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Revision 3
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REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

REGULATORY GUIDE 1.31

CONTROL OF FERRITE CONTENT IN STAINLESS STEEL WELD METAL

A. INTRODUCTION

General Design Criterion 1, "Quality Standards and Records," of Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 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. Criterion 14, "Reactor Coolant Pressure Boundary," of Appendix A requires that the reactor coolant pressure boundary be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure, and of gross rupture. Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants," to 10 CFR Part 50 requires that a quality assurance program be applied to the design, construction, and operation 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 be performed.

This guide describes a method acceptable to the NRC staff for implementing these requirements with regard to the control of welding in fabricating and joining safety-related austenitic stainless steel components and systems in light-water-cooled nuclear power plants. The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

B. DISCUSSION

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.

As part of achieving this control, recommendations to test production welds were made in the original version of this guide (Safety Guide 31, "Control of Stainless Steel Welding"), and these recommendations were retained in Revision 1. 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, a cooperative study group was formed by ASME, ANSI, and NRC 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. About 1500 test results were analyzed, and recommendations were made to both ASME and NRC on how testing of production welds could be reduced without sacrifice of ferrite content control. Revision 2 and this Revision 3 are based on those recommendations. At present, the ASME Code* provisions incorporated by reference into the NRC regulations require compliance with one of two alternative methods for control of delta ferrite in weld metal filler materials; either a chemical analysis method or a magnetic measurement method. The NRC staff does not consider either method adequate

* Lines indicate substantive changes from previous issue.

* Winter 1976 Addenda, Section III, "Nuclear Power Plant Components," ASME Boiler and Pressure Vessel Code. Copies may be obtained from the American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, New York 10017.

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Comments and suggestions for improvements in these guides are encouraged at all times, and guides will be revised, as appropriate, to accommodate comments and to reflect new information or experience. This guide was revised as a result of substantive comments received from the public and additional staff review.

Comments should be sent to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Branch.

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by itself to ensure controlled delta ferrite in production welds. The recommendations of 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 and Class 1 and 2 components.

The recommendations for testing of production welds in Revision 1 of this guide have been replaced by recommendations for process control by testing of weld test pads. These changes will considerably reduce the testing effort needed to control delta ferrite in welds.

The staff recommends that ferrite content in the weld filler metal as depicted by a ferrite number (FN) 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.

C. REGULATORY POSITION

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 and Class 1 and 2 components should be verified for each process to be used in production.

It is not necessary to make delta ferrite determinations for SFA-5.4 type 16-8-2 weld metal or for filler metal used for weld metal cladding. 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 using an applicable constitutional diagram to demonstrate compliance. Delta ferrite verification should be made for all other processes by 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.

2. Ferrite Measurement

Appendix A to this guide contains extracts from a future edition of the American Welding Society's AWS A5.4, "Specification for Corrosion-Resisting

* This specification has been recommended by the Subcommittee on Welding of Stainless Steels of the High Alloys Committee of the Welding Research Council and has been approved by the American Welding Society (AWS). It is expected to be published as AWS A5.4-78.

Chromium and Chromium-Nickel Steel Covered Welding Electrodes,"** which describes a procedure for pad preparation and ferrite measurement. The NRC staff considers this procedure acceptable for use with covered electrodes.

3. Instrumentation

The weld pad should be examined for ferrite content by a magnetic measuring instrument which has been calibrated against a Magnegage in accordance with American Welding Society Specification AWS A4.2-74, "Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal."** The Magnegage should have been previously calibrated in accordance with AWS A4.2-74 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 production welding of Class 1 and 2 austenitic stainless steel components and core support structures.

The upper limit of 20 may be waived for (a) welds that do not receive postweld stress relief heat treatment or welds for which such postweld stress relief treatment is conducted at temperatures less than 900°F, (b) welds that are given a solution annealing heat treatment, and (c) welds that employ consumable inserts.

5. Quality Assurance

The applicable provisions of 10 CFR Part 50, Appendix B, should be used in verifying compliance with requirements for delta ferrite as described herein.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which the applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the method described herein will be used in the evaluation of submittals in connection with construction permit applications docketed after October 1, 1978.

If an applicant wishes to use this regulatory guide in developing submittals for applications docketed on or before October 1, 1978, the pertinent portions of the application will be evaluated on the basis of this guide.

**Copies may be obtained from the American Welding Society, 2501 N.W. 7th Street, Miami, Florida 33125.

APPENDIX A

The following is mainly extracted from a future edition of the American Welding Society's (AWS) "Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes," which the AWS plans to publish as AWS A5.4-78.* This material describes a procedure for weld pad preparation and ferrite measurement of covered electrode** deposits.

EXTRACT:

A4.10 When it is desired to measure ferrite content, the following procedure is recommended:

A4.10.1 Weld pads as detailed in Figure 4 are prepared as prescribed in paragraphs A4.10.2 through A4.10.4.

A4.10.2 The weld pad shall be built up between two copper bars laid parallel on the base plate by depositing single weld bead layers, one on top of the other, to a minimum height of 13 mm ($\frac{1}{2}$ in.). The spacing between the copper bars for the size of the electrode being tested shall be as specified in Figure 4. An optional welding fixture is shown in Figure 5. If carbon steel is used as the base plate, the weld pad shall be built up to a minimum height of 16 mm ($\frac{5}{8}$ in.).

* When published, copies of AWS A5.4-78 may be purchased from the American Welding Society, 2501 N.W. 7th Street, Miami, Florida 33125.

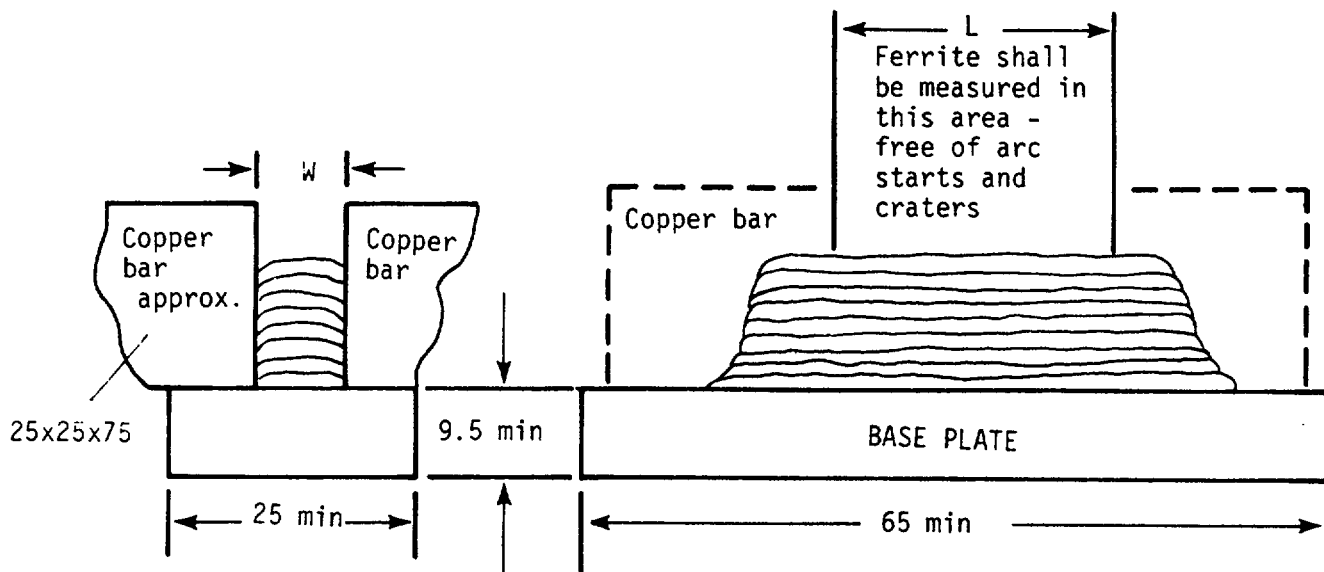
** Note: The U.S. customary units in this specification are given as equivalent values to the SI units. The standard sizes and dimensions used in the two systems are not identical and for this reason conversion from a standard size of dimension in one system will not always coincide with the standard size of dimension in the other. Suitable conversions encompassing standard sizes of both can be made if appropriate tolerances are applied in each case. The SI values (including tolerances) given here for filler metal diameter, length, and package size were selected to fit the product sizes which presently are U.S. standards. Tolerances are used in some cases in this specification but not in others. In those cases where no tolerances are given, the values are those that would be obtained if the measurements were taken in SI units. In this specification, a covered electrode is defined as follows: Covered Electrode—A composite filler-metal electrode consisting of a core of a bare electrode or metal cored electrode to which a covering sufficient to provide a slag layer on the weld metal has been applied. The covering may contain materials providing such functions as shielding from the atmosphere, deoxidation, and arc stabilization and can serve as a source of metallic additions to the weld.

A4.10.3 The welding current used for the size of the electrode being tested may be as specified in Figure 4 and the arc length shall be as short as practicable. The weld bead layers may be deposited with a weave, if necessary, to fill the space between the copper bars. The arc shall not be allowed to impinge on the copper bars. The welding direction for each pass shall be alternated and the weld stops and starts shall be located at the ends of the weld buildup. Each pass shall be cleaned prior to depositing the next weld bead. The maximum interpass temperature shall be 95°C (200°F).** Between passes, the weld pad may be cooled by quenching in water not sooner than 20 seconds after the completion of each pass. The last pass shall be air-cooled to below 430°C (800°F) prior to quenching in water.

A4.10.4 The completed weld pad shall be draw filed, machined, or surface ground to provide sufficient finished surface to make the required ferrite readings. Draw filing or its equivalent filing method shall be performed with a 360 mm (14 in.)** mill bastard file held on both sides of the weld with the long axis of the file perpendicular to the long axis of the weld. The file should preferably not have been previously used on ferritic material and should be free from loosely adhering materials if previously used. Draw filing shall be accomplished by smooth forward and backward strokes along the length of the weld while applying a firm downward pressure. Crossfiling shall not be permitted. The finished machined, ground, or filed surface shall be smooth with all traces of weld ripple removed and shall be continuous in the length where measurements are to be taken. The width of the prepared surface shall not be less than 3 mm ($\frac{1}{8}$ in.).**

A4.10.5 A total of six ferrite readings shall be taken on the prepared surface along the longitudinal axis of the weld pad with an instrument calibrated in accordance with the procedures specified in AWS A4.2, "Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal" (latest edition).

A4.10.6 The six readings obtained shall be averaged to a single value for conversion to Ferrite Number.



All dimensions in millimetres.

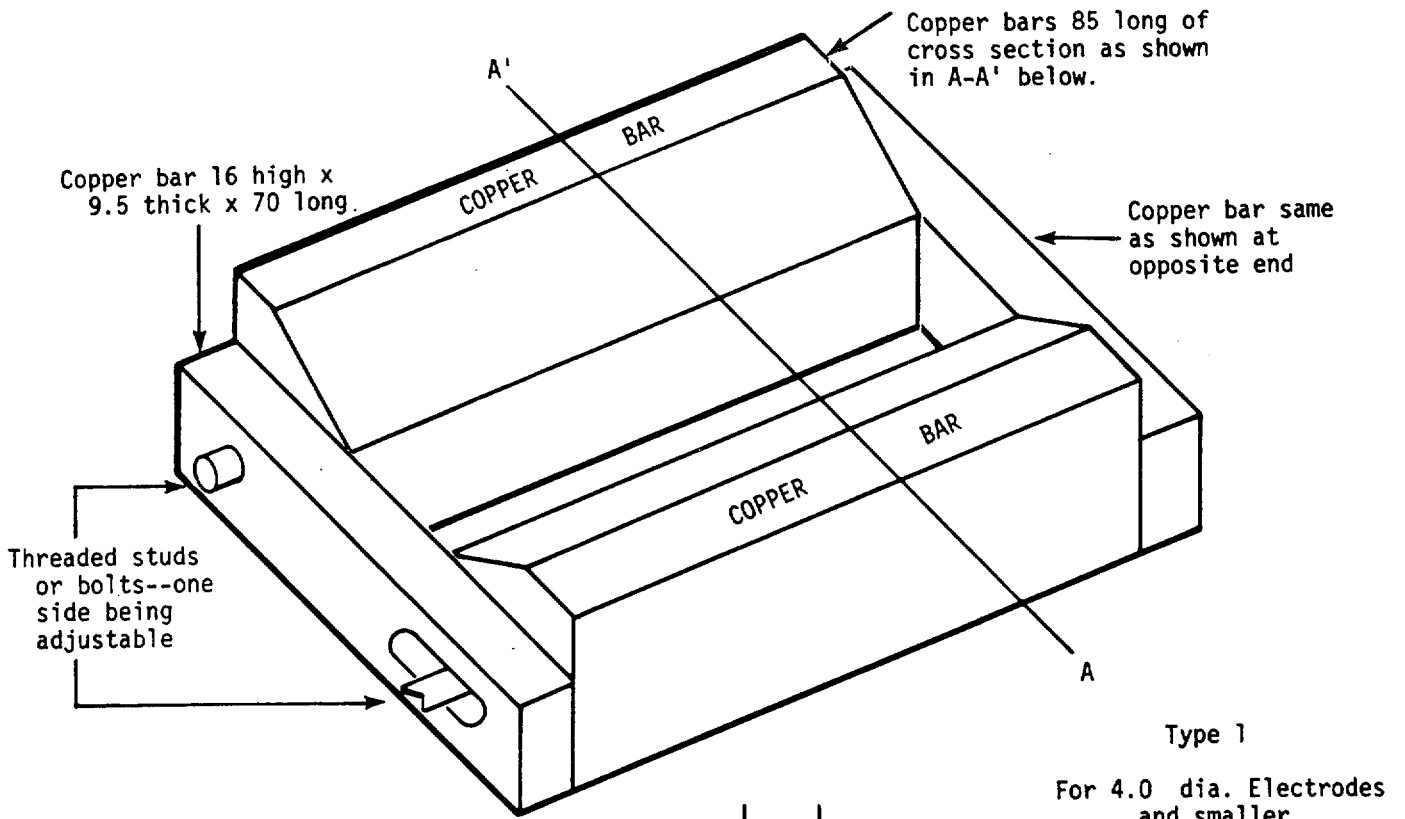
U.S. EQUIVALENTS *

mm	in.
1.6	1/16
2.0	5/64
2.4	3/32
3.2	1/8
4.0	5/32
4.8	3/16
6.4	1/4
6	0.25
8	0.3
9.5	3/8
10	0.4
13	0.5
15	0.6
18	0.7
25	1
30	1-1/4
40	1-1/2
65	2-1/2
75	3

Electrode diameter (mm)	Welding current (amperes)	In drawing above (approx. mm)	
		W	L
1.6	35-45	6	30
2.0	45-55	6	30
2.4	65-75	8	40
3.2	90-100	10	40
4.0	120-140	13	40
4.8	165-185	15	40
6.4	240-260	18	40

* See Editor's Note on Page 1.31-3.

Fig 4 - Details of Weld Pad for Ferrite Test



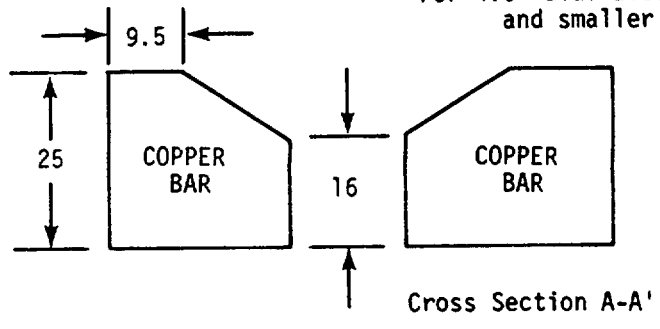
Type 1

For 4.0 dia. Electrodes and smaller

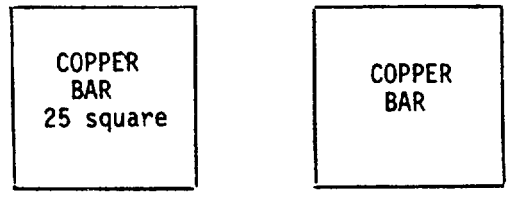
Note: All dimensions are in millimetres.

U.S. EQUIVALENTS*

mm	in.
4.0	5/32
4.8	3/16
9.5	3/8
16	5/8
25	1
70	2-3/4
85	3-3/8



This design allows increased visibility, making it easier to hold a short arc length.



Type 2

For 4.8 & larger welding electrodes and for any pads on carbon steel base plate

* See Editor's Note on Page 1.31-3.

Fig. 5 - Optional Welding Fixture for Welding Ferrite Test Pads