 max Sb: 0.003 max	NS	Fe: 38-42	Fe: 38.8
N/Al Ratio	4.0 min.	5.3		
C+N	>0.12	0.1276		

The welding parameters for each weldment are given in Tables 2 and 3. A 200°F (93°C) preheat and 250°F (121°C) maximum interpass was instituted; actual starting temperature of the weldment prior to each subsequent pass is shown in Tables 2 and 3. The fundamental layout of each weldment is shown in Figures 8 and 10. During welding, the fill layers were staggered along the length of the weld by ~1” (25.4mm) to allow for individual characterization of each layer, Figure 7. A completed weldment is shown in Figure 7, detailing the sections of the weldment utilized for destructive testing and metallographic analysis.

Metallographic samples were taken from each fill pass as shown in Figures 9 and 11. Analysis included detailed light microscopy and hardness mapping. An automated hardness mapping system, utilizing a Vickers hardness indenter, 200g load with a spatial distance of 0.15mm was utilized in the creation of the hardness maps. Mapping was done on as-polished samples and every indent was visually verified for accuracy.

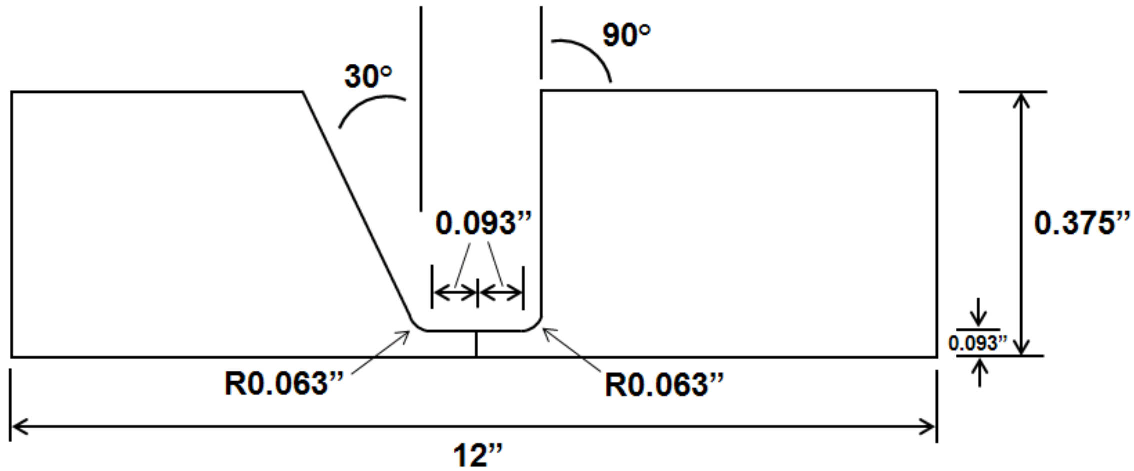

Figure 6
Weldment Dimensions

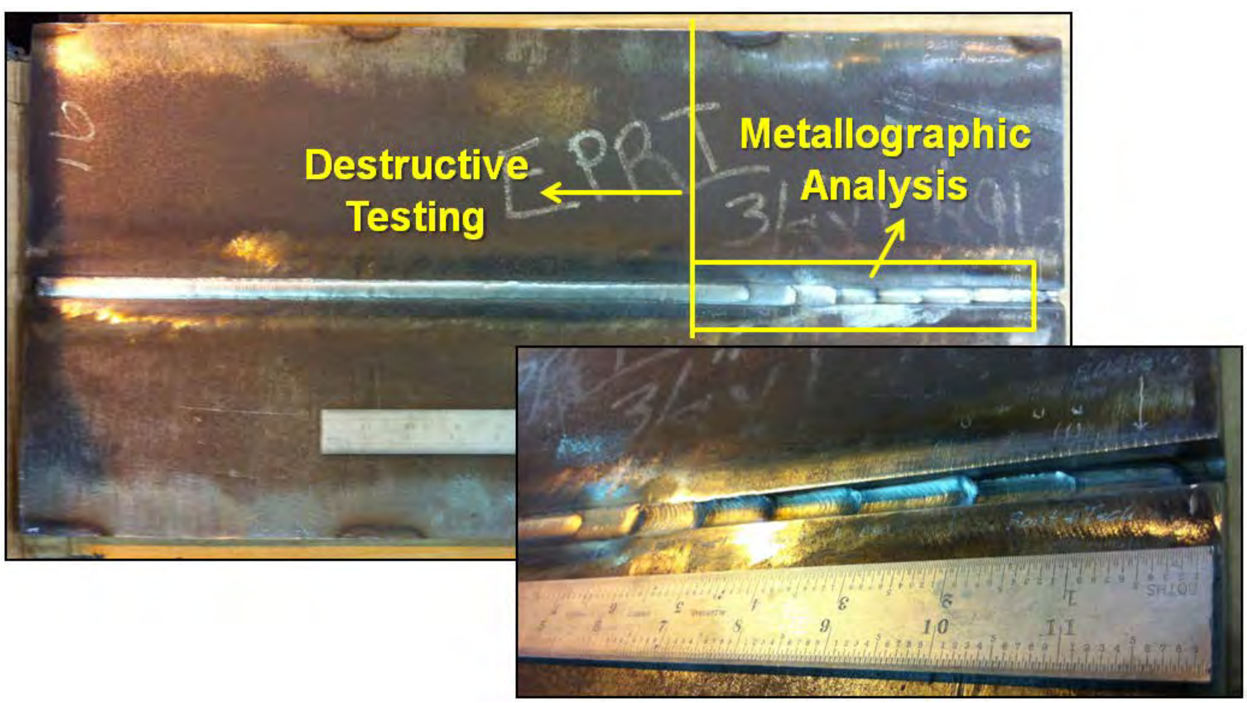

Figure 7
Example of Welded Plate and Sectioning

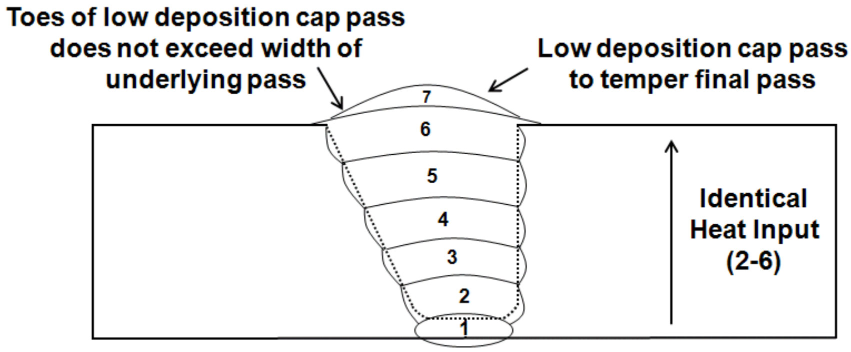

Figure 8
Consistent Layer Weldment Fill Layout

Table 2
Consistent Layer Weldment Parameters

	Current (A)	Voltage (V)	TS[1] (ipm, mm/s)	HI[2] (kJ/in, % inc.)	Start Temp.[4] (°F, °C)
Root	175			28.5, +0%	216, 102
Fill 1					220, 202
Fill 2					216, 198
Fill 3	190	9.5	3.5, 88.9	30.9, +8.4%	218, 200
Fill 4					207, 189
Fill 5					202, 184
Low Dep. Wash Pass	140			22.8, -26.2%	232, 214

[1]TS = Travel Speed

[2]HI = Heat Input; HI (kJ/in) = Voltage*Amperage*60/TS

[3]% inc. = Percentage increase in heat input over previous weld pass

[4]Start Temp. = Starting temperature of weldment prior to deposition of indicated weld pass

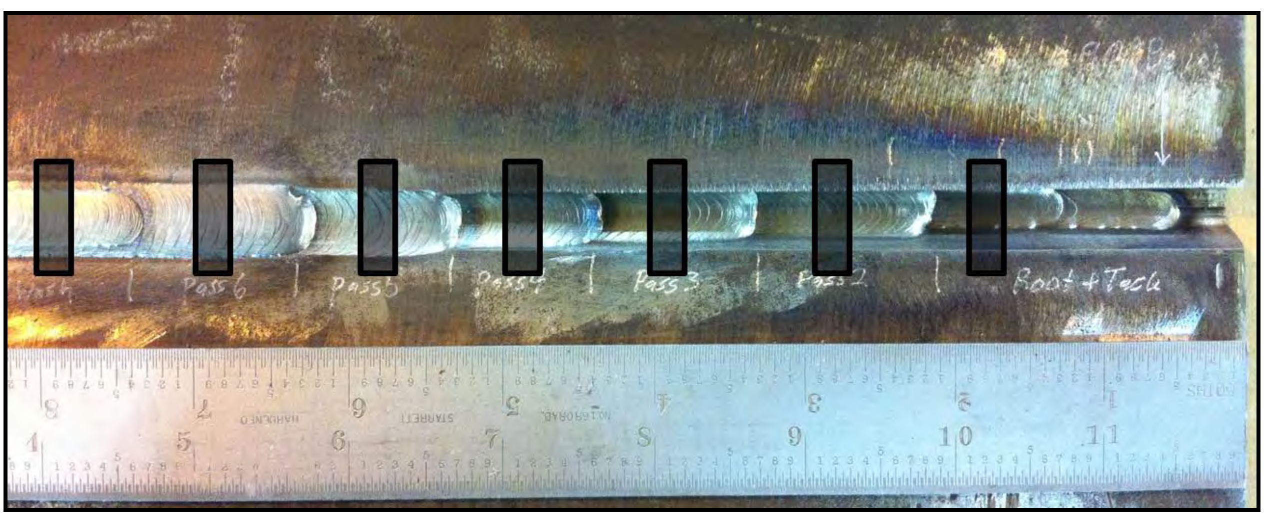

Figure 9
Consistent Layer Metallographic Sample Locations

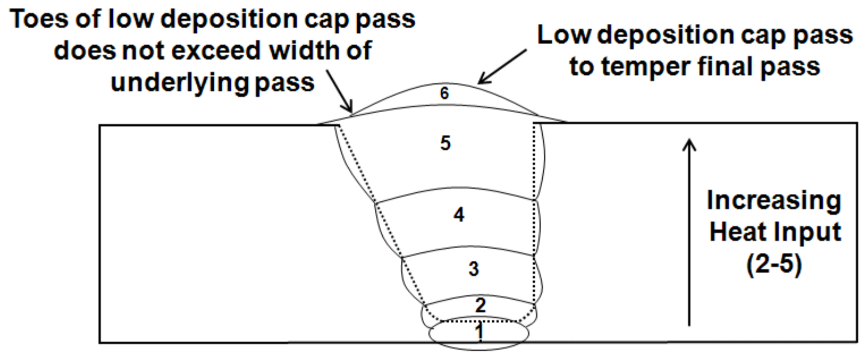

Figure 10
Controlled Deposition Weldment Fill Layout

Table 3
Controlled Deposition Weldment Parameters

Weld Pass	Current (A)	Voltage (V)	TS[1] (ipm, mm/s)	HI[2] (kJ/in, % inc.[3])	Start Temp.[4] (°F, °C)
Root	170	9.5	3.5, 88.9	27.7, +0%	220, 104
Fill 1	190			30.9, +11.5%	213, 195
Fill 2	200			32.6, +5.5%	214, 196
Fill 3	210			34.2, +4.9%	206, 188
Fill 4	220			35.8, +4.7%	219, 201
Low Dep. Wash Pass	140			22.8, -36.3%	229, 211

[1]TS = Travel Speed

[2]HI = Heat Input; HI = V*I*60/TS

[3]% inc. = Percentage increase in heat input over previous weld pass

[4]Start Temp. = Starting temperature of weldment prior to deposition of indicated weld pass

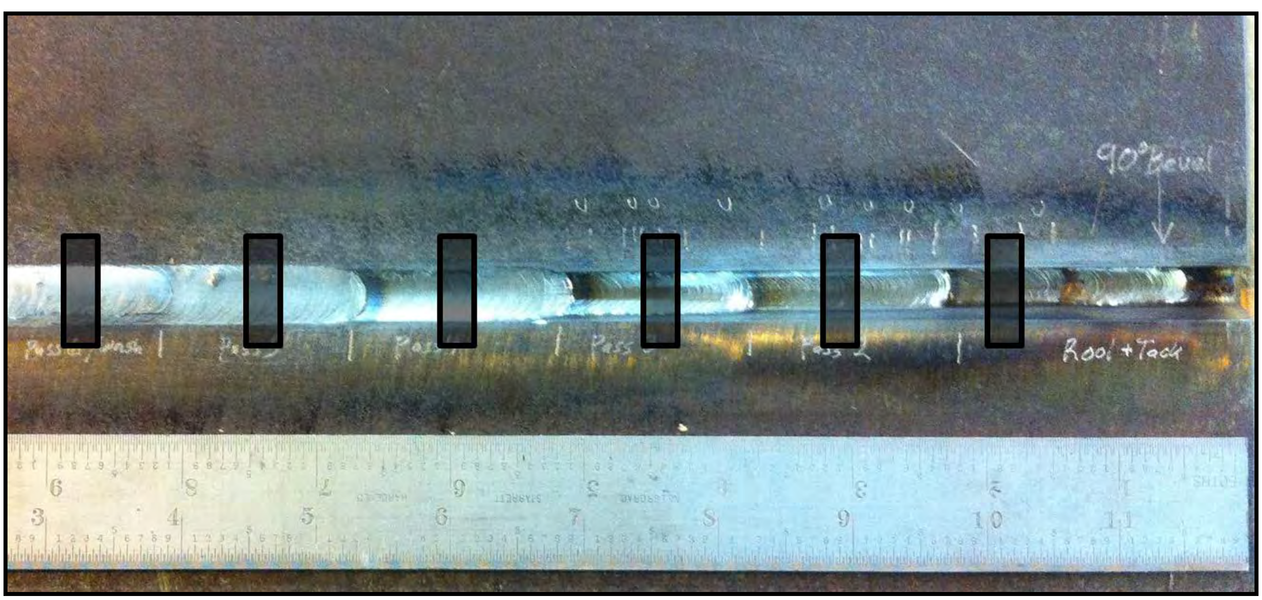

Figure 11
Controlled Deposition Metallographic Sample Locations

Results

Macro images for each weld pass in the consistent layer and controlled deposition weldments are shown in Figures 12 and 13, respectively. For each weldment, the width of the HAZ is similar with no major improvement in size or width in the 0° bevel side of the weldment. For the controlled layer technique, the wash pass provided necessary reinforcement to complete the weldment. In the case of the consistent layer technique, the wash pass was not needed to provide sufficient reinforcement. In either case, the wash pass could be ground away in the field should it be deemed excessive.

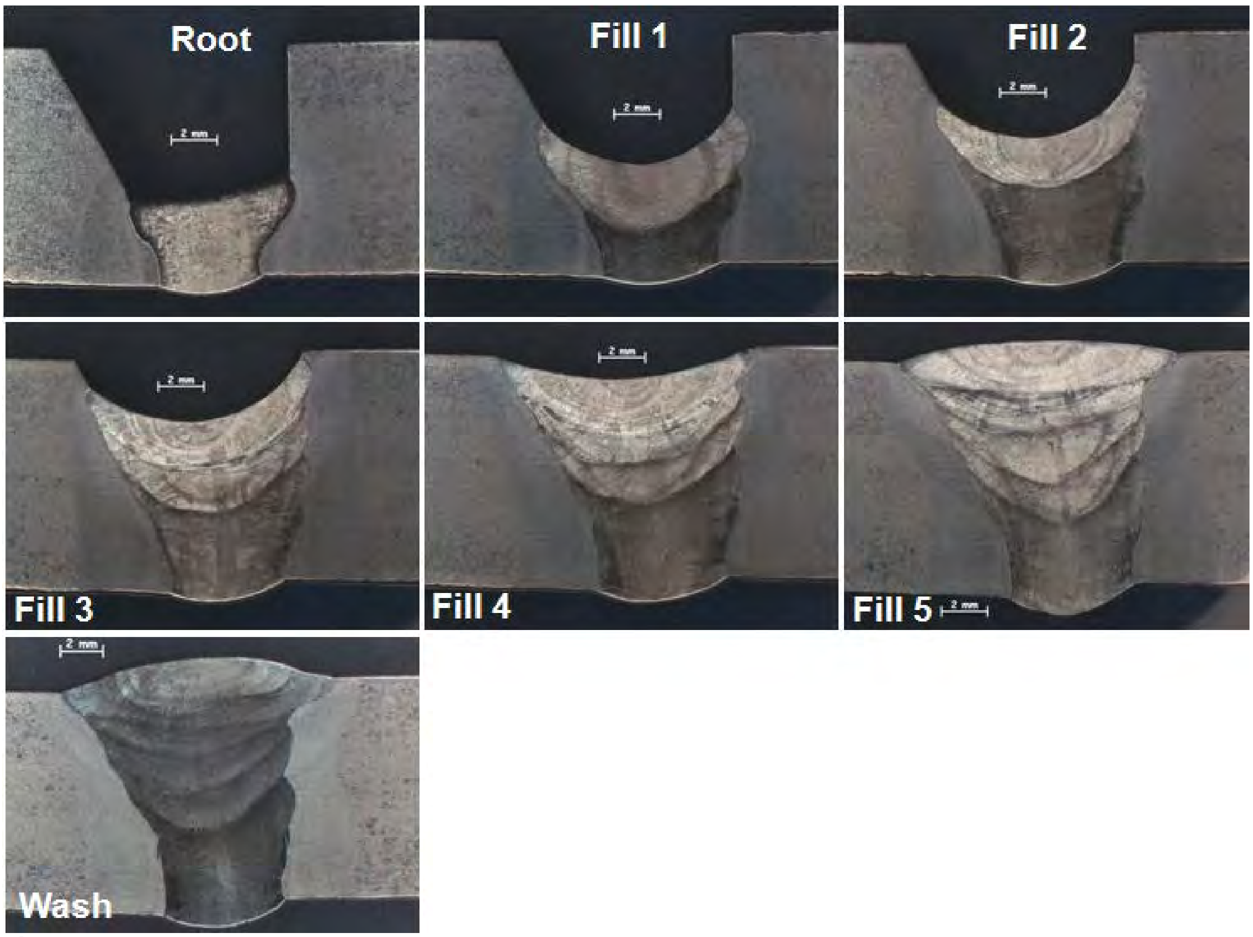

Figure 12
Consistent Layer Weld Passes

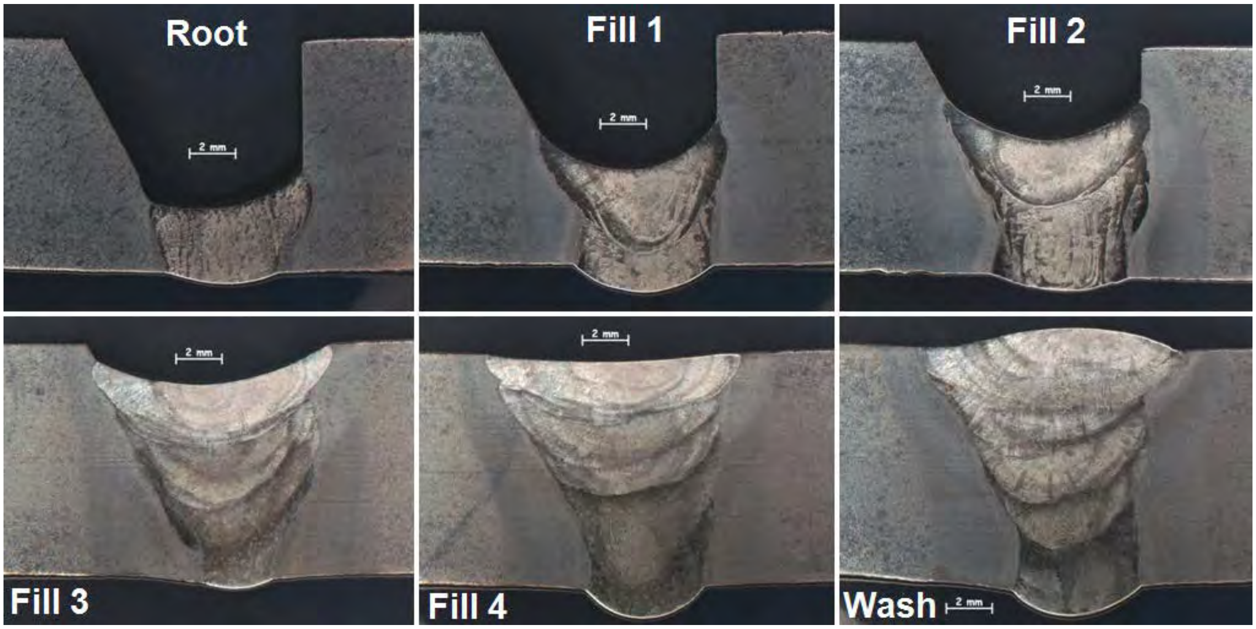

Figure 13
Controlled Deposition Weld Layers

The hardness data for each of the weldments was post-processed and plotted using a contour map. In Figures 14 and 15, each color represents a range of 50HV and the scales are identical for both maps:

- 150-200HV 0.2 ➔ Blue
- 200-250HV 0.2 ➔ Light Blue
- 250-300HV 0.2 ➔ Green
- 300-350HV 0.2 ➔ Yellow
- 350-400HV 0.2 ➔ Orange + Hashes
- 400-450HV 0.2 ➔ Red + Cross Hashes
- > 450HV 0.2 ➔ Black

To compare the overall tempering of the weldments more methodically, all of the data points in each hardness map below 225HV 0.2 were deleted for statistical analysis. This was done to eliminate all of the base metal hardness data and most (if not all) of the weld metal data. Using this comparison, the effectiveness of tempering in the HAZ was compared. The deletion of these data resulted in a sample size of 1102 indents for the consistent layer weldment and 1267 indents for the controlled deposition weldment. The histograms for each of these data sets are shown in Figure 16. The percentage of indents above a stated hardness value is shown in Table 4.

The hardness data for the consistent layer technique was plotted onto a macro image of the tested area, Figure 17. The hardness data plotted in Figure 17 was limited to the highest measured data points, those above 325HV.

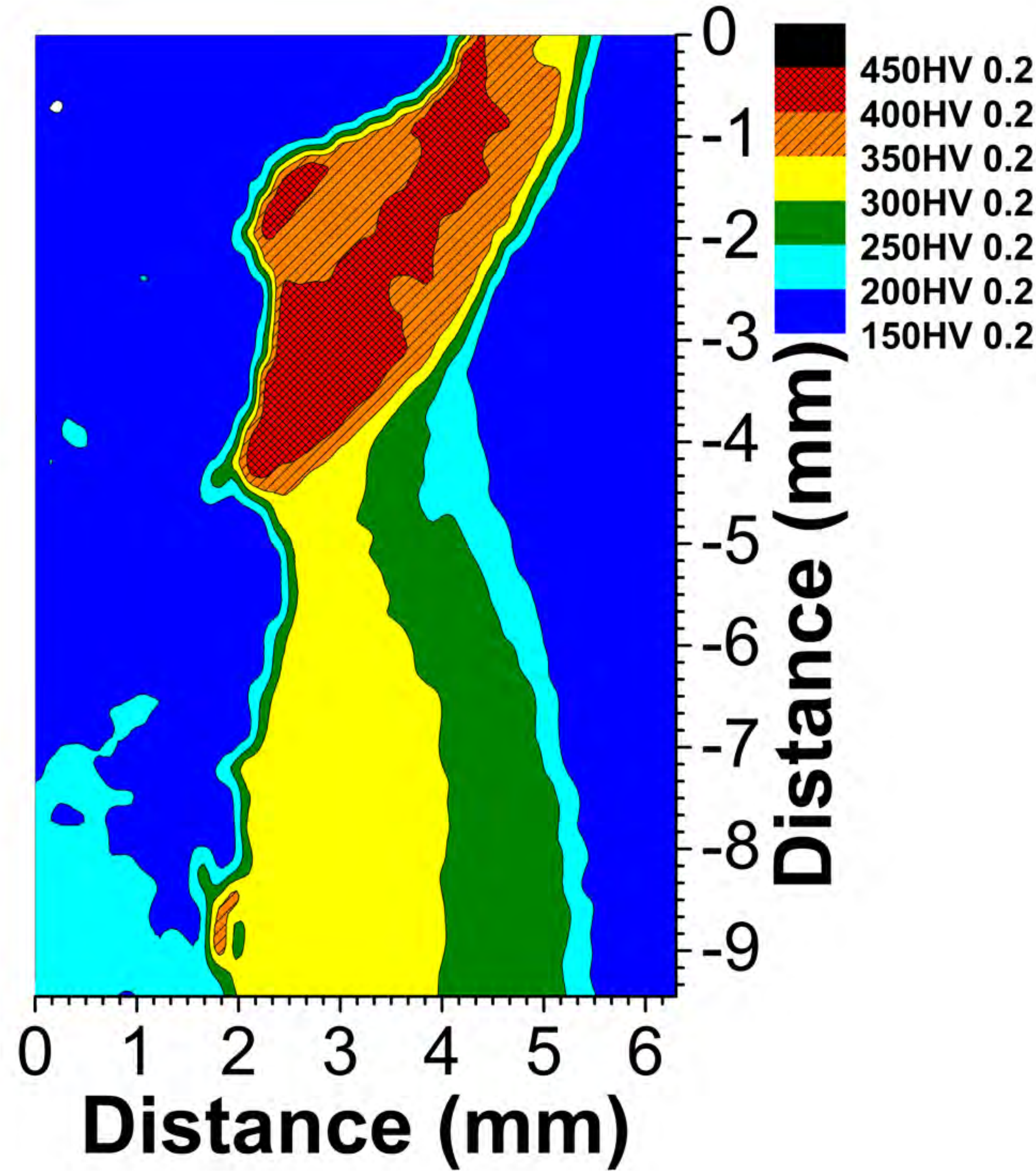

Figure 14
Consistent Layer Technique Hardness Map, 0° Bevel

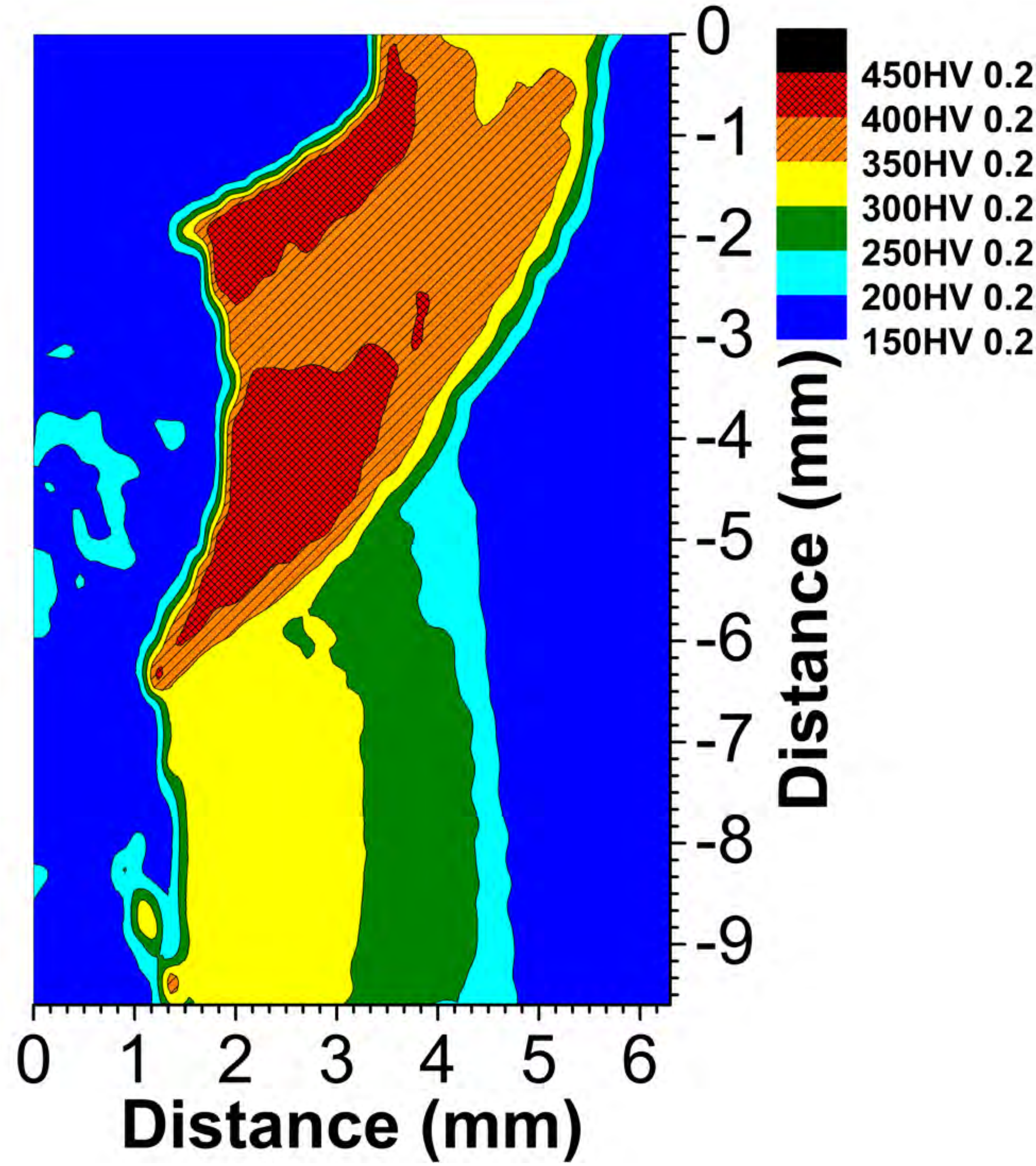

Figure 15
Controlled Deposition Technique, 0° Bevel

91

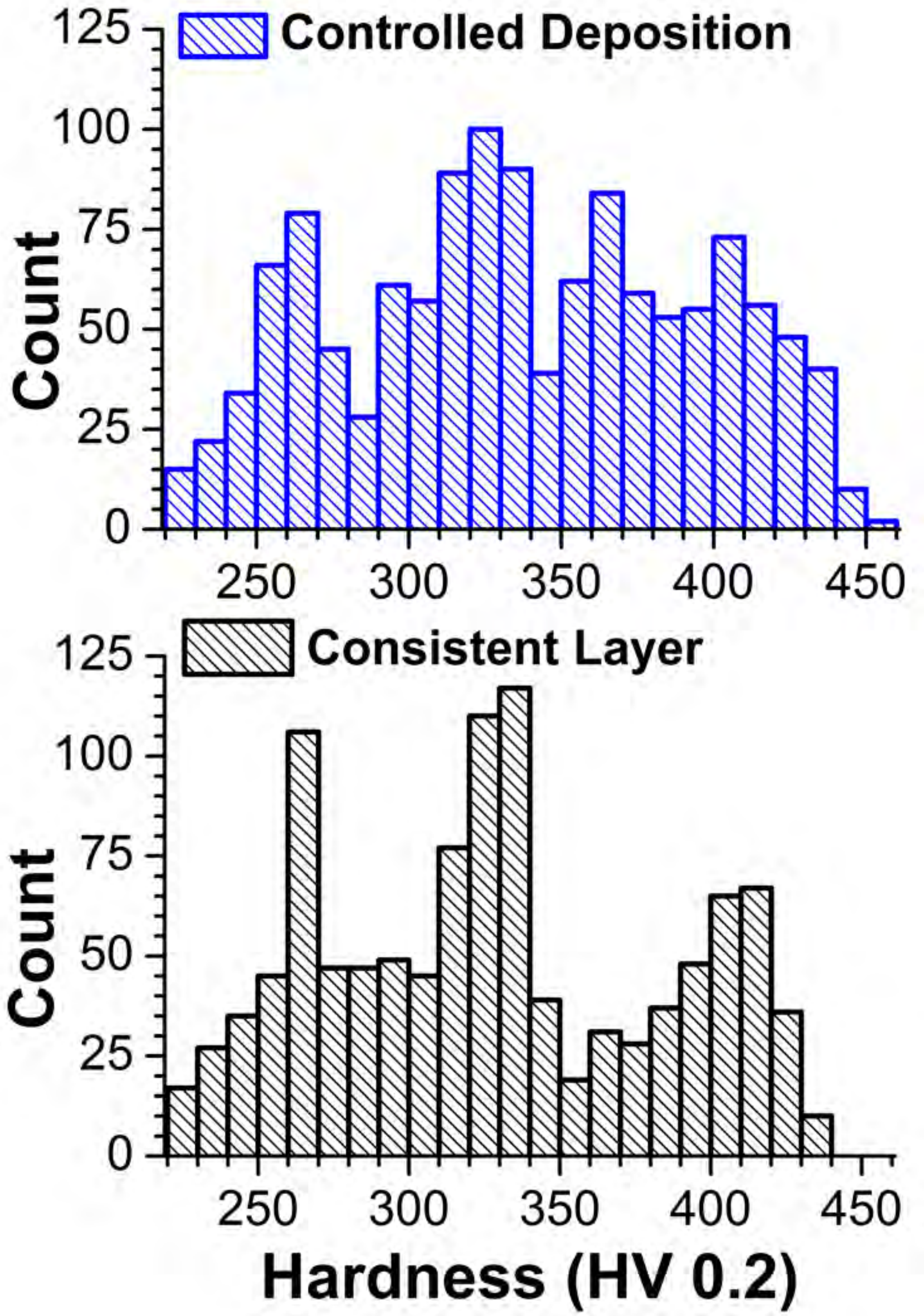

Figure 16
Histogram Comparison for Values above HV>225

Table 4
Percentage of Hardness Values for each Weldment above the Indicated Value

Weldment	>300HV	>325HV	>350HV	>375HV	>400HV	>425HV
Consistent Layer	65%	49%	34%	24%	15%	2%
Controlled Deposition	72%	56%	42%	28%	16%	5%

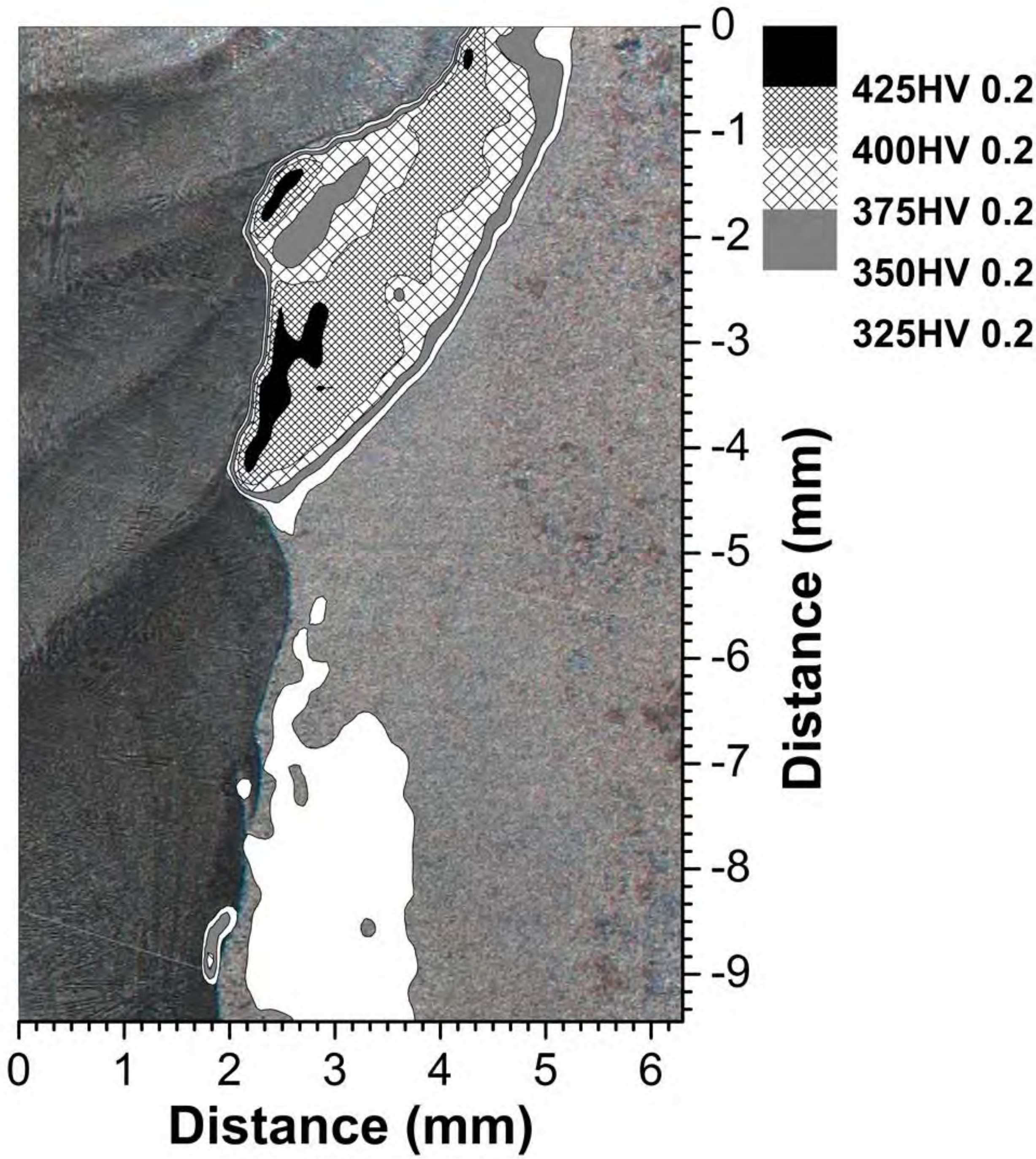

Figure 17
Location of Highest hardness Regions in the Consistent Layer Weldment

Discussion

The analysis of the 0° bevel of each procedure in Figures 14 and 15 show that ample tempering was achieved near the root and midwall on each weldment. Hardness data in typical Grade 91 weldments have shown values to approach 450HV in the HAZ. The data in Figures 14 and 15 indicate that virtually no data points lie above 450HV 0.2 with the vast majority of the data being below 400HV 0.2. To date, there has not been a systematic study governing acceptable hardness values in the HAZ of Grade 91, although hardness maximums have been instituted for as-received base material (263HV) and for the weld metal (295HV) following PWHT [9].

The consistent layer technique shows slightly better tempering through the entirety of the HAZ, as indicated in the histograms shown in Figure 16. The amount of data points below 350HV in the consistent layer technique are further shown in Table 4. The overall slight increase in tempering is likely attributed to the fact that there was one additional fill pass in this weldment as compared to the controlled deposition weldment. The increased heat input in the controlled deposition weldment appears to have had no significant affect in the tempering behavior of the Grade 91 HAZ. Based on these observations, it seems most beneficial to deposit as many fill passes as possible to increase the chances of tempering through the entirely of the HAZ.

A graph of the data points above 325HV overlaid on the analyzed area in Figure 17 shows the location of the hardest regions in the consistent layer technique. This graph clearly indicates that a great deal of the HAZ is below 325HV. The location of the hardest regions (in black) may be a result of the way in which the 0° bevel was welded. When approaching the 0° bevel, the automated voltage control will increase the arc length and cause the weld puddle to wash higher up on the wall (Figure 12, Fill 2). This added reinforcement on the wall may prevent adequate heat from overlying fill passes to penetrate the deposited weld pass to temper the HAZ.

Most of this preliminary analysis is concentrated around the measured hardness values. The importance of a threshold hardness value may have implications with respect to the stress corrosion cracking susceptibility (SCC) of the weldment. Although significant SCC has been documented in other CSEF steels (primarily Grades 23/24) [10, 11], the instances of SCC in Grade 91 weldments are not widely documented. In the few instances of documented SCC in Grade 91, the components were left in an uncontrolled environment for an extended period of time. More widespread cases of SCC have not been documented in Grade 91 due to the requirement of PWHT for *any* weld made in a Grade 91 component.

General SCC susceptibility is defined by the interaction of the environment, a susceptible material and the stress state. Because a wide variety of environments can pass through the ID of the tubing (acid cleaning, various steam qualities), it was especially prudent in these studies to reduce the hardness at the root of the weldment. The reduction in hardness at the root was evident in both procedures. Furthermore, it must be noted that the relationship between hardness and SCC susceptibility is not well understood for the CSEF family of alloys. Research on potential SCC mechanisms in Grade 24 weldments have revealed that the susceptibility of the material is not an obvious function of maximum hardness, but primarily on the water chemistry and secondarily to an acid cleaning environment passing through the tube [11]. Additionally, the application of Grade 24 in waterwalls induces this material to a very high restraint condition and creates the necessary conditions for SCC. Because the intended application of the temper bead welding procedure described in this paper is in T91, it is conceivable that the residual stresses are substantially lower than in other highly restrained situations. The application of a temper bead procedure to T91 likely further limits its use to tubing that is present inside the boiler, and inherently shielding these locations from environmental conditions which might induce SCC on the outside diameter of the tubing.

Conclusions & Future Plans

As-welded HAZ values in Grade 91 for typical welding procedures regularly approach values 450HV. Tempering of Grade 91 using a temper bead technique and relying solely on the heat input from welding is a challenging prospect. Despite this, tempering was observed in the Grade 91, with overall hardness values being reduced by ~100HV in specific regions. A few conclusions from these preliminary set of studies are shown below:

1. Use of a nickel-base filler material offers unique advantages for repair applications in Grade 91 because it does not require tempering or removal of material (as in half-bead) to ensure adequate tempering through the thickness. This greatly reduces the complexity of the applied temper bead welding procedure.
2. The consistent layer technique demonstrated overall lower hardness values than the controlled deposition technique.
3. Regardless of welding technique, the majority (~75%) of the overall hardness values were below 375HV. Because Grade 91 HAZ hardness values regularly exceed 400HV and can reach 450HV, tempering of the Grade 91 HAZ below 375HV is encouraging considering that Grade 91 was purposely designed to be resistant to tempering.
4. The majority of the observed tempering in each weldment was documented in the root and midwall locations. Such observations suggest that there was ample heat input to temper the HAZ through ~half of the weldment. These same observations suggest that more fill passes may be required to more effectively temper the upper half of the weldment.
5. The least tempering was documented in the cap location and indicated that a low deposition wash pass was not adequate to achieve any noticeable tempering.

Planned destructive test evaluation and individual analysis on the effect of each layer will demonstrate the individual and/or cumulative effect of the fill passes on the tempering behavior of each of these weldments. Additional future studies, should address the potential implications of a temper bead procedure in Grade 91. Such studies should address the tempering characteristics of the Grade 91 HAZ in the as-welded state and at service temperature, the cross-weld creep behavior, stress corrosion cracking susceptibility and fracture toughness.

The initial hardness values indicate that the Grade 91 HAZ can be consistently tempered with relatively simple approaches and carefully controlled procedures. This tempering provides an encouraging step in the on-going examination of temper bead procedures for at least temporary repair options in T91 applications.

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11. Private Correspondence, 10/25/11.

Novel Approaches to Repair of Grade 91 Using Temperbead Welding Procedures

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National Board Inspection Code

Introduction

- Two on-going projects within EPRI
  - Temperbead of T91 Using EPRI P87 Filler Metal
  - Weld Repair of Grade 91 Piping and Components
- Motivation
  - Grade 91 components have been used for >20 years and widely put into service over the last 15 years
  - Little thought has been given to establishing the best repair method for specific components
  - PWHT adds a layer of complexity
  - Ensuring *good PWHT* can be very difficult
  - More life may be obtainable through eliminating PWHT

Temperbead Concept for Tubing Applications

- Nickel-base filler metal reduces complexity
- Carefully controlled procedure to temper the T91 HAZ
- Use of EPRI P87 nickel-base filler metal (matching to Grade 91 in C, Cr and carbide-formers) prevents two potential, long-term failure mechanisms:
  - Carbon migration (and the formation of a weak zone)
  - Type I carbide nucleation **and growth** along ferritic-side of fusion line (growth eventually results in creep cavitation at Type I carbides)
  - For more information, EPRI Report 1019786 (free)
- **Goal: Provide an alternative repair approach that results in safe operation without the need for PWHT.**

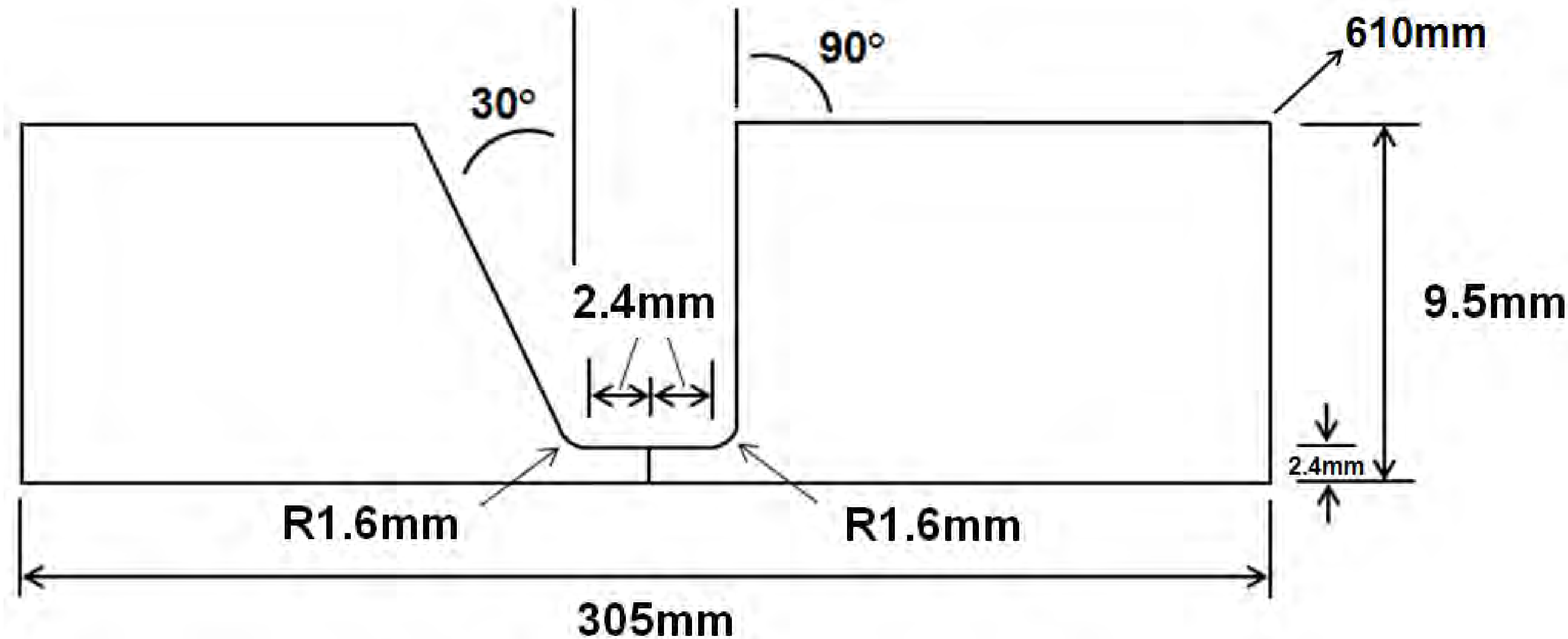
Approach

- Attempt two different, established temper bead welding techniques using automated GTAW process
  - **Consistent Layer** – heat input for fill passes was identical
  - **Controlled Deposition** – heat input was purposely increased through the thickness
- Weld was staggered to examine the effect of each layer on the tempering response of the Grade 91 HAZ
- Preheat 200°F with max interpass of 250°F to ensure complete transformation to martensite prior to deposition of the next, overlying layer

Procedure Validation and Testing

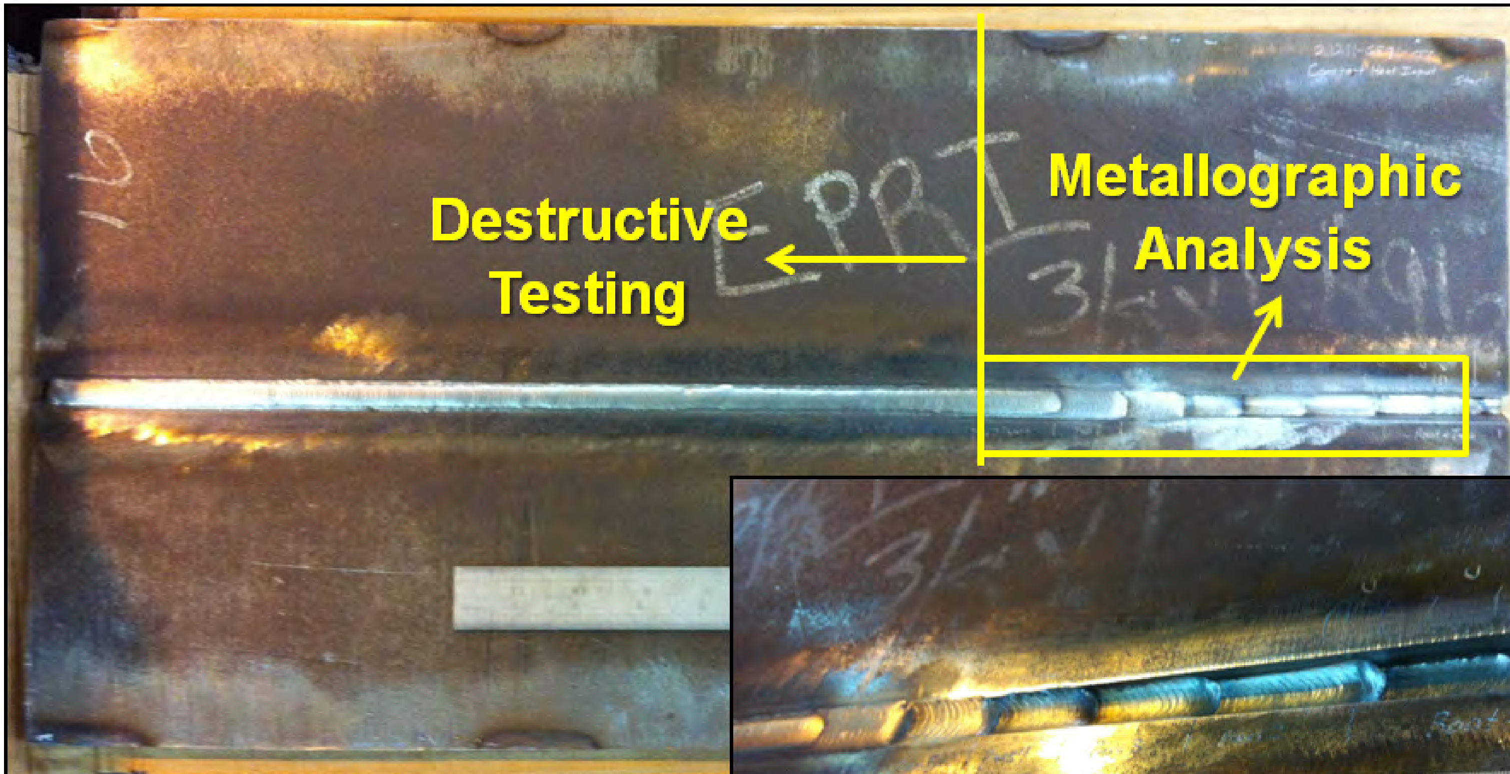
- Metallography
- Hardness (per procedure)
  - 200g Hardness Maps
  - 0.15mm spatial spacing
  - ~2800 indents per map on each side of the weld
- Mechanical Testing (per procedure)
  - Room temperature impact testing (10mm square)
  - ASME Section IX qualification (4 side bends + 2 RTTs)
  - Elevated temperature tensile testing (550-620°C @ 14°C increments)

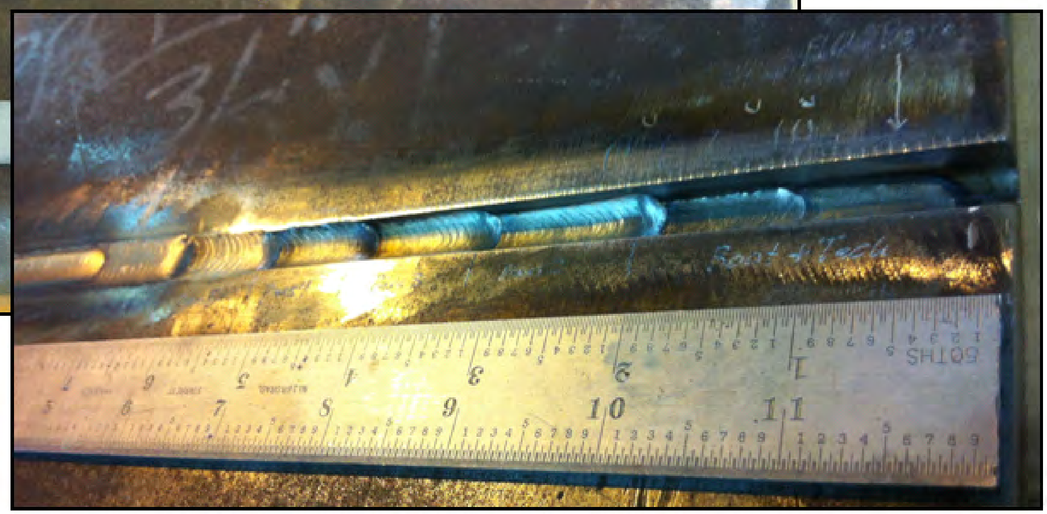
Welding Geometry



- Straight bevel was utilized for two reasons:
  - Potentially allows for impact strength measurement in HAZ
  - Establish if the bevel is a critical variable

Finished Weldment





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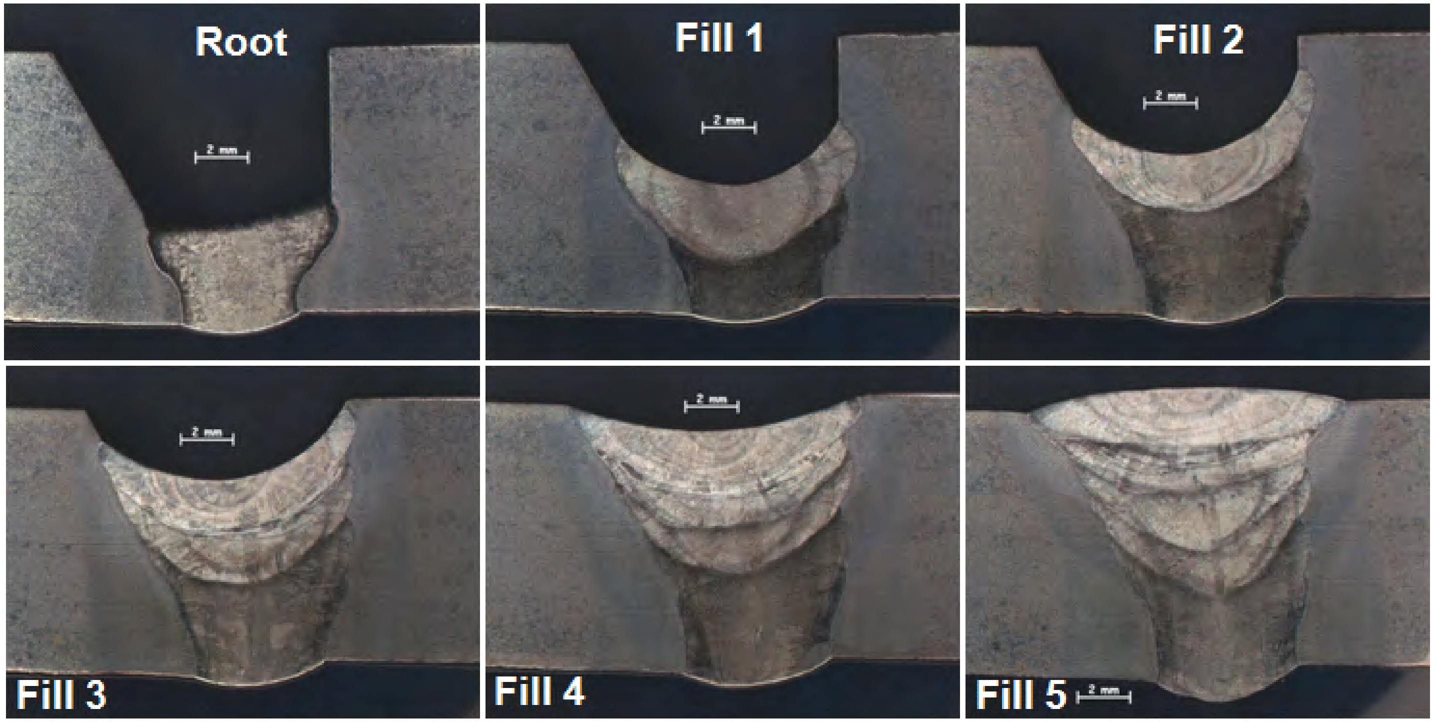
Consistent Layer Macro Images



- 1 Root Pass + 5 Fill Passes
- 1 "Low Deposition Wash" pass to temper cap area of weldment

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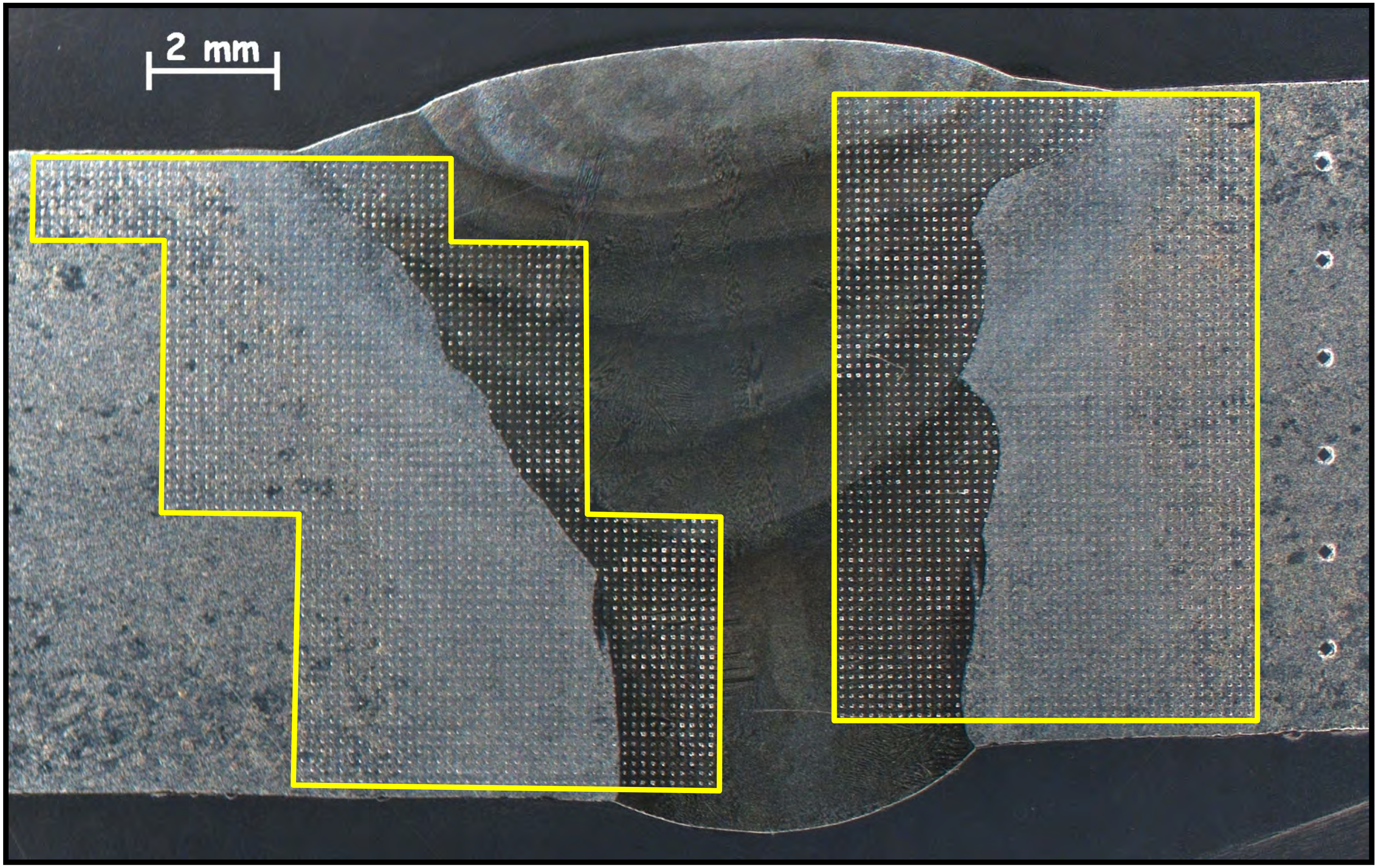
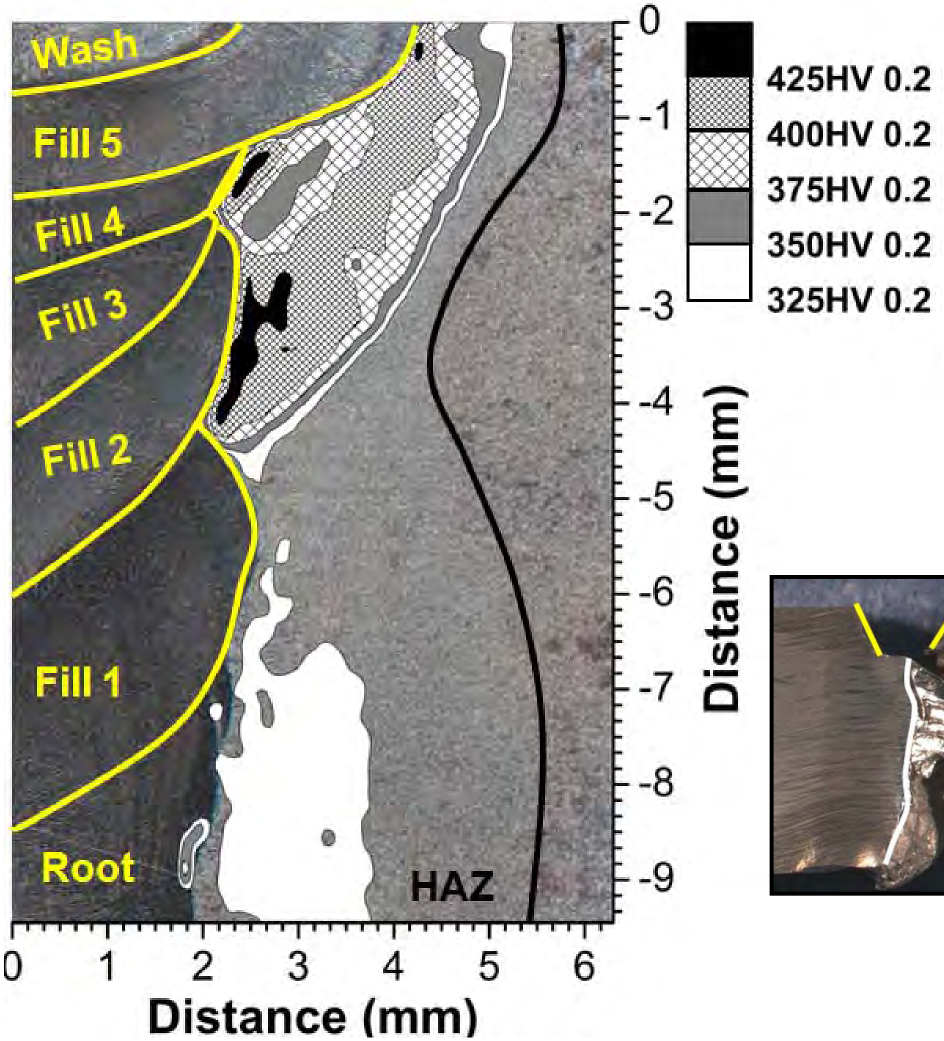
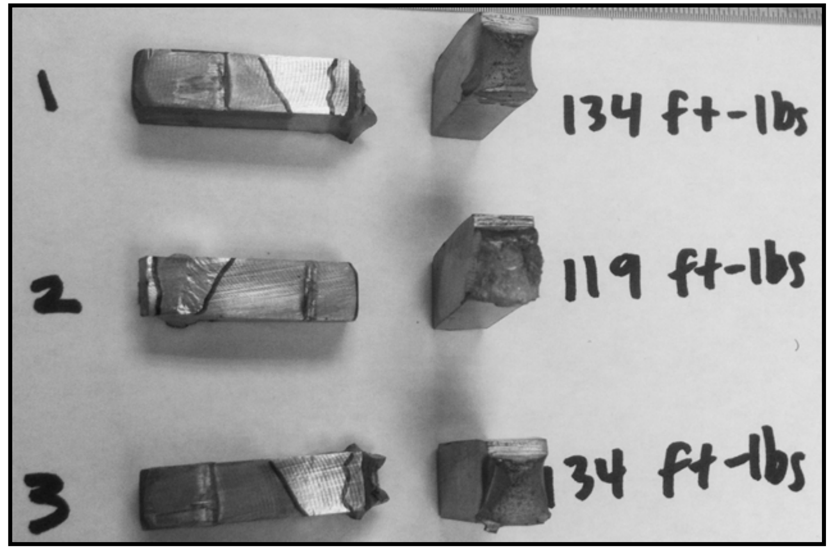
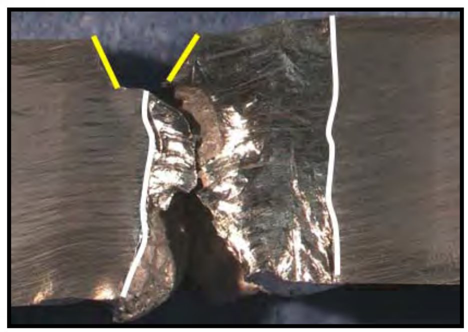
Consistent Layer Hardness Maps in Completed Weldment

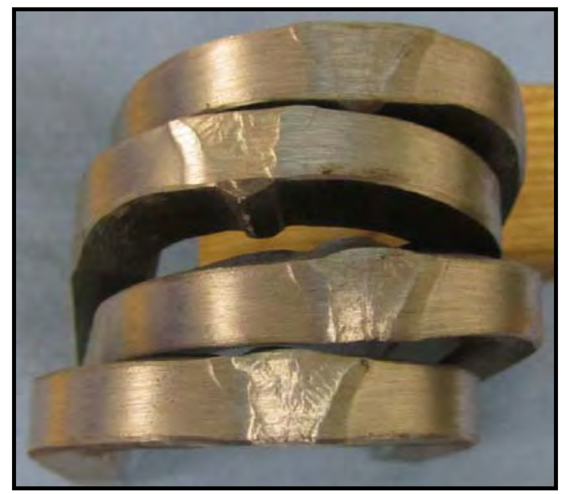


Consistent Layer – Example of Data Analysis









Conclusions to Date and Future Work

- It is possible to temper the Grade 91 HAZ and a reduction of hardness (<350HV 0.2) at root appears feasible
- Destructive evaluation results (thus far) are promising

<u>Future Work:</u>

- Application manual GTAW
- Application to manual GTAW root + SMAW fill
- Metallographic, hardness and destructive evaluation

- **Questions or comments ?**

Weld Repair of Grade 91 Piping and Components

Objectives and Scope

- Ability to remove damaged material efficiently and effectively
- Design and execute repairs
- Guide to lifing and ongoing inspection requirements of repair

Value

- Minimize the time and costs associated with making a repair
- Maximize the potential that the repair will provide at least adequate in-service performance.

Details and Contact

- The participant total cost is $40,000 payable over 2 years.
- Qualifies for Tailored Collaboration

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- jparker@epri.com, (704) 595-2791

SPN Number: 1022801

Have confidence that repair methods will be effective

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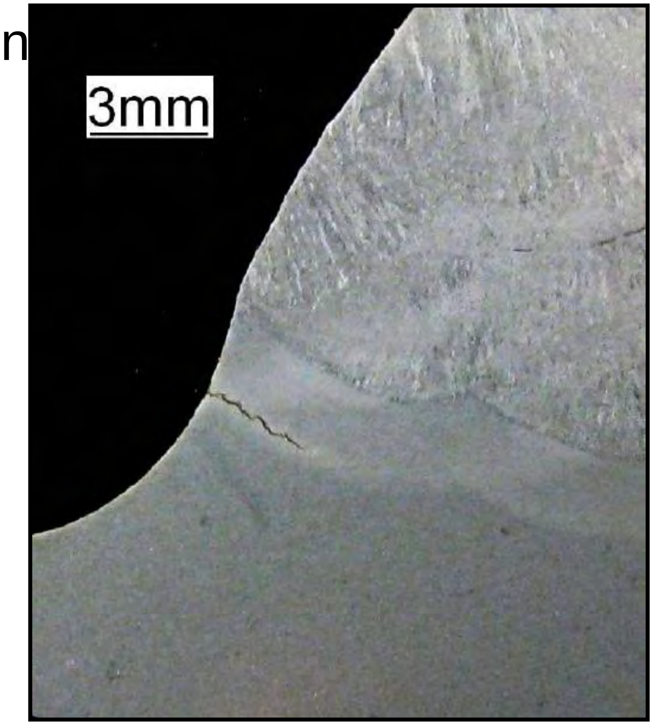
Phase 1 – Ranking of Repair Performance

- Discussion of methods and extent of excavation
- Weld procedure considerations – identified variables:
  - Base material condition (Renormalized and service-exposed)
  - Filler metal selection (6 total)
  - Temperbead vs. normal procedure comparison
  - Proper vs. improper temperbead
  - Temperbead layer procedure (4 total)
  - Post weld heat treatment (3 total)
- Post repair evaluation of microstructure, damage, etc.
- Specimen geometry and testing conditions
- Development of test matrix



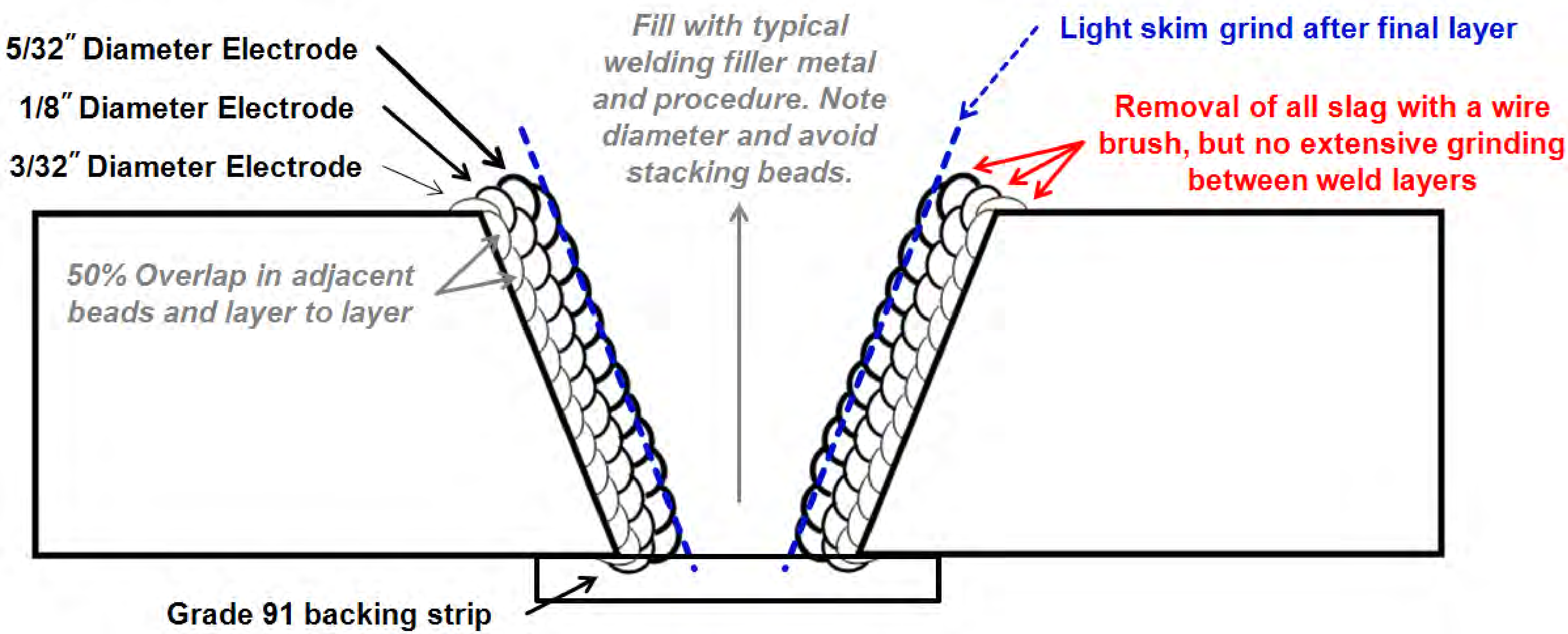
Analysis to identify best option repairs – generate ranking table

Phase 1 Welding Matrix – All Welds Completed

Weld	Base Material	Weld Metal		Preheat/ Interpass	Welding Procedure	PWHT
		AWS Desig.	Trade Name			
1A	As-received Grade 91 (Sample 8) "A" Material	E9015-B9 H4	Thermanit Chromo 9V Mod.	300°F/600°F	Normal + Rec'd. PWHT	1375±25°F/2h
2A				300°F/600°F	Normal + Min. PWHT	1250±10°F/2h
3A				300°F/600°F	Temperbead	None
4A				300°F/600°F	Poor Practice Temperbead	None
5A		E8015-B8	9Cr-1Mo	300°F/600°F	Temperbead	None
6A		E9015-G	Thermanit P23	300°F/600°F	Temperbead	None
7A				300°F/600°F	Normal + Rec'd. PWHT	1375±25°F/2h
8A		E9018-B3 H4	Bohler E9018-B3	300°F/600°F	Temperbead	None
9A		EPRI P87	EPRI P87	300°F/600°F	Temperbead	None
10A		ENiCrFe-2	INCO-WELD A	300°F/600°F	Temperbead	None
1B	Renormalized Grade 91 (Sample 8) "B" Material	E9015-B9 H4	Thermanit Chromo 9V Mod.	300°F/600°F	Normal + Renormalization + Temper	1930°F±20°F/2h 1375±25°F/2h
2B				300°F/600°F	Normal + Min. PWHT	1250±10°F/2h
3B				300°F/600°F	Temperbead	None
4B				300°F/600°F	Poor Practice Temperbead	None
5B		E8015-B8	9Cr-1Mo	300°F/600°F	Temperbead	None
6B		E9015-G	Thermanit P23	300°F/600°F	Temperbead	None
7B				300°F/600°F	Normal + Rec'd. PWHT	1375±25°F/2h
8B		E9018-B3 H4	Bohler E9018-B3	300°F/600°F	Temperbead	None
9B		EPRI P87	EPRI P87	300°F/600°F	Temperbead	None
10B		ENiCrFe-2	INCO-WELD A	300°F/600°F	Temperbead	None

Weldment 10B [ENiCrFe-2 Filler Metal, TBW]

Welding Procedure for Three Layer Approach



- SMAW Process
- 300°F (149°C) Preheat, 600°F (316°C) Interpass

Weldment 10B [ENiCrFe-2 Filler Metal, TBW]

Welding Assessment – Completed Weldment

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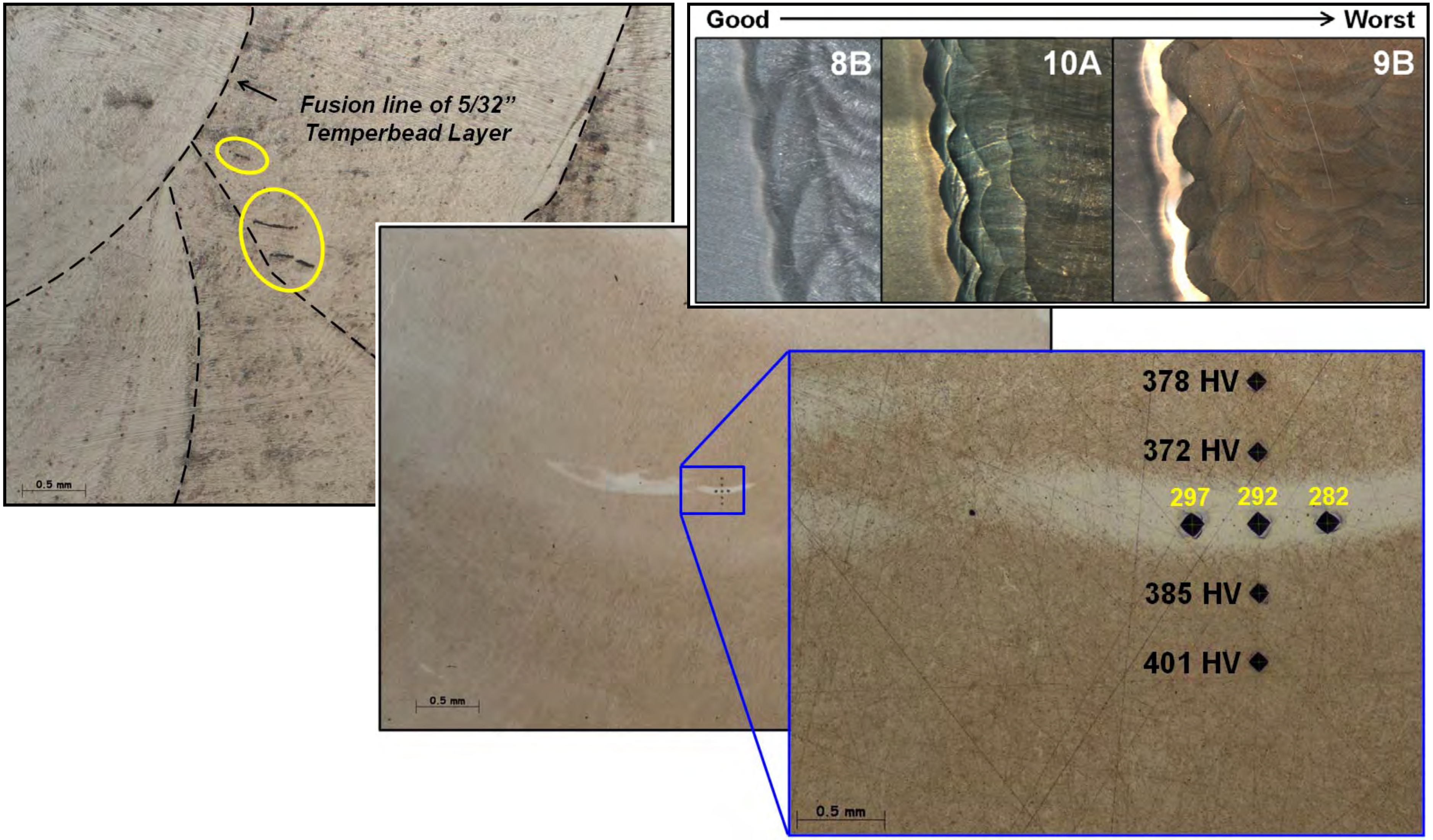
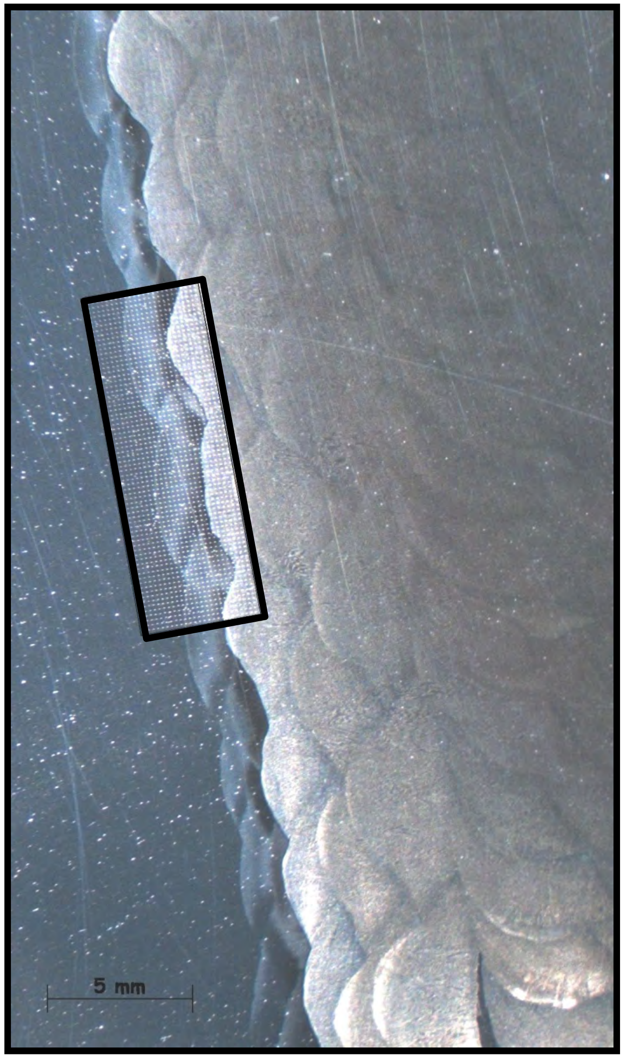
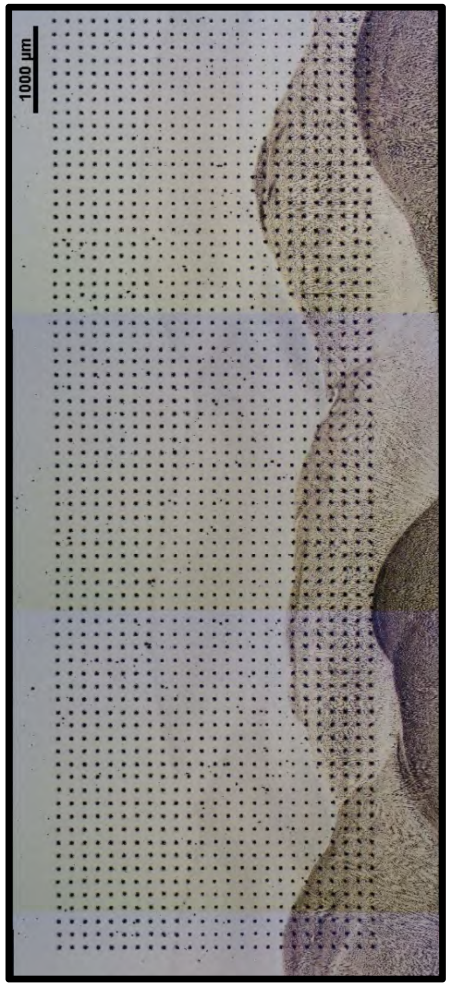
Metallographic Assessment

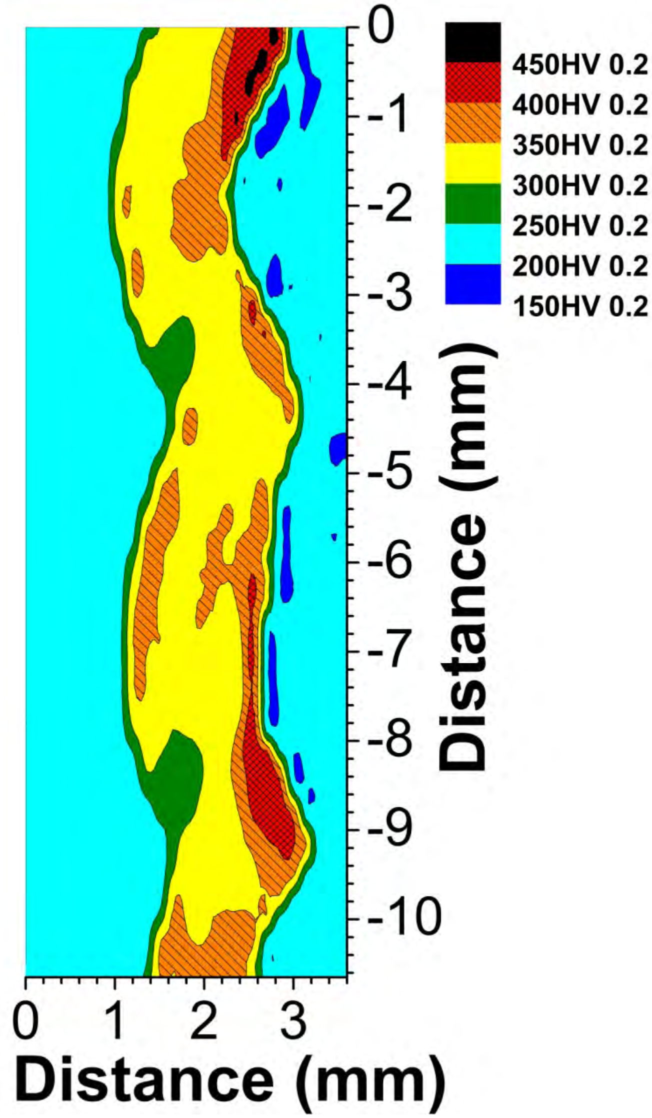


Weldment 10B [ENiCrFe-2, TBW]

Hardness Assessment – HAZ Hardness Map







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Machined and Tested Creep Samples

Creep testing being conducted at 625°C, 80MPa (~5,000 hr life)

Samples include the entirety of the weld metal and temperbead layers on either side of the weld

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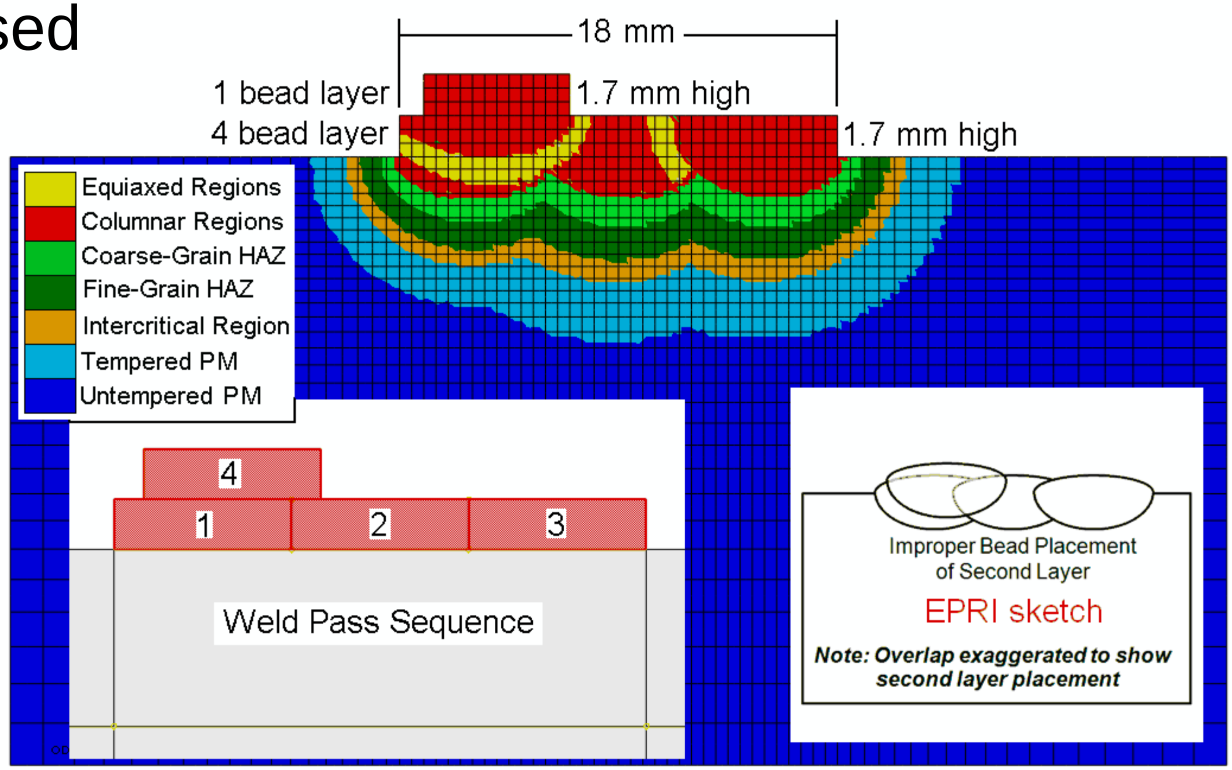
Modeling

- Modeling in Phase 1 is being conducted to understand procedure issues associated with temperbead welding (i.e. bead overlap, bead placement and electrode size)
- Modeling is focused in identifying the position and influence of overlapping thermal cycles



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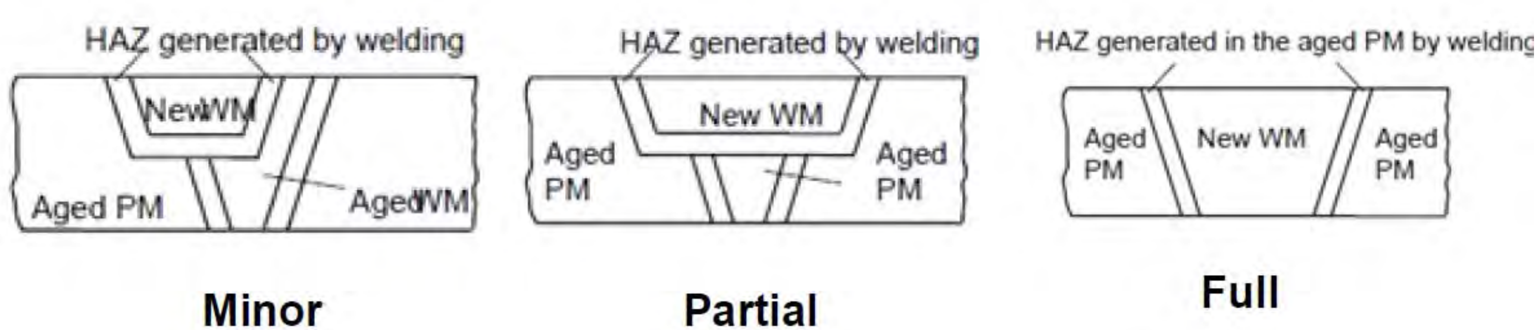
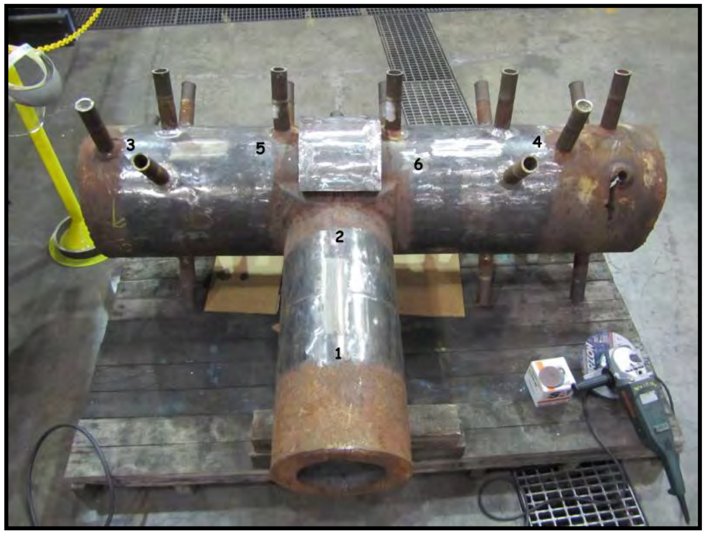
Phase 2 – Application of Best Option Repair Method(s) to Ex-service Header

- Discussion of methods and extent of excavation



- Weld procedure considerations
- Post repair evaluation of microstructure, damage, etc.
- Development of test matrix and cross-weld creep



Conclusions

- The 20 weldments have been completed and preliminary analysis has been conducted:
  - Metallographic
  - Hardness testing and mapping
  - Statistical analysis of hardness results
- Creep testing is underway of all weldments
  - Once completed, results will be presented to NBIC
- Modeling and bead on plate studies have provided insight to “best procedure guidelines” for future Phase 2 work
- Phase 2 to being ~September/October 2012
- **Questions or comments?**

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