Repair and Replacement Applications Center: Socket Weld Repair Issues

ASME Code Case N-666 for On-line Repair of Socket Weld Leakage
Technical Update Revision 2

1013562

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Technical Update, December 2006

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This document describes research sponsored by EPRI.

The publication is a corporate document that should be cited in the literature in the following manner:

Repair and Replacement Applications Center: Socket Weld Repair Issues – ASME Code Case N-666 for On-line Repair of Socket Weld Leakage Technical Update Revision 2. EPRI, Palo Alto, CA: 2006. 1013562.

ABSTRACT

To reduce costs associated with these common failures of small-bore piping and fittings, EPRI has conducted several studies to improve socket weld design, fabrication practices and repair applications to address high cycle fatigue. One of the options studied was an overlay repair of the leaking socket welded connections. The overlay repair was intended to extend the life of a failed connection or allow replacement of the connection to be scheduled during a routine outage. Results of preliminary high cycle fatigue test indicated that an overlay weld repairs could provide a fatigue life equal to that of the original standard socket weld.

The test data showed that the overlay repair is an effective method for repairing cracked socket welds subjected to high cycle fatigue. The tests demonstrated that overlay-repaired socket welds perform at least as well as, and often superior to the standard, equal leg socket welds. The test data was documented in a white paper (EPRI 1003689) to support an ASME Boiler and Pressure Vessel Code Case that would permit the use of this overlay repair technology for on-line repairs of leaking socket welds caused by high cycle fatigue in operating nuclear plants.

The Code Case submitted to ASME Section XI with the latest revisions is reproduced in this report. The Board of Nuclear Codes and Standards passed Code Case N-666, Reinforcement of Class 1, 2, and 3 Socket Welded Connections, on April 4, 2006.

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CODE CASE N-666

Background

Failures of small bore piping connections (2-inch and smaller) continue to occur frequently at nuclear power plants in the United States, resulting in degraded plant systems and unscheduled plant downtime. Fatigue-related failures are generally detected as small cracks or leaks but, in many cases, the leak locations are not isolable from the primary reactor coolant system, resulting in extended outages. Outages associated with fatigue failures have resulted in shut downs as long as 7 days with lost revenue costs exceeding $300K per day.

To reduce costs associated with these common failures of small-bore piping and fittings, EPRI has conducted several studies to improve socket weld design, fabrication practices and repair applications to address high cycle fatigue. One of the options studied was an overlay repair of the leaking socket welded connections. The overlay repair was intended to extend the life of a failed connection or allow replacement of the connection to be scheduled during a routine outage. Results of preliminary high cycle fatigue test indicated that an overlay weld repairs could provide a fatigue life equal to that of the original standard socket weld.

To further validate the effectiveness of the overlay repair technology a more extensive test matrix was conducted on NPS ¾ and NPS 2 sizes, both carbon and stainless steel materials and on cracks initiated from both the toe and root of the original socket weld. The original socket welds were cracked under high cycle fatigue conditions and then overlay-repaired under various conditions (temperature and pressure). The overlay repairs were again subjected to high cycle fatigue, until failure occurred, thus allowing a direct comparison to the original socket weld fatigue life.

The test data showed that the overlay repair is an effective method for repairing cracked socket welds subjected to high cycle fatigue. The tests demonstrated that overlay-repaired socket welds perform at least as well as, and often superior to the standard, equal leg socket welds. The test data was documented in a white paper (EPRI 1003689) to support an ASME Boiler and Pressure Vessel Code Case that would permit the use of this overlay repair technology for on-line repairs of leaking socket welds caused by high cycle fatigue in operating nuclear plants.

The Code Case submitted to ASME Section XI with the latest revisions is reproduced in Section 2 of this report. The Board of Nuclear Codes and Standards passed Code Case N-666, Reinforcement of Class 1, 2, and 3 Socket Welded Connections, on April 4, 2006. The attached Code Case is for reference only and ASME should be contacted to request published copies for production activities.

2
CODE CASE N-666

Case N-666

Reinforcement of Class 1, 2, and 3 Socket Welded Connections
Section XI, Division 1

Inquiry: Under the requirements of IWA-4420, structural integrity of components containing unacceptable defects may be restored by defect removal. As an alternative to defect removal of a cracked or leaking socket weld, if the failure is a result of vibration fatigue, is it permissible to restore the structural integrity by installation of weld reinforcement (weld overlay) on the outside surface of the pipe, weld, fitting, or flange?

Reply: It is the opinion of the Committee that, in lieu of the requirements of IWA-4420, the structural integrity of a cracked or leaking socket weld in Class 1, 2 and 3, NPS 2 (DN 50) and smaller piping may be restored by deposition of weld reinforcement (weld overlay) on the outside surface of the pipe, weld, fitting, or flange, provided the following requirements are met. This Case is not applicable to the full or partial penetration weld joining a pipe or fitting of a branch to the run pipe nor is it applicable to systems containing petroleum products such as lubricating oil or fuel or other substances that create a fire or explosion hazard.

1.0 General Requirements

(a) Reinforcement shall be performed in accordance with a Repair/Replacement Program satisfying the requirements of IWA-4150 in the Edition and Addenda of Section XI applicable to the plant in-service inspection program, or later Edition and Addenda. The references used in this Case refer to the 2001 Edition with the 2002 Addenda. For use with other Editions and Addenda, refer to Table 1 for applicable references.

(b) Use of this Case is limited to Class 1, 2, or 3 NPS 2 (DN 50) and smaller socket welded connections with base material of P-Number 1 Group 1, P-Number 1 Group 2, or P-Number 8. This Case is not applicable to the full or partial penetration weld joining a pipe or fitting of a branch to the run pipe. The Case is also not applicable to systems that contain petroleum products such as lubricating oil or fuel or other substances that create a fire or explosion hazard.

(c) Reinforcement weld metal (structural and seal layers) shall be deposited in accordance with a Welding Procedure Specification (WPS) qualified in accordance with IWA-4440.

(d) For repairs that are performed when the system is at a temperature greater than 200 F or a pressure greater than 275 psig. the Owner shall implement measures to prevent separation of the pipe from the fitting or flange during the repair process. In addition, the Owner shall verify that the pipe base material adjacent to the socket weld requiring reinforcement meets the required minimum wall thickness.

(e) A socket weld may not be reinforced more than one time.

(f) The reinforcement shall meet all applicable requirements of IWA-4000, except as stated in this Case.

2.0 Evaluation

(a) The Owner shall verify that the socket weld failure is, a result of vibration fatigue. This determination shall include review of the design, operating history, including changes in the piping system, and visual inspection of the failed socket weld. Metallurgical analysis of the flaw surface for failure determination is not required.

(b) If review of the design, operating history and changes to the piping system indicates that the current system configuration has not been changed for one or more fuel cycles, the reinforcement shall be acceptable until the next refueling outage if no action is taken to reduce the vibration to acceptable levels. If corrective action is taken that reduces the vibration to acceptable levels, the reinforcement shall be acceptable for the remaining life of the piping system. If the time to failure of the original socket weld was less than one fuel cycle, corrective action that reduces

(c) the vibration to acceptable levels must be taken. Vibration acceptance standards shall be in accordance with ASME-OMb-S/G-2002, Part 3.

(d) The evaluations required by this Case shall be documented and maintained in accordance with IWA-4180.

3.0 Design

(a) The Owner shall consider, in the suitability evaluation required by IWA-4160, the source of the vibration that caused the original socket weld failure. *The completed weld reinforcement shall meet the dimensional requirements of Fig. 1. The minimum throat dimension shall be 0 .77 t_n for fittings and flanges except that Section III socket-welded flanges shall be 0.98 t_n. This dimension shall be maintained from the seal weld surface and the original socket weld face as shown in Fig. 1.When the fatigue crack is located in the base metal adjacent to the toe of the socket weld the minimum throat dimensions shall be measured from the location of the crack farthest from the weld toe.*

(b) The filler metal for structural reinforcement of P-No. 1 materials shall be AWS Classification E70XX-X, E7XT-X, or ER70S-X. Filler metal for structural reinforcement of P-No. 8 materials shall be AWS Classification E3XX-XX, E3XXTX-X or ER3XX. The filler metal for the seal weld may be any filler metal permitted by a qualified WPS.

When the weld reinforcement is applied to a socket weld(s), without any other modifications to the piping system, stress analysis of the effect of the reinforcement is not required. When physical modifications are made to the piping system, the effect of the physical modifications on the piping stress analysis shall be evaluated. Stress indices and stress intensification factors for the reinforced socket weld shall be the same as the minimum value that would be calculated for a standard socket weld in accordance with the Construction Code selected in accordance with IWA 4220.

4.0 Procedure

(a) Prior to welding, the location and approximate extent of cracking shall be determined visually.

(b) The crack shall be sealed by depositing one or more weld beads. The seal weld may be deposited on wet surfaces. Peening may be used in combination with welding to seal the crack.

(c) The seal weld, remaining socket weld, and adjacent base material that will be reinforced shall be examined using VT-1 visual examination.

(1) The procedure and personnel performing this visual examination shall meet the requirements of 5.0(a)(2) and 5.0(a)(3).

(2) The examination surfaces shall be acceptable when no cracks or evidence of leakage are detected and the surfaces are suitable for reinforcement.

(d) At least two structural reinforcement layers shall be deposited around the entire circumference of the fitting, weld, and pipe. The completed weld reinforcement shall meet the dimensional requirements of Fig. 1. The throat dimensions shall not include the seal layers deposited in accordance with 4.0(b).

(e) As-welded surfaces are permitted; however they shall be sufficiently free of coarse ripples, grooves, overlaps and abrupt ridges and valleys to permit interpretation of the required nondestructive examinations.

5.0 Final Examination and Testing

(a) Visual and nondestructive examination of the final structural reinforcement weld shall be performed in accordance with (1) through (3) below:

(1) VT-1 visual examination shall be performed on the completed structural reinforcement weld. In addition, the reinforcement shall be nondestructively examined in accordance with the Construction Code identified in the Repair/ Replacement Plan. The type of examination and coverage shall be as specified for a socket weld. When the metal temperature of austenitic stainless steel piping exceeds 350° F (177°C) prior to welding, any surface examination required by the Construction Code need not be performed.

(2) VT-1 visual examination shall be performed using a procedure that meets the requirements of IWA–2210 and shall be capable of resolving text with lower case characters (e.g. a,c,e,o) not exceeding a height of .044 inch (1 mm) at the examination distance. The maximum direct VT-1 distance shall not exceed 2 feet (600mm).

(3) Personnel performing VT-1 visual examinations shall be qualified in accordance with IWA-2300 and shall have received additional training in examination of weldments for fabrication conditions, including dimensional requirements and fabrication flaws

(4) Visual indications shall be evaluated using the acceptance standards in (a) through (e) below.

(a) Cracks and incomplete fusion are unacceptable.

(b) Concavity and convexity of the surface of the reinforcement and craters are acceptable provided the criteria for weld size can be satisfied.

(c) Undercut at the toe of the weld on the pipe side is unacceptable. Undercut at the toe of the weld on the fitting side shall not exceed a depth of 1/32 in. (0.8mm).

(d) Only surface porosity whose major dimension exceeds 1/16 in. (1.5 mm) shall be considered relevant. Reinforcement welds that contain surface porosity are unacceptable if a pore exceeds 1/8 in. (3 mm) diameter or the sum of diameters of random porosity exceeds 3/8 in. (10 mm), or if four or more pores are aligned and the pores are separated by 1/16 in. (1.5 mm) or less, edge to edge.

(e) Arc strikes and associated blemishes on the reinforcement or in the adjacent pipe are unacceptable.

(b) The completed reinforcement shall be dimensionally inspected to verify compliance with the criteria of 4.0(d).

(c) A system leakage test shall be performed in accordance with IWA-4540.

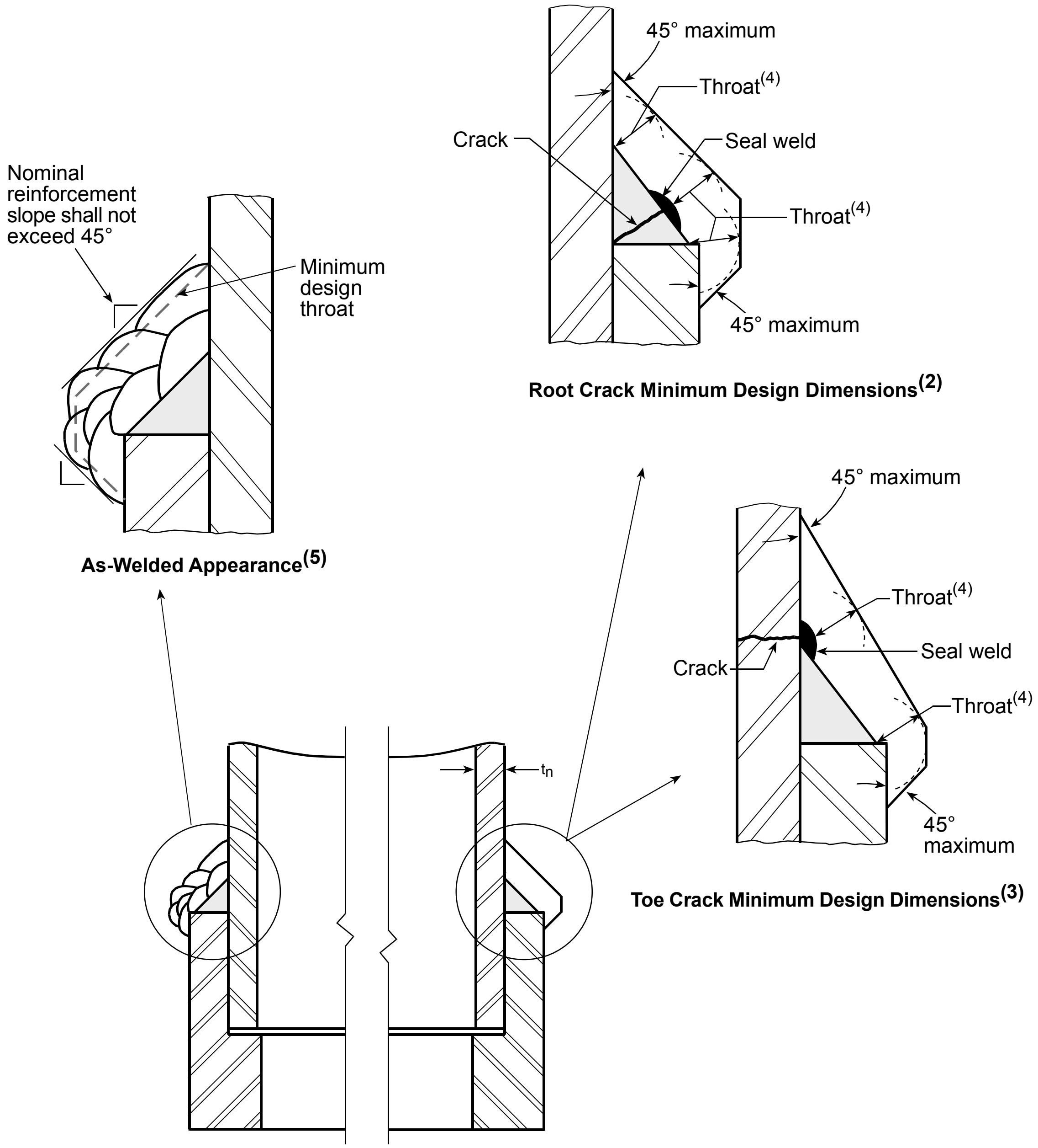
6.0 Documentation

Use of this Case shall be documented on an NIS-2 Form.

Table 2-1
References for Alternative Editions and Addenda of Section XI

1995 Addenda through 2001 Edition with 2002 Addenda	**1991 Addenda through 1995 Edition**	**1988 Addenda through 1990 Addenda**	**1983 Winter Addenda through 1987 Addenda**	**1981 Winter Addenda through 1983 Summer Addenda**
4110 Scope	4110	4110 & 7110	4110 & 7110	4110 &7110
4120 Applicability	4120 (91A-92E) 4111 (92A to 95E)	7400	7400	7400
4150 R/R Program and Plan	4140 & 4170	4120 & 4130 & 7130	4130 & 4120 7130 added W85A	4130
4160 Verification of Acceptability	4150	7220 & 4130	7220 & 4130	7220 & 4130
4180 Documentation	4910	4800 &7520	4700 & 7520	4700 & 7520
4400 Welding, Brazing, Defect Removal and Installation	4200 & 4300 through 93A & 4170	4120, 4200,4300 & 4400 and IWB-4200 88A to 89A	4120, 4200,4300 & 4400 IWB-4200	4120, 4200 & 4300 IWB-4200
4500 Examination and Test	4700 &4800	4600 & 4700	4400 & 4500	4400 & 4500
4530 Preservice Inspection and Testing	4820	4600 & 7530	4500 & 7530	4500 & 7530
4540 Pressure Testing	4700	4700	4400	4400
4600 Alternative Welding Methods	4500	4500	IWB-4300	IWB-4300

The Applicability of this Case shall be the 1980 Edition with the Winter 1981 Addenda through the 2001 Edition with the 2003 Addenda



(1) The details on the right show the minimum design dimensions while the detail on the left shows an acceptable as-welded appearance.
(2) A root crack initiates from the root of the socket weld and propagates through to the face of the fillet weld.
(3) A toe crack initiates at the OD of the pipe at or near the toe of the fillet weld and propagates through to the ID of the pipe.
(4) The minimum throat dimension shall be 0.77 tn for fittings and flanges except that Section III socket welded flanges shall be 0.98 tn. The minimum throat dimension shall be maintained from the seal weld and from the toe of the original socket weld at the pipe and at the fitting shoulder. The minimum throat dimension(s) and 45-degree maximum reinforcement slope shall both be satisfied.
(5) Final surfaces may be as-welded or ground provided the minimum throat dimension(s) are met and the nominal reinforcement slope does not exceed 45 degrees.

Figure 1-1
MINIMUM SOCKET WELD REINFORCEMENT DIMENSIONS

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