UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

OF THE

OF AN ALTERNATIVE TO ASME CODE REPAIR REQUIREMENTS

FOR CANOPY SEAL WELDS FOR

FOR

TENNESSEE VALLEY AUTHORITY

WATTS BAR NUCLEAR PLANT

DOCKET NUMBER 50-390

1.0 INTRODUCTION

The Code of Federal Regulations, 10 CFR 50.55a, requires that inservice inspection (ISI) of certain American Society of Mechanical Engineers (ASME) Code Class 1, 2, and 3 components be performed in accordance with Section XI of the ASME Boiler and Pressure Vessel (B&PV) Code applicable Edition and Addenda, except where specific written relief has been granted by the Comission pursuant to 10 CFR 50.55a(g)(6)(i). In 10 CFR 50.55a(a)(3), it states that alternatives to the requirements of paragraph (g) may be used, when authorized by the NRC, if:
(i) the proposed alternatives would provide an acceptable level of quality and safety, or
(ii) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

10 CFR 50.55a authorizes the Commission to grant relief from ASME Code requirements or to approve proposed alternatives upon making the necessary findings. The U.S Nuclear Regulatory Commission (NRC) staff's findings with respect to granting the requested relief or authorizing the proposed alternative as part of the licensee's ISI program are contained in this Safety Evaluation (SE).

The purpose of this evaluation is to determine the acceptability of the use of an alternative to ASME Code Section XI repair and examination requirements proposed by the Tennessee Valley Authority (TVA) for two canopy seal welds (CSWs).

During the Unit 1 Cycle 1 Refueling Outage (U1C1 RFO) while disassembling the reactor vessel, Tennessee Valley Authority (TVA), the licensee, noticed boric acid residue on a control rod drive mechanism (CRDM). Further inspection showed that two CRDMs started leaking at the lower canopy seal weld. The licensee determined that stress corrosion cracking was the likely mode of failure based on similar experiences at Zion and Sequoyah.

By letter dated September 20, 1997, TVA requested approval of an alternative to the ASME Code, Section XI repair and examination requirements under 10 CFR 50.55a(a)(3)(i). TVA proposed to repair two lower canopy seal welds by applying weld buildup rather than removing the defect and performing a Code weld repair.

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The CRDM penetrations are considered part of the reactor vessel and are thus classified as Code Class 1. The CRDM housings, as part of the reactor vessel, are within the reactor coolant system as defined by the Final Safety Analysis Report (FSAR). The 1971 Edition, Addenda through Winter 1972 of the ASME Section III, established the design specification and the construction code for the CRDMs. The 1971 Edition, Addenda through Winter 1971 of ASME Section III, established the design specification and the construction code for the reactor vessel.

The CRDMs are fabricated in sections with threaded joints providing the pressure-retaining capabilities. Since the threaded joint provides pressure retention, the canopy seal weld is not pressure retaining and is for leakage control. The 1971 Edition, Addenda through Winter 1972 of ASME Section III, does not allow threaded joints as the only seal as described in Paragraph NB-3671.3. Paragraphs NB-3227.7 and NB-4360 address the design of canopy seal welds and qualification requirements for welding specially designed welded seals, respectively.

Paragraph NB-5271, "Welds of Specially Designed Seals," of ASME Section III, requires seal welds to receive either a magnetic particle or liquid penetrant examination. TVA has determined that either examination would be impractical. Therefore, TVA plans to use an alternative examination technique--a remote video camera.

TVA's proposed alternative canopy seal weld repair and inspection methods have been implemented at TVA's Sequoyah Nuclear Plant as approved by NRC in a letter dated April 24, 1996. Similar weld overlay repairs have also been used at other nuclear plants.

2.0 DISCUSSION

ASME Section XI Code Requirement

ASME Section XI, 1989 Edition, IWA-4110 (a) states, "This Article provides rules and requirements for repair of pressure retaining components and their supports, including appurtenances, subassemblies, parts of a component, and core support structures, by welding, brazing, or metal removal."

For repair of the defect, TVA requested relief from the following ASME Section XI, 1989 Edition, IWA-4000, Repair Procedure requirements:

- Paragraph IWA-4120(a): "Repairs shall be performed in accordance with the Owner's Design Specification and the original Construction Code of the component or system. Later Editions and Addenda of the Construction Code or of Section III, either in their entirety or portions thereof, and Code Cases may be used. If repair welding cannot be performed in accordance with these requirements, the applicable alternative requirements of IWA-4500 and the following may be used: (1) IWB-4000 for Class 1 components."

- Paragraph IWA-4130(a)(2): "Repair operations shall be performed in accordance with a program delineating essential requirements of the complete repair cycle including ...(2)... below: (2) the flaw removal method, method of measurement of the cavity created by removing the flaw, and dimensional requirements for reference points during and after the repair;"

- Subarticle IWA-4300, "Defect Removal," in its entirety.

For examination, TVA requests relief from the following ASME Section III, 1971 Edition, through Winter 1971 Addenda, Paragraph NB-5200, "Examination of Weld" requirements.

- Paragraph NB-5271: "Welds of this type (welds of specially designed seals, i.e., canopy seal welds) shall be examined by either the magnetic particle or liquid penetrant method."

Basis for Relief

Due to physical space limitations and in consideration of the need to keep worker dose as low as reasonably achievable, removal and repair of the defects is not the most favorable method of repair. The affected canopy seal welds are located in a high radiation area (1 rem/hour on contact and 800 millirem/hour general area) and access to the welds is difficult due to the limited clearance between the adjacent CRDMs. In addition, if the defects were removed, it would be impossible to restore the configuration of the canopy seal to its original design condition as required by IWA-4000.

Proposed Alternative

TVA proposed the following alternative:

In lieu of removing the flaw and performing a Code weld repair, TVA will apply a weld overlay repair and allow the flaw to remain.

TVA's Code of Record for Repairs and Replacements is ASME Section XI, 1989 Edition. TVA will use IWB-3640 "Evaluation Procedures and Acceptance Criteria for Austenitic Piping," and Appendix C, "Evaluation of Flaws in Austenitic Piping," of this edition to perform the required fracture mechanics and determine the acceptability of the flaw. IWB-3640 provides criteria for acceptance of flaws without repair in ductile, austenitic materials. The basis for such acceptance is the evaluation of the structural adequacy of the flawed component after considering the predicted flaw growth over the evaluation period. The acceptance criteria is based upon the net section collapse (limit load) criteria defined in detail in Appendix C of Section XI.

TVA will also use parts of ASME Section XI Code Case N-504, "Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping," for guidance in designing a weld overlay repair of the flawed weld. Code Case N-504 allows repair by addition of weld material without removal of the underlying defect to be considered as a code repair. Code Case N-504 is endorsed by the NRC in Regulatory Guide 1.147, "Inservice Inspection Code Case Acceptability ASME Section XI Division," Revision 11.

TVA will also use NUREG-0313, "Technical Report on Material Selection and Processing Guidelines for BWR Coolant Pressure Boundary Piping, Final Report," Revision 2, for guidance. The use of NUREG-0313 will result in the repair design being based upon a conservative treatment of applied stresses and allowing for continued flaw growth, as required by Section XI.

Instead of applying a magnetic particle or liquid penetrant examination, TVA will perform an enhanced visual examination with a remote video camera with a magnification of approximately 8X . It will use the camera to monitor the repair and visually examine the final weld.

Licensee's Evaluation

Structural Integrity Associates (SIA), a company that performed similar overlay repairs at other plants, performed TVA's flaw evaluation and overlay repair. SIA stated that the geometry and dimensions of the CRDM lower canopy seal and design of the overlay at Watts Bar are essentially identical to those at Zion and Sequoyah.

SIA determined that transgranular stress corrosion cracking was the likely mode of failure, based on similar experiences at Zion. It therefore evaluated the IGSCC resistance of the repair to predict the remaining life. SIA evaluated the predicted weld residual stress distributions resulting from the repair and the applied stresses to determine the design life of the overlay repaired CSWs, assuming the mechanism for repair degradation to be IGSCC.

SIA designed a weld overlay repair to meet the requirements of ASME Section XI, IWB-3640 and followed the guidance in NUREG-0313 Rev. 2 for the repair of IGSCC flaws. SIA selected Inconel 625 weld material which has a tensile strength of approximately 110 kips per square inch (ksi) and is stronger than the underlying base material (304 stainless steel), more resistant to degradation mechanisms such as stress corrosion cracking, and is highly ductile. The load carrying capability of the repaired location will thus be greater than that of the original component.

SIA computed weld residual stresses with the WELD3 computer program for the repair model. The model consisted of depositing 3 layers of Alloy 625 weld metal. The model was confirmed on a weld mock-up performed for the Zion spare CRDM overlay.

The fracture mechanics analysis assumes that an initial defect is an infinitely long crack completely through the original wall of the CSW. To bound the crack growth for Alloy 625, TVA used the upper bound NRC curve for IGSCC of Type 304 stainless steel specified in NUREG 0313, divided by a factor of 10. This rate is based on experience with CSW cracking of Type 308 welds, on crack growth rate data for Alloys 600 and 690, and on a comparison of the IGSCC resistance of Alloys 600 and 625 with that of Type 304 in various off-normal chemistry environments. This crack growth law, combined with the 3 -layer overlay residual stress distribution, and a bounding 2 ksi applied membrane stress, predicted the remaining IGSCC life to be over 50 years.

Liquid penetrant examinations required by NB-5271 will not be performed because of space limitations that prevent examiners from having the needed access to successfully perform the examination and the need to keep the worker dose as low as reasonably achievable. As an alternative, TVA will use a remote video camera with a magnification of about 8X to visually examine the final weld and record the entire process of the repair on video tape. The basis for this approach is that post-weld liquid penetrant examinations, being surface examinations, provide minimal assurance of repair integrity compared to an enhanced visual examination. Additionally, fracture mechanics analyses that postulate a flaw in the heat affected zone and going into the pressure boundary, show that the critical flaw size (several inches) is significantly larger than a flaw that would be reliably detected by the enhanced visual examination.

TVA has previously performed a demonstration examination for the Authorized Nuclear Inspector using the remote video equipment at Sequoyah Nuclear Plant's (SQN) Unit 1 before using the equipment to examine the repair of canopy seal welds at SQN and documented the results in a letter to the NRC dated April 3, 1996. The demonstration determined that a 1/32 inch graduation on a machinist's scale could be distinguished and the equipment was thus acceptable.

TVA evaluated the operability of the CRDM canopy seal welds after the weld repair using the guidance provided in Generic Letter 91-18, "Information to Licensees Regarding Two NRC Inspection Manual Sections on Resolution of Degraded and Nonconforming Conditions and on Operability." TVA determined that the CRDM housing will be fully operable after the repair and examination of the weld.

Staff Evaluation

The staff accepts TVA's basis for its proposed alternative repair and inspection methods, that is that access to the welds is difficult due to the limited clearance between the adjacent CRDMs and the welds are located in a high radiation area. The staff finds TVA's alternative acceptable. The flaw evaluation and overlay repair are in accordance with staff approved methods-- ASME Section XI and NUREG-0313, Rev. 2. Results of the analyses showed that the weld overlay will provide an adequate level of quality and safety. The alloy selected for the repair, Alloy 625, is more resistant to IGSCC than the originally used stainless steel. TVA showed by video qualification that a through-wall flaw of a size much smaller than the critical flaw size could be detected by visual examination, thus assuring a wide safety margin.

The alternative is also virtually identical to that the staff approved in its letter of April 24, 1996 for the Sequoyah plant and similar to those approved for several other plants. Weld overlay repairs have been used frequently and successfully to repair IGSCC cracks in BWR stainless steel piping welds. They have also been used for CRDM canopy seal repairs at Zion, Diablo Canyon, Prairie Island and others.

On the basis of the above discussion, the staff finds the licensee's proposed actions to be a technically adequate alternative to ASME Code, Section XI repair requirements.

The staff concludes that the licensee's proposed alternative to certain of the ASME B&PV Code Section XI requirements for the repair and inspection of two lower canopy seal welds, as contained in the relief request submitted by TVA letters dated September 20 and October 10, 1997, and evaluated in this SE provide an acceptable level of quality and safety. Therefore, the licensee's request is authorized pursuant to 10 CFR 50.55a(3)(a)(i).

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