Code Case for On-line Repair Technology for Socket Weld Leakage

Technical Update

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ABSTRACT

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 practices to address high cycle fatigue. One of the options evaluated was an overlay repair of the leaking connections that was intended to extend the life of a failed connection and allow replacement to be scheduled during a routine outage. Preliminary results indicated that an overlay weld repairs can provide a fatigue life equal to that of the original standard socket weld.

The goal of this program is to develop the test data 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. To validate the repair technology, a series of standard socket welds were cracked by high cycle fatigue and then overlay-repaired and tested again by high cycle fatigue until failure. Tests were 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 socket weld to substantiate the effectiveness of the repair method.

Test data show 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 much better than standard, equal leg socket welds. The draft Code Case submitted to ASME Section XI is attached.

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1
CODE CASE

Case N-XXX

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 predominantly 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 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 weld joining a pipe or socket-weld fitting of a branch to the run pipe.

1.0 General Requirements

(a) The 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 of Section XI. The references used in this Case refer to the 2001 Edition with the 2002 Addenda of Section XI. 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 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 weld joining a pipe or socket-weld fitting of a branch to the run pipe
(c) Reinforcement weld metal (structural and seal layers) shall be deposited in accordance with a welding procedure specification qualified in accordance with IWA-4440.
(d) The Owner shall verify that the pipe base material adjacent to the socket weld requiring reinforcement meets the required minimum wall thickness.
(e) This Case may only be applied once per socket weld. 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 mechanism is predominantly 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) The reinforcement shall be acceptable for service for one refueling cycle if no action is taken to reduce the vibration to acceptable levels. Vibration acceptance standards shall be in accordance with O&M Standards Part 3. The reinforcement shall be acceptable for the remaining life of the piping system if corrective action is taken to reduce vibration to acceptable levels. When the time to failure of the original socket weld was less than one fuel cycle, corrective action to reduce the vibration to acceptable levels must be taken.

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

3.0 Design

(a) The Owner shall consider the source of the vibration that failed the original socket weld in the suitability evaluation required by IWA-4160.

(b)The completed weld reinforcement shall meet the dimensional requirements specified in Figure l. The minimum reinforcement dimensions also apply when the fatigue crack is located in the base metal adjacent to the toe of the socket weld. The minimum reinforcement dimensions shall be measured from the location of the crack farthest from the weld toe.

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

(d) All relevant applied loads in the system shall be evaluated in accordance with the Construction Code as determined by IWA-4220. Stress indices and stress intensification factors for the reinforced socket weld shall be no lower than the minimum value that would be calculated for a standard socket weld in accordance with the Construction Code.

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 on the cracked area. Peening may be used in combination with welding to seal the crack. The seal weld may be deposited on wet surfaces.

(c) The seal weld, remaining socket weld, and adjacent base material that will be reinforced shall be examined by the VT-1 visual method. The procedure and personnel performing this visual examination shall meet the requirements of 5.0(a)(2) and 5.0(a)(3). In lieu of the acceptance criteria of 5.0(a)(2), this examination is acceptable if there are no cracks or evidence of leakage, and if the surface is suitable for reinforcement.

(d) Two or more structural reinforcement layers shall be deposited around the entire circumference of the fitting, weld, and pipe. The minimum required deposit length, throat dimensions and end slope shall be in accordance with Figure 1. The throat dimensions shall not include the seal layers deposited in accordance with (b) above.

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

5.0 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) A VT-1 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 reinforcement metal temperature of austenitic stainless steel piping exceeds 350° F (177°C), any liquid penetrant examination required by the Construction Code need not be performed.

(2) The VT-1 examination shall be performed using a procedure that meets the requirements of IWA–2200 and shall be capable of resolving a one-mil diameter wire on the weld surface. 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" (.8mm).

(d) Only surface porosity whose major dimension exceeds 1/16"(1.6 mm) shall be considered relevant. Reinforcement welds that contain surface porosity are unacceptable if a pore exceeds 1/8" (3.2 mm) diameter or the sum of diameters of random porosity exceeds 3/8" (9.6 mm), or if four or more pores are aligned and the pores are separated by 1/16" (1.6 mm) or less, edge to edge.

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

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

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

(c) Following completion of all repair/replacement activities, the affected restraints, supports, and snubbers shall be VT-3 visually examined to determine that design tolerances are met.

(d) A system leakage test shall be performed in accordance with IWA-5213.

6.0 Documentation

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

TABLE 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 2002 Addenda.

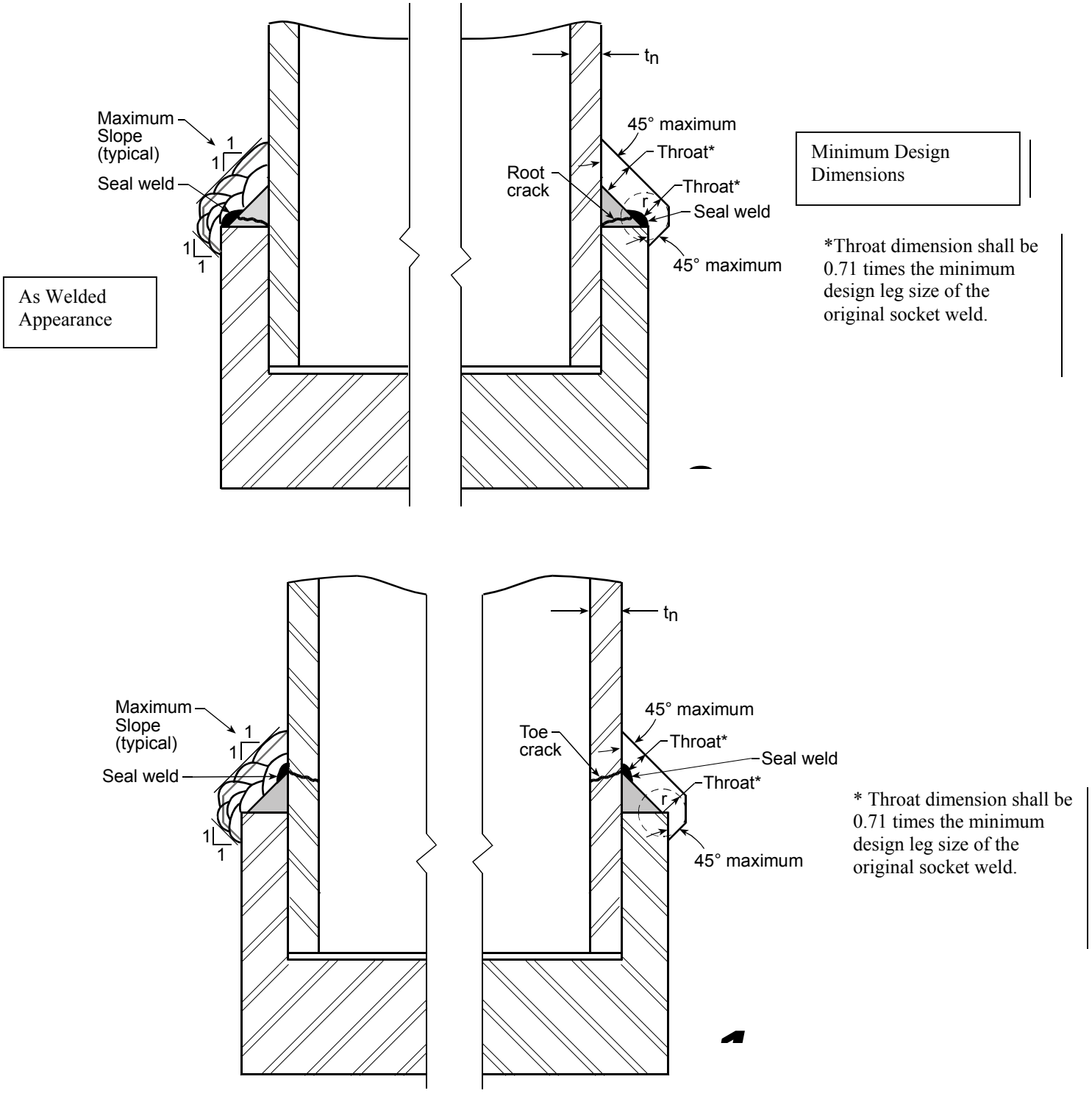

Figure 1 Socket Weld Reinforcement Dimensions. The right side of the figures shows the design dimensions while the left side shows the as-welded appearance. The final surface of the overlay may be left in the as-welded condition.

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