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**REGULATORY GUIDE**

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Revision 4

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## REGULATORY GUIDE 1.31

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# CONTROL OF FERRITE CONTENT IN STAINLESS STEEL WELD METAL

## A. INTRODUCTION

### Purpose

This guide describes a method that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for controlling ferrite content in stainless steel weld metal.

### Applicable Rules and Regulations

Title 10 of the *Code of Federal Regulations*, Part 50, “Domestic Licensing of Production and Utilization Facilities” (10 CFR Part 50) (Ref. 1), Appendix A, “General Design Criteria for Nuclear Power Plants,” General Design Criterion (GDC) 1, “Quality Standards and Records,” requires that components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. GDC 14, “Reactor Coolant Pressure Boundary,” requires that the reactor coolant pressure boundary be designed, fabricated, erected, and tested so that it has an extremely low probability of abnormal leakage, rapidly propagating failure, or gross rupture. Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants,” to 10 CFR Part 50 requires that a quality assurance program be applied to the design, construction, operation, and testing of structures, systems, and components. Appendix B also requires that measures be established to ensure that special processes, including welding, are controlled and accomplished by qualified personnel using qualified procedures and that proper process monitoring is performed.

### Purpose of Regulatory Guides

The 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 accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions that differ from those set forth in regulatory guides will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

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Electronic copies of this regulatory guide, previous versions of this guide, and other recently issued guides are available through the NRC’s public Web site under the Regulatory Guides document collection of the NRC Library at <http://www.nrc.gov/reading-rm/doc-collections/>. The regulatory guide is also available through the NRC’s Agencywide Documents Access and Management System (ADAMS) at <http://www.nrc.gov/reading-rm/adams.html>, under ADAMS Accession No. ML13211A485. The regulatory analysis may be found in ADAMS under Accession No. ML13211A490 and the staff responses to the public comments on DG-1279 may be found under ADAMS Accession No. ML13211A483.

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## **Paperwork Reduction Act**

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**

### **Reason for Revision**

To achieve control of ferrite content in stainless steel welds, the original version of this guide, Safety Guide 31, "Control of Stainless Steel Welding," issued August 1972 (Ref. 2), provided guidance to test production welds. This guidance was retained in Revision 1 of the Safety Guide, which was issued June 1973 as Regulatory Guide 1.31, "Control of Ferrite Content in Stainless Steel Weld Metal" (Ref. 3). Revision 2 (issued May 1977) and Revision 3 (issued April 1978) to this guide were based on recommendations from an NRC/industry study group. Revision 2 of this guide replaced the guidance for testing production welds in Revision 1 with guidance for process control through testing weld test pads. These changes considerably reduced the testing effort needed to control delta ferrite in welds.

This revision (Revision 4) references the latest consensus standards. It supplements the American Society of Mechanical Engineers (ASME) Code requirements to ensure control of delta ferrite in welds in austenitic stainless steel core support structures, reactor internals, and Class 1, 2, and 3 components. Also, the Appendix of the previous version has been removed and incorporated into the relevant specifications that are referenced in this guide.

### **Background**

Inspection of some welds in austenitic stainless steel components of nuclear reactors has revealed the presence of microfissures. Further investigations related the presence of the microfissures to the low delta ferrite content of the deposited weld metal. Since microfissures in austenitic welds may have an adverse effect on the integrity of components, the control of weld deposits to ensure the presence of delta ferrite in these welds is advisable.

Because licensees and other representatives of the nuclear industry believed that adequate control of filler metal ferrite content would consistently provide sound weld deposits with an absence of microfissures, ASME, the American National Standards Institute (ANSI), and the NRC formed a cooperative study group to investigate the problem and the alternatives that would ensure adequate control of ferrite content. The study group analyzed data from welds prepared by eight different procedures. The group analyzed about 1,500 test results and made recommendations to both ASME and the NRC on how testing of production welds could be reduced without sacrificing control of the ferrite content. Welding Research Council (WRC) Bulletin Number 318 (Ref. 4) provides a summary of the work performed, round robin test results including statistical analysis of the reproducibility of ferrite number measurements, and the study group's recommendations.

The provisions of the ASME Boiler and Pressure Vessel Code (ASME Code), Section III (Ref. 5), incorporated by reference into the NRC regulations, require compliance with one of two alternative methods (either a chemical analysis method or a magnetic measurement method) to control delta ferrite in weld metal filler materials. The NRC staff does not consider the use of the chemical analysis method for every welding process adequate by itself to ensure control of delta ferrite in production welds. The staff

positions in this guide are intended to supplement the ASME Code requirements to ensure control of delta ferrite in welds in austenitic stainless steel core support structures, reactor internals, and Class 1, 2, and 3 components.

The staff concludes that ferrite content in the weld metal, as depicted by a ferrite number, should be between 5 and 20. This lower limit provides sufficient ferrite to avoid microfissuring in welds, whereas the upper limit provides a ferrite content adequate to offset dilution and reduce thermal aging effects.

### **Harmonization with International Standards**

The NRC has an interest in facilitating the harmonization of standards used domestically and internationally. This regulatory guide endorses standards from the American Welding Society (AWS) and ASME, which publish standards that are used internationally for a wide range of materials, products, systems, and services. The NRC staff reviewed guidance from the International Atomic Energy Agency (IAEA), but did not identify any standards related to this regulatory guide that provided useful information to NRC staff, applicants, or licensees.

### **Documents Discussed in Staff Regulatory Guidance**

This regulatory guide endorses, in part, the use of one or more codes or standards developed by external organizations, and other third party guidance documents. These codes, standards and third party guidance documents may contain references to other codes, standards or third party guidance documents (“secondary references”). If a secondary reference has itself been incorporated by reference into NRC regulations as a requirement, then licensees and applicants must comply with that standard as set forth in the regulation. If the secondary reference has been endorsed in a regulatory guide as an acceptable approach for meeting an NRC requirement, then the standard constitutes a method acceptable to the NRC staff for meeting that regulatory requirement as described in the specific regulatory guide. If the secondary reference has neither been incorporated by reference into NRC regulations nor endorsed in a regulatory guide, then the secondary reference is neither a legally-binding requirement nor a “generic” NRC approval as an acceptable approach for meeting an NRC requirement. However, licensees and applicants may consider and use the information in the secondary reference, if appropriately justified and consistent with current regulatory practice, consistent with applicable NRC requirements such as 10 CFR 50.59.

## **C. STAFF REGULATORY GUIDANCE**

### **1. Verification of Delta Ferrite Content of Filler Materials**

Prior to production usage, the delta ferrite content of test weld deposits from each lot and each heat of weld filler metal procured for the welding of austenitic stainless steel core support structures, reactor internals, and Class 1, 2, and 3 components should be verified for each process to be used in production. The definition of heat and lot of material in ASME Code, Section III, NB-2420 can be used.

For all processes, delta ferrite verification should be performed through tests using magnetic measuring devices on undiluted weld deposits. For submerged arc welding processes, the verification tests for each wire and flux combination may be made on a production weld or simulated production weld. All other delta ferrite weld filler verification tests should be made on weld pads that contain undiluted layers of weld metal.

Delta ferrite determinations are not necessary for type 16-8-2 filler metal in ASME Code Section II filler metal specifications SFA-5.4, "Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding," SFA-5.9, "Specification for Bare Stainless Steel Welding Electrodes and Rods" and SFA-5.22, "Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding," or for filler metal used for weld metal cladding (Ref. 6).

Alternatively, delta ferrite determinations for consumable inserts, electrodes, rod, or wire filler metal used with the gas tungsten arc welding process, and deposits made with the plasma arc welding process, may be predicted from their chemical composition of the undiluted weld deposit by using a constitutional diagram in the applicable filler metal specification (e.g., WRC-1992 diagram for stainless steel weld metal in ASME Code Section III, Figure NB-2433.1.1). Use of the magnetic test method is also acceptable to the staff for determining delta ferrite content in welds fabricated with gas tungsten arc welding and plasma arc welding.

## 2. Ferrite Measurement

The NRC staff considers the procedures for pad preparation and ferrite measurement in SFA-5.4 of Section II of the ASME Code acceptable.

## 3. Instrumentation

The weld pad should be examined for ferrite content by using a magnetic measuring instrument that has been calibrated against a Magnegage in accordance with AWS A4.2, "Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal" (Ref. 7). The Magnegage should have been previously calibrated in accordance with AWS A4.2 using primary standards as defined therein.

## 4. Acceptability of Test Results

Weld pad test results showing an average ferrite number from 5 to 20 indicate that the filler metal is acceptable for the production welding of Class 1, 2, and 3 austenitic stainless steel components, reactor internals, and core support structures.

## 5. Quality Assurance

The applicable provisions of Appendix B to 10 CFR Part 50 should be used to verify compliance with requirements for delta ferrite of each lot and each heat of weld filler metal as described herein.

## D. IMPLEMENTATION

The purpose of this section is to provide information on how applicants and licensees<sup>1</sup> may use this guide and information regarding the NRC's plans for using this regulatory guide. In addition, it describes how the NRC staff complies with 10 CFR 50.109, "Backfitting," and any applicable finality provisions in 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

### Use by Applicants and Licensees

Applicants and licensees may voluntarily<sup>2</sup> use the guidance in this document to demonstrate compliance with the underlying NRC regulations. Methods or solutions that differ from those described in this regulatory guide may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged.

Licensees may use the information in this regulatory guide for actions that do not require NRC review and approval, such as changes to a facility design under 10 CFR 50.59, "Changes, Tests, and Experiments." Licensees may use the information in this regulatory guide or applicable parts to resolve regulatory or inspection issues.

### Use by NRC Staff

The NRC staff does not intend or approve any imposition or backfitting of the guidance in this regulatory guide. The NRC staff does not expect any existing licensee to use or commit to using the guidance in this regulatory guide, unless the licensee makes a change to its licensing basis. The NRC staff does not expect or plan to request licensees to voluntarily adopt this regulatory guide to resolve a generic regulatory issue. The NRC staff does not expect or plan to initiate NRC regulatory action that would require the use of this regulatory guide. Examples of such unplanned NRC regulatory actions include issuance of an order requiring the use of the regulatory guide, requests for information under 10 CFR 50.54(f) as to whether a licensee intends to commit to use of this regulatory guide, generic communication, or promulgation of a rule requiring the use of this regulatory guide without further backfit consideration.

During regulatory discussions on plant specific operational issues, the staff may discuss with licensees various actions consistent with staff positions in this regulatory guide, as one acceptable means of meeting the underlying NRC regulatory requirement. Such discussions would not ordinarily be considered backfitting even if prior versions of this regulatory guide are part of the licensing basis of the facility. However, unless this regulatory guide is part of the licensing basis for a facility, the staff may not represent to the licensee that the licensee's failure to comply with the positions in this regulatory guide constitutes a violation.

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1 In this section, "licensees" refers to licensees of nuclear power plants under 10 CFR Parts 50 and 52, and "applicants" refers to applicants for licenses and permits for (or relating to) nuclear power plants under 10 CFR Parts 50 and 52, and applicants for standard design approvals and standard design certifications under 10 CFR Part 52.

2 In this section, "voluntary" and "voluntarily" mean that the licensee is seeking the action of its own accord, without the force of a legally binding requirement or an NRC representation of further licensing or enforcement action.

If an existing licensee voluntarily seeks a license amendment or change and (1) the NRC staff's consideration of the request involves a regulatory issue directly relevant to this new or revised regulatory guide and (2) the specific subject matter of this regulatory guide is an essential consideration in the staff's determination of the acceptability of the licensee's request, then the staff may request that the licensee either follow the guidance in this regulatory guide or provide an equivalent alternative process that demonstrates compliance with the underlying NRC regulatory requirements. This is not considered backfitting as defined in 10 CFR 50.109(a)(1) or a violation of any of the issue finality provisions in 10 CFR Part 52.

Additionally, an existing applicant may be required to comply with new rules, orders, or guidance if 10 CFR 50.109(a) (3) applies.

If a licensee believes that the NRC is either using this regulatory guide or requesting or requiring the licensee to implement the methods or processes in this regulatory guide in a manner inconsistent with the discussion in this Implementation section, then the licensee may file a backfit appeal with the NRC in accordance with the guidance in NUREG-1409, "Backfitting Guidelines," (Ref. 8) and the NRC Management Directive 8.4, "Management of Facility-Specific Backfitting and Information Collection" (Ref. 9).

## REFERENCES<sup>3</sup>

1. U.S. Code of Federal Regulations (CFR) “Domestic Licensing of Production and Utilization Facilities,” Part 50, Chapter 1, Title 10, “Energy”
2. Safety Guide 31, “Control of Stainless Steel Welding,” U.S. Nuclear Regulatory Commission, Washington, DC.
3. Regulatory Guide 1.31, “Control of Ferrite Content in Stainless Steel Weld Metal,” U.S. Nuclear Regulatory Commission, Washington, DC.
4. Welding Research Council (WRC) Bulletin Number 318, “Factors Influencing the Measurement of Ferrite Content in Austenitic Stainless Steel Weld Metal Using Magnetic Instruments,” W. W. Pickering, E. S. Robitz, and D. M. Vandergriff, September 1986 (ISBN#1-58145-317-5).<sup>4</sup>
5. American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, “Rules for Construction of Nuclear Facility Components,” American Society of Mechanical Engineers (as incorporated by reference in 10 CFR 50.55a). 5
6. ASME Boiler and Pressure Vessel Code, Section II, Part C, “Specifications for Welding Rods, Electrodes, and Filler Metals,” American Society of Mechanical Engineers, (as approved by the ASME in those Editions and Addenda of the ASME Boiler and Pressure Vessel Code, Section III, Subsection NCA-1140 which are incorporated by reference into 10 CFR 50.55a).
7. Welding Society (AWS) A4.2, “Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal,” AWS, (as approved by the ASME in those Editions and Addenda of the ASME Boiler and Pressure Vessel Code, Section III, which are incorporated by reference into 10 CFR 50.55a.). 6
8. NUREG 1409, “Backfitting Guidelines,” U.S. Nuclear Regulatory Commission, Washington, DC.

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3 Publicly available NRC published documents are available electronically through the NRC Library on the NRC’s public Web site at <http://www.nrc.gov/reading-rm/doc-collections/> and also available through the NRC’s Agencywide Documents Access and Management System (ADAMS) at <http://www.nrc.gov/reading-rm/adams.html>. The documents can also be viewed online or printed for a fee in the NRC’s Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD. For problems with ADAMS, contact the PDR staff at 301-415-4737 or (800) 397-4209; fax (301) 415-3548; or e-mail [pdr.resource@nrc.gov](mailto:pdr.resource@nrc.gov).

4 This reference is available for purchase at the Welding Research Council (WRC) website at <http://www.forengineers.org/wrc/> or by contacting WRC at P.O. Box 201547, Shaker Heights, OH 44120.

5 Copies of American Society of Mechanical Engineers (ASME) standards may be purchased from ASME, Three Park Avenue, New York, NY 10016-5990; telephone (800) 843-2763. Purchase information is available through the ASME Web-based store at <http://www.asme.org/Codes/Publications/>.

6 Publications of the American Welding Society (AWS) may be obtained through the AWS Website at <http://www.aws.org/w/a> or by contacting the AWS at 8669 Doral Boulevard, Suite 130 Doral, FL.

9. Management Directive 8.4, "Management of Facility-Specific Backfitting and Information Collection," U.S. Nuclear Regulatory Commission, Washington, DC.