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DRAFT REGULATORY GUIDE

Contact: J. Hixon
(301) 251-7639

DRAFT REGULATORY GUIDE DG-1221

(Proposed Revision 1 of Regulatory Guide 1.43, dated May 1973)

CONTROL OF STAINLESS STEEL WELD CLADDING OF LOW-ALLOY STEEL COMPONENTS

A. INTRODUCTION

General Design Criterion I, "Quality Standards and Records," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10, Part 50, "Domestic Licensing of Production and Utilization Facilities," of the *Code of Federal Regulations* (10 CFR Part 50) requires that components important to safety be designed, fabricated, and tested to quality standards commensurate with the importance of the safety function to be performed. Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants," to 10 CFR Part 50 requires that measures be established to ensure control of special processes such as welding and that proper testing be performed. This guide describes acceptable methods of implementing these requirements with regard to the selection and control of welding processes used for cladding ferritic steel components with austenitic stainless steel to restrict practices that could result in underclad cracking. This guide is limited to forgings and plate material and does not apply to other product forms such as castings and pipe. Adequate resistance to underclad cracking for these latter items should be assured on a case-by-case basis. This guide applies to light-water-cooled reactors.

The U.S. Nuclear Regulatory Commission (NRC) issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated

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This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received final staff review or approval and does not represent an official NRC final staff position.

Public comments are being solicited on this draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rulemaking, Directives, and Editing Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; e-mailed to nrcrep.resource@nrc.gov; submitted through the NRC's interactive rulemaking Web page at http://www.nrc.gov; or faxed to (301) 492-3446. Copies of comments received may be examined at the NRC's Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by August 31, 2009.

Electronic copies of this draft regulatory guide are available through the NRC's interactive rulemaking Web page (see above); the NRC's public Web site under Draft Regulatory Guides in the Regulatory Guides document collection of the NRC's Electronic Reading Room at http://www.nrc.gov/reading-rm/doc-collections/; and the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under Accession No. ML090750044.

accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations and compliance with them is not required.

This regulatory guide contains information collection requirements covered by 10 CFR Part 50 that the Office of Management and Budget (OMB) approved under OMB control number 3150-0011. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

The presence of intergranular cracking in low-alloy steel under stainless steel weld cladding has been observed[1, 2, 3] in reactor vessels and other components for nuclear systems in varying degrees, depending on the material and the cladding processes. This condition has been reproduced experimentally[4] using specific materials and welding processes common to the reactor components. Two types of underclad cracking have been identified.

Reheat underclad cracking (or "hot" underclad cracking) has been reported only in forgings and plate material of SA-508 Class 2 composition[5] made to coarse-grain practice. High-deposition-rate welding processes such as the submerged-arc wide-strip and the submerged-arc 6-wire result in coarse grains in the weld metal. Reheat underclad cracking occurs when the second layer of high-heat-input cladding is added, which reheats the heat-affected zone (HAZ) in the carbon steel causing a liquid phase along the grain boundaries and grain boundary separation upon cooling. Reheat underclad cracking was not observed in SA-508 Class 2 materials clad by "low-heat-input" processes controlled to minimize heating of the base metal. Cold underclad cracking (or "hydrogen-induced" underclad cracking) has occurred in American Society of Mechanical Engineers (ASME) SA-508 Class 3 forgings after deposition of the second and third layers of cladding, where neither preheating nor postweld heat treatment was applied during the cladding process. Further, cracking was not observed in clad SA-533 Grade B Class 1 plate material, which is produced to fine-grain practice, regardless of the welding process used.

Characteristically, the underclad cracking occurs only in the grain-coarsened region of the base metal HAZ at the weld bead overlap. The subsurface location and size of these cracks [0.5 in. (1.3 cm) long x 0.165 in. (4.2 mm) deep, maximum] make them challenging to detect using nondestructive examination. Detection often requires destructively removing the cladding to the weld fusion line and examining the exposed base metal either by metallographic techniques or with liquid penetrant or magnetic particle testing methods.

1 Westinghouse Nuclear Energy Systems Report WCAP-7733, "Reactor Vessels Weld Cladding-Base Metal Interaction," by T.R. Mager, et al., April 1971.

2 Oak Ridge National Laboratory, Heavy Section Steel Technology Program, 6th Annual Information Meeting, April 25-26, 1972, Paper No. 5, PVRC Task Group Report on "Under-Clad Cracking," by R.D. Wylie, Southwest Research Institute.

3 Westinghouse Electric Company Report WCAP-15338, "A Review of Cracking Associated with Weld Deposited Cladding in Operating PWR Plants," by W. Bamford and R.D. Rishel, March 2000.

4 Babcock and Wilcox Nuclear Power Generation Report B&W 10013, "Study of lntergranular Separations in Low-Alloy Steel Heat Affected Zones Under Austenitic Stainless Steel Weld Cladding," by P.S. Ayres, et al., December 1971.

5 SA-508, "Specification for Quenched and Tempered Vacuum Treated Carbon and Alloy Steel Forgings for Pressure Vessels," does not cover plate. However, plate with a composition similar to SA-508 Class 2 has been reported to have underclad cracking.

From the results of certain analytical evaluations, it has been concluded that cracks of this nature will have no detrimental effect on the structural integrity of components under operating conditions. However, because uncertainties exist concerning assumptions made in the analyses, as well as concerning the combined effects of strain concentration and cyclic loading on crack growth, the presence of these cracks is undesirable, and they should be avoided to the extent practical. Accordingly, fabrication processes known to produce this condition should be controlled.

Welding processes known to induce underclad cracking, such as the high-heat-input processes indicated above, should not be used for cladding material susceptible to underclad cracking, such as SA-508 Class 2 forgings or plate material of similar composition. This restriction need not apply to the cladding of SA-533 Grade B Class I plate material made to fine-grain practice and heat-treated to refine the grain structure since such material has been demonstrated to exhibit resistance to underclad cracking.

Since welding procedures for a given cladding process may vary significantly among manufacturers, the essential variables of these procedures must be qualified to Section IX, "Welding Qualifications," of the ASME Boiler and. Pressure Vessel Code.[6] This qualification includes a test for soundness of the weldment, but the test is not adequate for establishing resistance to underclad cracking because it may be performed using material resistant to underclad cracking, such as SA-533 Grade B Class 1 plate, and because it is not designed to detect cracks that have the location and orientation of typical underclad cracking. Therefore, supplementary criteria are needed for the cladding procedure qualification, including suitable tests to demonstrate that underclad cracking is not induced.

When crack-susceptible materials are involved, the weld qualification test specimen should be made using material that is representative of production material. A postweld heat treatment comparable to the appropriate production heat treatment should be applied before any testing, because such a heat treatment may contribute to the formation or growth of cracks. The area examined must be sufficiently large to ensure that the test includes overlap regions where cracking occurs.

Although a standard test for determining susceptibility to underclad cracking does not exist at this time, several test methods developed for this purpose are considered satisfactory for determining the existence of cracks. One such test method includes the removal of cladding to the fusion line and examining the base material for cracks using one of the following examination methods: metallography, liquid penetrant, or magnetic particle. This is followed by progressive grinding and examination through the HAZ until the cracks are completely revealed.

An alternative test method includes the use of standard guided bend tests in which the bend specimens are oriented approximately parallel (deviations not greater than 15 degrees) to the direction of welding. In this test, the tensile face must be located at the weld-bead-overlap area.

Production weld cladding for safety-related components should comply with the fabrication requirements specified in Section III, "Nuclear Power Plant Components," as well as Section IX, of the ASME Boiler and Pressure Vessel Code. Complying with these requirements and with the supplementary criteria for the procedure qualification identified herein is considered reasonable assurance that underclad cracking will be avoided in production weld cladding. Deviation from the qualification procedure during production welding should be accompanied by additional assurance that underclad cracking has not resulted, such as the removal of a section of cladding followed by a suitable examination or a requalification of the procedure to include the actual conditions used in production.

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6 Copies of ASME standards discussed herein may be obtained from the American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990; telephone (800) 843-2763; http://www.asme.org/Codes/Publications//.

C. REGULATORY POSITION

Controls should be exercised to limit the occurrence of underclad cracking in low-alloy steel safety-related components clad with stainless steel. Welding processes that induce underclad cracking by generating excessive heating and promoting grain coarsening in the base metal should not be used for cladding any grade of material that has a known susceptibility to underclad cracking. Welding procedures used for cladding these grades of material should be qualified for use to demonstrate that underclad cracking is not induced. These controls need not be applied to the cladding of materials demonstrated to be resistant to underclad cracking, such as SA-533 Grade B Class 1 plate made to fine-grain practice and heat-treated to develop a fine-grained structure. Weld cladding practices used in the fabrication of low-alloy steel safety-related components should be conducted in accordance with the following guidelines:

1. For weld cladding of SA-508 Grade 2 forgings made to coarse-grain practice and plate material of similar composition, the following apply:
   a. High-heat-input welding processes that induce underclad cracking such as the submerged-arc wide-strip welding process and the submerged-arc 6-wire process should not be used.
   b. Weld cladding procedures should be qualified for use in accordance with Regulatory Position 2, below.

2. The weld cladding procedure described in Regulatory Position 1 should be qualified for use by a performance test to demonstrate that it does not induce excessive underclad cracking. The test should include the following:
   a. Base material for the test should be of the same grade as that to be used in production. A minimum of three representative heats of material should be tested. Where less than three heats of material are used in production, these heats may be tested in lieu of the three representative heats.
   b. The qualification block from which test specimens are to be taken should be of sufficient size and thickness to develop thermal restraint conditions typical of those developed in production welding.
   c. The qualification block from which test specimens are to be taken should be suitably postweld heat-treated at temperatures and times at least as great as those encountered in production heat treatment before removal of specimens.
   d. A minimum of two weld clad-overlap areas per test specimen should be evaluated.
   e. The following indications on any 1-in. length of evaluation test specimen should be the basis for rejection of the welding procedure:
      (1) any fissures greater than 0.030 inch (0.76 mm) in length or 0.010 inch (0.25 mm) in depth, or
      (2) more than three fissures 0.005 inch (0.13 mm) to 0.010 inch (0.25 mm) in depth.

3. Production welding should be monitored to verify compliance with the limitations on essential variables established by the procedure qualification. If the production welding procedure does not conform to these limitations, an examination for cracking should be performed on the production part from which a section of cladding has been removed, or the cladding procedure should be requalified in accordance with Regulatory Position 2, above.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this draft regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

The NRC has issued this draft guide to encourage public participation in its development. The NRC will consider all public comments received in development of the final guidance document. In some cases, applicants or licensees may propose an alternative or use a previously established acceptable alternative method for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with the applicable regulations for license applications, license amendment applications, and amendment requests.

REGULATORY ANALYSIS

Statement of the Problem

The NRC initially issued Regulatory Guide 1.43, "Control of Stainless Steel Weld Cladding of Low-Alloy Steel Components," in May 1973. The guidance does not reflect changes in the ASME Boiler and Pressure Vessel Code since 1973. Therefore, revision of this regulatory guidance is necessary to reflect updates in the ASME Code.

Objective

The objective of this regulatory action is to update the NRC's guidance for the control of stainless steel weld cladding of low-alloy steel components, consistent with changes in the ASME Code since May 1973.

Alternative Approaches

The NRC staff considered the following alternative approaches:

Do not revise Regulatory Guide 1.43.
Revise Regulatory Guide 1.43.

Alternative 1: Do Not Revise Regulatory Guide 1.43

Under this alternative, the NRC would not revise the guidance, and the current guidance would be retained. If the NRC does not take action, there would not be any changes in costs or benefit to the public, the licensees, or the NRC. However, the "no-action" alternative would not address identified concerns with the current version of the regulatory guide. The NRC would continue to review each application on a case-by-case basis. This alternative provides a baseline condition from which any other alternatives will be assessed.

Alternative 2: Revise Regulatory Guide 1.43

Under this alternative, the NRC would revise Regulatory Guide 1.43, taking into consideration the changes in the ASME Code.

One benefit of this action is that it would clarify the guidance and references to the ASME Code for applicants building new nuclear power plants, as well as for licensees.

The impact to the NRC would be the costs associated with preparing and issuing the regulatory guide revision. The impact to the public would be the voluntary costs associated with reviewing and providing comments to the NRC during the public comment period. The value to the NRC staff and applicants would be the benefits associated with enhanced efficiency and effectiveness in using a common guidance document as the technical basis for license applications and other interactions between the NRC and its regulated entities.

Conclusion

Based on this regulatory analysis, the NRC staff recommends revision of Regulatory Guide 1.43. The staff concludes that the proposed action will reduce unnecessary confusion when referencing the ASME Code. It could also lead to cost savings for the industry, especially with regard to applications for standard plant design certifications and combined licenses.