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REGULATORY GUIDE

DIRECTORATE OF REGULATORY STANDARDS

REGULATORY GUIDE 1.50

CONTROL OF PREHEAT TEMPERATURE FOR WELDING OF LOW-ALLOY STEEL

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 control of materials and of special processes such as welding, and that proper process monitoring be performed. This guide describes an acceptable method of implementing these requirements with regard to the control of welding for low-alloy steel components during initial fabrication. This guide applies to light-water-cooled 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 Boiler and Pressure Vessel Code (ASME B&PV Code), Section III, "Nuclear Power Plant Components,"[1] specifies certain requirements associated with manufacturing Code Class 1, 2, and 3 components.

Procedure Qualification

Section III requires adherence to Section IX, "Welding Qualifications,"[1] of the ASME B&PV Code, including the requirements governing procedure qualifications for welds. Review of the requirements of Section IX for procedure qualifications and the fabrication requirements of Section III indicates the desirability of supplementary requirements to assure adequate control of welding variables in the production welding of low-alloy steels. The assurance of satisfactory welds in low-alloy steels can be increased significantly and, in particular, the propensity for cracks (cold cracks) or reheat cracks forming in underbead areas and heat-affected zones (HAZ) can be minimized by maintaining proper preheat temperatures on the base metals concurrent with controls on other welding variables.

Cold cracking can occur when the steel is hardened; i.e., undergoes a phase transformation to martensite in the HAZ and/or weld metal. The martensite exhibits brittle fracture tendencies, and it may not be able to withstand rapid cooling and the volume change associated with the phase transformation without the occurrence of local cracking. This susceptibility to cracking increases with higher stresses, such as those experienced with increased thickness of the part being welded, and also increases with a decrease in welding energy input. In order to avoid or minimize the effects of hardening associated with phase transformation, a longer cooling time is needed for the weld; in other words, the preheat temperature should be maintained high enough to achieve an acceptable condition of the phase transformation.

It is generally recognized that atomic hydrogen absorption and diffusion into and through the region being welded have an important influence on the ten ency to form cracks. The level of hydrogen in weld fill metal is low enough to preclude adverse effects in the welds, but greater quantities of hydrogen can be present in the weld region from the dissociation of moisture in hygroscopic welding fluxes or due to adsorption on metal surfaces if the welding fluxes and surfaces have not been properly dried before weld deposition. Embrittlement of metal in the weld area due to the presence of hydrogen generally occurs at lower temperatures and may be prevented by prolonging the

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

time the weldment is maintained at preheating temperature or by performing a post-weld heat treatment. Prolonged time at preheating can prevent or interrupt local hardening and assist in reducing adverse effects of a potential hydrogen gradient. This gradient would disappear by means of diffusion of the hydrogen before the weldment is returned to room temperature. Therefore, the minimum preheat temperature should be established to assure a desirable cooling rate for the weld, and this temperature should be maintained until a post-weld heat treatment has been achieved.

In addition to the minimum preheat temperature, a maximum interpass temperature should be specified. If the weld metal should transform at too high a temperature, the required mechanical properties for the metal may not be met. The maximum interpass temperature varies for different steels, as does the minimum preheat temperatures, and should be selected on the basis of such influencing factors as the chemical composition of the steel.

Production Welds

The procedure qualification by itself does not assure that the production welds will be made within the specified preheat temperature range. To assure that the welds will be acceptable, the metal temperature should be monitored during the welding process and through post-weld heat treatment.

C. REGULATORY POSITION

Weld fabrication[2] for low-alloy steel components should comply with the fabrication requirements specified in Section III and Section IX of the ASME B&PV Code supplemented by the following:

1. The procedure qualification should require that:
   a. A minimum preheat and a maximum interpass temperature be specified.
   b. The welding procedure be qualified at the minimum preheat temperature.

2. For production welds, the preheat temperature should be maintained until a post-weld heat treatment has been performed.

3. Production welding should be monitored to verify that the limits on preheat and interpass temperatures are maintained.

4. In the event that regulatory positions C.1., C.2. and C.3. above are not met, the weld is subject to rejection. However, the soundness of the weld may be verified by an acceptable examination procedure.

[2] Does not apply to weld repairs after initial fabrication.