U.S. NUCLEAR REGULATORY COMMISSION

March 2011
Revision 1

# REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

## REGULATORY GUIDE 1.50

*(Draft was issued as DG-1222, dated June 2009)*

## CONTROL OF PREHEAT TEMPERATURE FOR WELDING OF LOW-ALLOY STEEL

## A. INTRODUCTION

This guide describes a method that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for implementing regulatory requirements related to the control of welding for low-alloy steel components during initial fabrication. This guide applies to light-water-cooled reactors.

General Design Criterion 1, "Quality Standards and Records," of Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10, of the *Code of Federal Regulations*, Part 50, "Domestic Licensing of Production and Utilization Facilities" (10 CFR Part 50) (Ref. 1), 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, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 requires that measures be established to ensure control of materials and of special processes such as welding and that proper process monitoring be performed.

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. This Regulatory Guide is a rule as designated in the Congressional Review Act (5 U.S.C. 801–808). However, the NRC has determined this Regulatory Guide is not a major rule as designated by the Congressional Review Act and has verified this determination with the OMB.

# B. DISCUSSION

Section III, "Nuclear Power Plant Components," of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME B&PV Code) (Ref. 2) specifies certain requirements associated with manufacturing Code Class 1, 2, and 3 components.

## Procedure Qualification

Section III requires adherence to Section IX, "Welding and Brazing Qualifications," 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 ensure 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 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., it undergoes a phase transformation to martensite in the heat-affected zone, weld metal, or both). 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. 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 tendency to form cracks. The level of hydrogen in weld filler metal may be 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 from 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 as the result of the presence of hydrogen generally occurs at lower temperatures and may be prevented by prolonging the time the weldment is maintained at preheating temperature or by performing a postweld heat treatment. Preheating at the recommended temperatures can reduce local hardening by reducing the cooling rate during welding. Prolonged time at the preheating temperature can assist in reducing the 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 ensure a desirable cooling rate for the weld, and this temperature should be maintained until the achievement of a postweld heat treatment or a postweld hydrogen bakeout.

In addition to the minimum preheat temperature, a maximum interpass temperature must be specified in accordance with the requirements of ASME B&PV Code Section IX if toughness is a requirement of the construction code or the design. For low-alloy steel welds not requiring impact testing, a maximum interpass temperature 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 ensure that the production welds will be made within the specified preheat temperature range. To ensure that the welds will be acceptable, the metal temperature should be monitored during the welding process and through postweld heat treatment or postweld hydrogen bakeout.

## C. REGULATORY POSITION

Weld fabrication[1] for low-alloy steel (P Nos. 3, 4, and 5A) components should comply with the fabrication requirements specified in Sections III and IX of the ASME B&PV Code, supplemented by the regulatory positions below.

1. The Welding Procedure Specification should specify a maximum interpass temperature and a minimum preheat temperature that are equal to the maximum interpass temperature and minimum preheat temperature used during procedure qualification.

2. For production welds, the preheat temperature should be maintained until final postweld heat treatment or a post weld hydrogen bakeout is performed between 200 and 400ºC (400 and 750ºF) for a minimum of four hours after which the component may be slowly cooled to ambient temperature prior to the performance of the final post weld heat treatment. . The postweld hydrogen bakeout temperature and soak time should be based on the materials being welded, the geometry, and the welding process used.

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

4. If Regulatory Positions 1, 2, and 3 above are not met, the weld is subject to rejection. However, the soundness of the weld may be demonstrated by an acceptable examination procedure meeting the acceptance criteria specified in Section III of the ASME B&PV Code.

## D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this regulatory guide. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

In some cases, applicants or licensees may propose 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.

---

1 This position does not apply to weld repairs after initial fabrication.

# REFERENCES

1. 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," U.S. Nuclear Regulatory Commission, Washington, DC.[2]

2. ASME Boiler and Pressure Vessel Code, American Society of Mechanical Engineers, New York, NY.[3]

[2] All NRC regulations listed herein are available electronically through the Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/cfr/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail pdr.resource@nrc.gov.

[3] 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/.