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DRAFT REGULATORY GUIDE

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DRAFT REGULATORY GUIDE DG-1224

(Proposed Revision 1 of Regulatory Guide 1.44, dated May 1973)

CONTROL OF THE PROCESSING AND USE OF STAINLESS STEEL

A. INTRODUCTION

General Design Criterion 1, "Quality Standards and Records," and Criterion 4, "Environmental and Dynamic Effects Design Bases," 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) require that components be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed and that they be designed to accommodate the effects of and be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accident conditions. Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 requires that measures be established to ensure materials control and control of special processes such as welding and heat treating and to ensure performance of reliable testing programs. This guide describes acceptable methods of implementing the above requirements with regard to control of the application and processing of stainless steel to avoid severe sensitization that could lead to stress-corrosion cracking. 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

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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. ML090750744.

regulations, to explain techniques that the staff uses in evaluating specific problems or postulated 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

Control of the application and processing of stainless steel to avoid severe sensitization is needed to diminish the numerous occurrences of stress-corrosion cracking in sensitized stainless steel components of nuclear reactors. Test data demonstrate that sensitized stainless steel is significantly more susceptible to stress-corrosion cracking than is nonsensitized (solution heat-treated) stainless steel. Of specific concern in this guide are the unstabilized austenitic stainless steels, which include American Iron and Steel Institute (AISI) Types 304 and 316, normally used for components of the reactor coolant system and other safety-related systems. This guide does not cover stabilized stainless steels (e.g., AISI Types 321 and 347), which also provide some protection against sensitization.

Process controls should be exercised during all stages of component manufacturing and reactor construction to minimize exposure of stainless steel to contaminants that could lead to stress-corrosion cracking. Since some degree of material contamination is inevitable during these operations, halogens and halogen-bearing compounds (e.g., die lubricants, marking compounds, and masking tape) should be avoided to the degree practical.

All cleaning solutions, processing compounds, degreasing agents, and other foreign materials should be completely removed at any stage of processing before any elevated temperature treatment and before hydrotests. Reasonable care should be taken to keep (1) fabrication and construction areas clean, (2) components protected and dry during storage and shipment, and (3) all crevices and small openings protected against contamination. Pickling of sensitized stainless steel should be avoided. Special precautions should be taken to avoid surface contamination with fluorides from welding rod coatings and fluxes. The quality of water used for final cleaning or flushing of finished surfaces during installation should be in accordance with Regulatory Guide 1.37, “Quality Assurance Requirements for Cleaning of Fluid Systems and Associated Components of Water-Cooled Nuclear Power Plants.”

Solution heat treating and testing should normally be performed on starting material. However, to ensure the proper solution heat-treated condition of the surface areas of finished components, it may be preferable to perform the solution heat treating and testing operation at a later stage of component manufacturing.

Solution heat treating should include cooling rates sufficiently rapid to prevent precipitation of carbides to a degree that the material is not susceptible to intergranular stress corrosion. Water quenching (used for simple shapes such as bars and plates) should produce an acceptable cooling rate. However, cooling by means other than water quenching is acceptable only when the cooling rate is sufficiently rapid to prevent sensitization. This determination is made by subjecting the material to a suitable intergranular corrosion test such as Practice E, “Copper-Copper Sulfate-Sulfuric Acid Test,” of American Society for

Testing and Materials (ASTM) A 262, "Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels."[1]

Practice E of ASTM A 262 and the accompanying screening test Practice A, "Oxalic Acid Etch Test," are considered suitable tests for verifying the nonsusceptibility of the material to intergranular stress corrosion. Although these accelerated tests use different environments than anticipated in reactors and do not provide information relating directly to susceptibility to stress-corrosion cracking in reactor environments, these tests do readily detect the presence of significant sensitization of the material, a condition that has been related to actual intergranular stress-corrosion attack in reactor environments. These specific tests are identified here because they are the only known tests endorsed by a consensus standard that includes acceptance criteria (acceptable-nonacceptable basis) for the material being tested. Alternate test methods that can be qualified are also acceptable.

Specimens for the intergranular corrosion tests from material with carbon content greater than 0.03 percent should be tested in the solution heat-treated condition. Specimens from material with carbon content of 0.03 percent or less should be tested after a sensitizing treatment of one hour at 677 °C (1,250 °F) plus or minus 14 °C (25 °F).

Controls should be maintained on the chemistry of the reactor coolant and auxiliary systems fluids to which the material is exposed. Chloride and fluoride ion concentrations should be specified to be less than 0.15 parts per million (ppm) at all times. Dissolved oxygen concentrations should be maintained below 0.10 ppm during periods when the material is at elevated temperatures. When the oxygen content regularly exceeds this level, such as occurs in boiling-water reactor coolants during normal operation, sensitization of material that is welded without subsequent solution heat treatment should be further controlled by limiting the carbon level in the material to 0.03 percent. Carbon level control is not needed for weld metal and castings with duplex structures since these product forms with normal carbon levels have demonstrated adequate resistance to intergranular attack. Carbon level control may not be required for piping if its diameters are sufficiently small (e.g., instrument lines and control rod drive hydraulic systems) that it could withstand a single failure without an accompanying loss-of-coolant accident as defined in Appendix A to 10 CFR Part 50.

Stainless steel subjected to sensitizing temperatures [425 to 815 °C (800 to 1,500 °F)] during fabrication (except during welding) should be retested with a suitable intergranular corrosion test (such as ASTM A 262) to demonstrate that the thermal treatment did not result in undue sensitization. Specimens for the retest should be subjected to a thermal treatment that duplicates the temperatures, number of cycles, holding time at each cycle, and minimum heating and cooling rate in the range of 425 to 815 °C (800 to 1,500 °F). If more than one cycle at only one temperature is to be used in production, one cycle with a holding time equivalent to the total time would be acceptable for testing purposes.

Under certain conditions material subjected to sensitizing temperatures [425 to 815 °C (800 to 1,500 °F)] during special processing may be acceptable for intended use (e.g., nitrided control rod drive material). These conditions should include, as a minimum, assurance of the following:

- The process is properly qualified and controlled to develop a consistent and uniform product, irrespective of heat of material and equipment used.
- Adequate documentation exists that the processed material will not develop intergranular stress corrosion during its service life. Adequate documentation should include actual service

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1 Copies of ASTM standards may be purchased from the American Society for Testing and Materials, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959; telephone (610) 832-9585. Purchase information is available through the ASTM Web site at http://www.astm.org.

experience and/or test data in simulated environments and operating conditions. Service experience should include positive evidence through destructive examination that intergranular stress corrosion did not occur.

All welding processes will result in some carbide precipitation in the weld metal and in the base metal heat-affected zone of stainless steel welds, but significant sensitization does not normally result when typical welding procedures and material chemistry are used and when no further heating of material occurs. However, there is evidence that atypical welding methods using very high heat input could result in stress-corrosion cracking in the heat-affected zone of the weld. To avoid this, the welding procedures and material chemistry (if necessary) should be controlled to prevent undue sensitization of the heat-affected zones of the weldments. Controls to prevent sensitization of the material during welding may include (1) avoiding welding practices that result in the generation of high heat, (2) maintaining low heat input by controlling current, voltage, and travel speed, (3) limiting interpass temperature, (4) using stringer bead techniques and avoiding excessive weaving, and (5) limiting the carbon level of the material where section thickness makes the material more prone to sensitization.

In addition, welding procedures[2] should be qualified by passing a suitable intergranular corrosion test in all cases where the procedure is used for welding stainless steel having a carbon level greater than 0.03 percent. The qualification test should be performed using base material with the maximum carbon content anticipated and the minimum and maximum thicknesses anticipated.

As a minimum, the qualification test should control the variables of heat input, interpass temperature, and welding techniques for specific section thicknesses.

C. REGULATORY POSITION

Unstabilized, austenitic stainless steel of the AISI Type 3XX series used for components that are part of (1) the reactor coolant pressure boundary, (2) systems required for reactor shutdown, (3) systems required for emergency core cooling, and (4) reactor vessel internals that are relied on to permit adequate core cooling for any mode of normal operation or under credible postulated accident conditions should meet the following criteria:

1. Material should be suitably cleaned and suitably protected against contaminants capable of causing stress-corrosion cracking during fabrication, shipment, storage, construction, testing, and operation of components and systems.

2. Material from which components and systems are to be fabricated should be solution heat treated[3] to produce a nonsensitized condition in the material.

3. Nonsensitization of the material[4] should be verified using ASTM A 262, "Standard Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steel," Practices A or E, or another method that can be demonstrated to show nonsensitization in austenitic stainless steel. Test

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[2] "Welding procedure" means procedures qualified in accordance with the rules of Section IX, "Welding Qualifications," of the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code.

[3] "Solution heat treated" means heating to a suitable temperature, holding at that temperature long enough to cause all carbides to enter into solution, and then cooling rapidly enough to keep the carbon in solution.

[4] Material of product forms with simple shapes not subject to distortion during heat treatment such as plate, sheet, bars, pipe, and tubes need not be tested provided that water quenching follows the solution heat treatment.

specimens should be selected from material subjected to each different heat treatment practice and from each heat.

4. Material subjected to sensitizing temperature in the range of 425 to 815 °C (800 to 1,500 °F), subsequent to solution heat treating in accordance with Regulatory Position 2 above and testing in accordance with Regulatory Position 3 above, should be L Grade material; that is, it should not have a carbon content greater than 0.03 percent. Exceptions are the following:
   a. material exposed to reactor coolant that has a controlled concentration of less than 0.10 ppm dissolved oxygen at all temperatures above 90 °C (200 °F) during normal operation; or
   b. material in the form of castings or weld metal with a ferrite content of at least 5 percent; or
   c. piping in the solution annealed condition whose exposure to temperatures in the range of 425 to 815 °C (800 to 1,500 °F) has been limited to welding operations, provided it is of sufficiently small diameter so that in the event of a credible postulated failure of the piping during normal reactor operation, the reactor can be shut down and cooled down in an orderly manner, assuming that the reactor coolant makeup system provides the only makeup.

5. Material subjected to sensitizing temperatures in the range of 425 to 815 °C (800 to 1,500 °F) during heat treating or processing other than welding, subsequent to solution heat treating in accordance with Regulatory Position 2 above, and testing in accordance with Regulatory Position 3 above, should be retested in accordance with Regulatory Position 3, to demonstrate that it is not susceptible to intergranular attack, except that retest is not required for the following:
   a. cast metal or weld metal with a ferrite content of 5 percent or more; or
   b. material with a carbon content of 0.03 percent or less that is subjected to temperatures in the range of 425 to 815 °C (800 to 1,500 °F) for less than one hour; or
   c. material exposed to special processing, provided that the processing is properly controlled to develop a uniform product and provided that adequate documentation exists of service experience and/or test data to demonstrate that the processing will not result in increased susceptibility to intergranular stress corrosion.

Specimens for the above retest should be taken from each heat of material and should be subjected to a thermal treatment representative of the anticipated thermal conditions that the production material will undergo.

6. Welding practices and, if necessary, material composition should be controlled to avoid excessive sensitization of base metal heat-affected zones of weldments. An intergranular corrosion test, such as specified in Regulatory Position 3 above, should be performed for each welding procedure to be used for welding material having a carbon content of greater than 0.03 percent.

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 1.44, "Control of the Use of Sensitized Stainless Steel," 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 the use of sensitized stainless steel, 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 1.44.
Revise Regulatory Guide 1.44.

Alternative 1: Do Not Revise Regulatory Guide 1.44

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 1.44

Under this alternative, the NRC would revise Regulatory Guide 1.44, 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 its 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 1.44. The staff concludes that the proposed action will reduce any 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.