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U.S. ATOMIC ENERGY COMMISSION

REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.34

CONTROL OF ELECTROSLAG WELD PROPERTIES

A. INTRODUCTION

General Design Criterion 1, "Quality Standards and Records," of Appendix A to 10 CFR Part 50, "General Design Criteria for Nuclear Power Plants," requires that structures, systems, and components important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety function to be performed. Appendix B to 10 CFR Part 50, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," requires that measures be established to assure materials control and control of special processes such as welding, and that proper testing be performed. This guide describes an acceptable method of implementing these requirements with regard to the control of weld properties when fabricating electroslag welds for nuclear components made of ferritic or austenitic materials. This guide applies to light water reactors. The Advisory Committee on Reactor Safeguards has been consulted concerning this guide and has concurred in the regulatory position.

B. DISCUSSION

The American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section III, "Nuclear Power Plant Components,"[1] specifies certain requirements associated with manufacturing Class 1 and 2 components. Although not presently within the scope of Section III, welds for core support structures should, as a minimum, meet the requirements specified for Class 1 components.

Procedure Qualifications

Section III[2] requires adherence to ASME Boiler and Pressure Vessel Code Section IX, "Welding Qualifications,"[3] which includes the requirements for the procedure qualification for welds. Review of the requirements of the procedure qualification stated in Section IX indicates that supplementary requirements are desirable to provide assurance of adequate weld metal properties when the electroslag welding process is used. The assurance of satisfactory electroslag welds for low-alloy steel and stainless steel can be increased by maintaining a weld metal solidification (dendritic) pattern with a strong intergranular bond in the center of the weld. A number of electroslag welding process variables, such as slag pool depth, electrode feed rate and oscillation, current, voltage, and slag conductivity, have been shown to influence the weld metal solidification pattern. If the combination of process variables results in a deep pool of molten weld metal, the crystalline (dendritic) growth direction from the pool sides will join at an obtuse angle in the center of the weld and cracks may develop because of the weaker centerline bond between dendrites. Section I - I in Figure A of this guide illustrates the dendritic growth pattern. A combination of process variables resulting in a shallow pool of molten weld metal will promote a dendritic growth pattern with an acute joining angle and will result in a strong centerline bond. Acceptable welds should show a dendritic freezing pattern with a joining angle of less than 90 degrees in the weld center.

Tests should be made to assure that the acceptable weld metal solidification pattern specified above is obtained and that unacceptable patterns will not result. The use of a macro-etch examination is a satisfactory technique to determine the weld solidification pattern, and it should be included in the procedure qualification.

Section III, as modified by the Summer 1972 Addenda, requires as part of the procedure qualification for low-alloy steel welds that dropweight tests be made

[1] Copies may be obtained from American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, New York 10017.

[2] ASME B&PVC, Section III and Summer 1972 Addenda to Section III.

[3] ASME B&PVC, Section IX and Code Case 1355-3.

to determine the reference temperature (RT_{NDT}) for base metal, the heat-affected zone (HAZ), and the weld metal for Class 1 vessels. For Class 2 vessels, Section III states that the need for impact-testing should be determined by the owner and included in the design specifications. Experience has shown that the reference temperature for the quenched and tempered (Q&T) low-alloy steel electroslag weld metal is generally higher than for the adjacent base metal, and the weld metal establishes the minimum pressurization temperature instead of the base metal. To provide a measure of assurance that the weld metal has responded adequately to the Q&T heat treatment and to obtain a reference temperature, the procedure qualification should specify that impact-testing as required by Section III be included for Class 2 vessels. All results of the above tests and examinations should be included in a certified qualification test report.

Production Welds

The procedure qualification by itself does not assure that low-alloy steel production welds will meet the weld solidification pattern and mechanical property requirements specified in the procedure qualification. To assure that welds do comply, it is necessary that the production welds themselves be examined.

Where the electroslag welding process is used for longitudinal welds in low-alloy steel vessels, it is customary to continue the welding process into prolongations to the base metal. These prolongations contain both base metal and weld metal and provide representative samples for testing the mechanical properties of the base metal and the weld metal. The weld solidification pattern can be determined from weld samples taken from these prolongations. A macro-etch test on a weld center sample taken across the weld from base metal to base metal in the direction of the weld progression, as shown in Figure A of this guide, would be an acceptable method of verifying that the specified solidification pattern has been obtained and this test should be made. An acceptable alternative to the macro-etch test for assuring the soundness of the center weld metal would be to perform an impact test with the specimen notch located at the weld center as shown in Figure A of this guide.

Section III, as modified by the Summer 1972 Addenda, specifies requirements for low-alloy weld metal, but it does not specifically cover the situation where the weld is Q&T heat treated. Section III does require that material having its mechanical properties enhanced by a heat treatment must subsequently be tested to assure the effectiveness of the heat treatment. To provide this assurance for low-alloy steel electroslag production welds, the mechanical properties of the weld metal should be determined from the weld prolongation by tests similar to those required for the Q&T base metal. For Class 2 vessels it would not be necessary to test all electroslag weld seams, but at least one weld should be tested for each shell course.

Industry experience with electroslag welded stainless steel components has shown that cracking in the weld solidification region is not a problem when the process is properly qualified and controlled. In addition, the weld metal structure and mechanical properties are generally acceptable. To assure that the production welds are satisfactory, the welding process variables specified in the procedure qualification should be monitored during the welding process.

C. REGULATORY POSITION

Electroslag welds for core support structures should comply with the fabrication requirements specified for Section III[2] Class 1 components. Electroslag weld fabrication for core support structures and Class 1 and 2 vessels and components should comply with Section III and Section IX[3] supplemented by the following:

1. The procedure qualification[3] for low-alloy steel and stainless steel welding should require that:

a. Process variables such as slag pool depth, electrode feed rate and oscillation, current, voltage, and slag conductivity be selected to produce a solidification pattern (dendritic grain pattern) with a joining angle of less than 90 degrees in the weld center;

b. A macro-etch test be performed in the longitudinal weld direction of the center plane across the weld from base metal to base metal as shown in Figure A of this guide. The test should verify that the desired solidification pattern resulting from regulatory position 1.a. above has been obtained and that the weld is free of unacceptable fissures or cracks; and

c. Impact testing be specified for Class 2 low-alloy steel vessels in accordance with paragraph NC-2310 of Section III.[2]

2. The results of the tests required by regulatory position 1. above should be included in the certified qualification test report.

3. For longitudinal production welds of low-alloy steel vessels, material containing base metal and weld metal taken from weld prolongations should be tested as follows:

a. Tensile and impact tests similar to those required for the base metal by paragraph NB-3211(d) of Section III should be made to determine the mechanical properties of the quenched and tempered weld metal;

b. To verify that the specified weld solidification pattern has been obtained and that the weld center is sound, one of the following methods should be used:

(1) A macro-etch test similar to requirement of regulatory position 1.b. above, or

(2) Impact testing with the specimen notch located at the weld center as shown in Figure A of this guide.

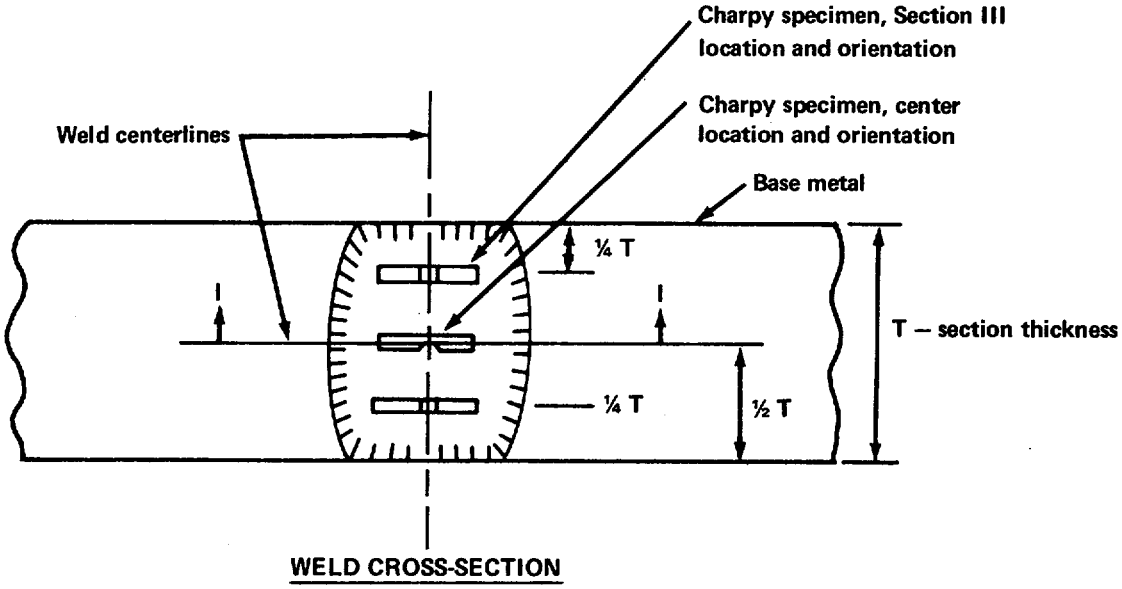
c. The tests specified in regulatory positions 3.a. and 3.b. above should be applied to:

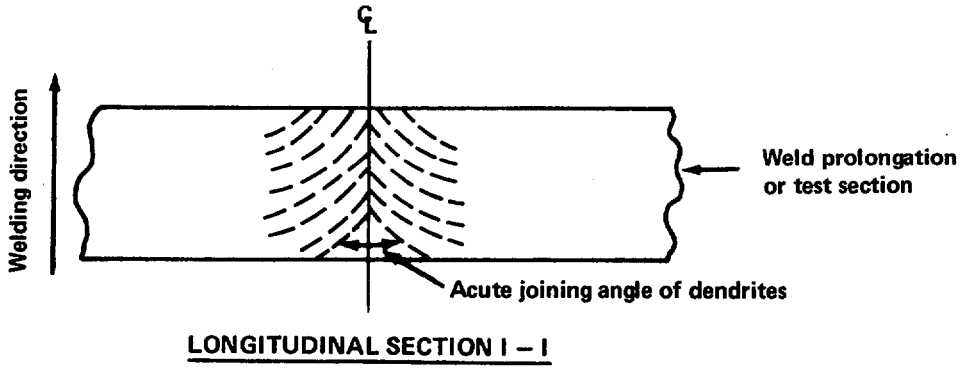
(1) Each of the welds for Class 1 vessels,

(2) One weld per shell course for Class 2 vessels.

4. For production welds for austenitic stainless steel core support structures and fluid system components, the production welding should be monitored to verify compliance with the limits for the process variables specified in the procedure qualification.

5. In the event that properties obtained from tests identified in regulatory positions 3. and 4. above are not acceptable, additional procedure qualifications should be performed in accordance with regulatory position 1. above.





WELD CROSS-SECTION SHOWING SOLIDIFICATION PATTERN AND CHARPY TEST SPECIMENS

FIGURE A