February 8, 2008

Mr. William R. Campbell, Jr.
Chief Nuclear Officer and
Executive Vice President
Tennessee Valley Authority
6A Lookout Place
1101 Market Street
Chattanooga, TN 37402-2801

SUBJECT: WATTS BAR NUCLEAR PLANT, UNIT 1 - SAFETY EVALUATION OF RELIEF REQUEST G-RR-2, PROPOSED ALTERNATIVE TO AMERICAN SOCIETY OF MECHANICAL ENGINEERS BOILER AND PRESSURE VESSEL CODE, SECTION XI, REACTOR PRESSURE VESSEL HEAD PENETRATION TUBE REMOTE INNER-DIAMETER TEMPER BEAD REPAIR (TAC NO. MD3766)

Dear Mr. Campbell:

By letter dated December 6, 2006, as supplemented by letters dated December 14, 2007, and February 7, 2008, Tennessee Valley Authority (TVA, the licensee) submitted Relief Request G-RR-2 for the Watts Bar Nuclear Plant, Unit 1 (WBN-1). Specifically, TVA requested relief from certain American Society of Mechanical Engineers (ASME) Code requirements pertaining to alternative repair methods for the repair and replacement of reactor pressure vessel head (RPVH) penetration tube welds and J-groove welds in the event that inservice examination results were determined unacceptable.

The initial request also applied to Sequoyah Nuclear Plant, Units 1 and 2 (TAC Nos. MD3764 and MD3765), but in the December 14, 2007, supplement, TVA withdrew the request for Sequoyah.

The Nuclear Regulatory Commission (NRC) staff has reviewed TVA's submittal and concludes the following: (1) that compliance with the ASME Code-required in-process and postrepair examinations, flaw characterization and successive examinations of the remnant J-groove welds are impractical for WBN-1, (2) that the ASME Code, Section XI required post weld heat treatment, elevated preheat and post weld soak are impractical, and the proposed alternative to use ambient temperature temper bead process of ASME Code Case N-638-1, with modifications, would produce a permanent repair weld and provide reasonable assurance of structural integrity, and (3) that the proposal to leave cracks in the non-pressure boundary portion of the remaining J-groove partial penetration weld and to evaluate crack growth using the appropriate ASME Code, Section XI criteria for a worst-case crack growth scenario is acceptable for 3 calendar years from the time of completing the repair.

Therefore, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a(g)(6)(i), the proposed relief is granted for the remainder of the second 10-year Inservice Inspection Interval at WBN-1, which ends on May 26, 2016, subject to the following requirement. If a nozzle is repaired (i.e., establishing a new pressure boundary weld), the grant of relief is limited to 3 calendar years from the time of completing the repair, and TVA is required to submit to the NRC for review and approval any plans for corrective actions on the existing J-groove weld and/or the RPVH to demonstrate acceptable RPVH soundness beyond 3 calendar years.

This granting of relief pursuant to 10 CFR 50.55a(g)(6)(i) is authorized by law and will not endanger life or property or the common defense and security, and is otherwise in the public interest giving due consideration to the burden upon the licensee that could result if the requirements were imposed on the facility.

Further details on the bases for the NRC staff's conclusions are contained in the enclosed safety evaluation. If you have any questions regarding this issue, please feel free to contact the WBN-1 Project Manager, Margaret Chernoff, at (301) 415-4041.

Sincerely,

/RA/

Joseph F. Williams, Acting Chief
Watts Bar 2 Special Projects Branch
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-390

Enclosure: Safety Evaluation

cc w/enclosure: See next page

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WATTS BAR NUCLEAR PLANT

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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELIEF REQUEST G-RR-2

REACTOR PRESSURE VESSEL HEAD PENETRATION TUBE

REMOTE INNER-DIAMETER TEMPER BEAD REPAIR

TENNESSEE VALLEY AUTHORITY

WATTS BAR NUCLEAR PLANT UNIT 1

DOCKET NUMBER 50-390

1.0 INTRODUCTION

By letter dated December 6, 2006, as supplemented by letters dated December 14, 2007, and February 7, 2008, Tennessee Valley Authority (TVA, the licensee) requested approval for the contingent use of alternatives to the requirements of American Society of Mechanical Engineers (ASME) Code, Section XI, 2001 Edition with 2003 Addenda (2001A03 Edition), Article IWA-4000 for Sequoyah Nuclear Plant, Units 1 and 2, and Watts Bar Nuclear Plant, Unit 1 (WBN-1). Specifically, Relief Request G-RR-2 (G-RR-2) requested approval to use an alternative repair and replacement (R&R) process related to the performance of ambient temperature temper bead weld techniques on the reactor pressure vessel head (RPVH) penetration tubes and J-groove welds in the event unacceptable indications are discovered during examination. In the December 14, 2007, supplemental letter, the licensee withdrew G-RR-2 for Sequoyah Nuclear Plant, Units 1 and 2. Therefore, this safety evaluation will address only WBN-1.

TVA plans to examine the RPVH penetration tubes and associated J-groove welds during the WBN-1 spring 2008 outage. These examinations are to be performed in accordance with the directives of U.S. Nuclear Regulatory Commission (NRC) Order EA-03-009, "Issuance of First Revised NRC Order (EA-03-009) Establishing Interim Inspection Requirements for RPVH at Pressurized Water Reactors," dated February 20, 2004. In the event that unacceptable indications are identified, repairs or replacements of the RPVH penetration tubes or the associated J-groove weld areas may be necessary.

TVA proposes to use repair methodologies that result in the establishment of a new pressure boundary at the individual penetration tubes and J-groove welds. TVA proposes the combined use of certain provisions of ASME Code, Section XI code cases, and ASME Code, Section III, with some minor changes in order to achieve high quality weld repair techniques. These repairs would

Enclosure

remove the existing J-groove welds from the pressure boundary and restore long-term stability to the penetration tube areas within the wall thickness of the RPVH assembly. This process reduces the susceptibility of penetration tube weld degradation from primary water stress corrosion cracking (PWSCC). TVA proposes to use the provisions of ASME Code Case N-638-1, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine Gas Tungsten-Arc Welding (GTAW) Temper Bead Technique, ASME Code, Section XI, Division 1," for potential inner diameter temper bead (IDTB) repairs at WBN-1 with some minor modifications to the R&R process.

Certain safety factors used in the original TVA evaluation of the proposed repair were different than those previously approved by the NRC for similar requests. In the December 14, 2007, supplement, TVA evaluated the use of the alternative R&R methods using the analysis safety factors previously approved by the NRC staff in connection with the other utility requests.

2.0 REGULATORY EVALUATION

The inservice inspection (ISI) of ASME Code Class 1, Class 2, and Class 3 components shall be performed in accordance with the ASME Code, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," and applicable edition and addenda as required by Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a(g), except where specific relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). It is stated in 10 CFR 50.55a(g)(6)(i) that, ". . .the Commission will evaluate determinations . . . that [ASME] code requirements are impractical. The Commission may grant such relief and may impose such alternative requirements as it determines is authorized by law and will not endanger life or property or the common defense and security, and is otherwise in the public interest giving due consideration to the burden upon the licensee that could result if the requirements were imposed on the facility."

Pursuant to 10 CFR 50.55a(g)(4), ASME Code Class 1, 2, and 3 components (including supports) must meet the requirements, except the design and access provisions and the preservice examination requirements, set forth in the ASME Code, Section XI to the extent practical within the limitations of design, geometry, and materials of construction of the components. The regulations require that ISI of components and system pressure tests conducted during the first 10-year interval and subsequent intervals comply with the requirements in the latest edition and addenda of Section XI of the ASME Code incorporated by reference in 10 CFR 50.55a(b) 12 months prior to the start of the 120-month interval, subject to the limitations and modifications listed therein.

Pursuant to 10 CFR 50.55a(a)(3), alternatives to requirements may be authorized by the NRC if the licensee demonstrates that: (i) the proposed alternatives 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. In its submittal, the licensee proposed its alternatives pursuant to 10 CFR 50.55a(a)(3)(i), but the NRC staff concluded that 10 CFR 50.55a(g)(6)(i) was more appropriate.

3.0 RELIEF REQUEST G-RR-2

3.1 System/Component(s) for Which Relief is Requested

The components that will receive J-groove weld and nozzle penetration tube examinations include

WBN-1 RPVH assemblies in the Alloy 600 J-groove weld areas for the control rod drive mechanism (CRDM) penetration tubes, the head adapter plug nozzles, the incore thermocouple instrumentation (ICI) penetration tubes, and the head vent (HV) pipe penetration tubes. The breakdown for the specific components is as follows:

WBN-1 INCLUDES 79 RPVH PENETRATION TUBES and the ASSOCIATED PARTIAL-PENETRATION J-GROOVE WELDS COMPRISED of the FOLLOWING:	
Totals	**Components**
57	CRDM Nozzles with Thermal Sleeves
8	Part Length CRDM Nozzles
8	Dummy Cans with Head Adapter Plug Nozzles
5	Incore Instrument Thermocouple Column Nozzles
1	RPVH Vent Pipe Nozzle

3.2 <u>Code Requirements</u>

The following table lists the current applicable ISI Program 10-year interval, the ASME Code, Section XI, ISI Code-of-Record (COR) (Code Edition, or Edition with Addenda), the ISI/Nondestructive Examination (NDE) Program COR for the repair examinations, the ASME Code, Section XI, R&R COR, and the ASME Code, Section III, COR to be used for the design of the IDTB repairs.

PLANT/UNIT	ISI PROGAM INTERVAL/PERIOD	ISI CODE (ASME XI)	NDE CODE (ASME XI)	R&R CODE (ASME XI)	IDTB CODE (ASME III)
WBN-1*	$2^{ND}/1^{ST}$	2001A03	2001A03*	2001A03	2001A03

*NOTE: TVA recently received permission to update applicable ISI/NDE procedures to meet the 2001A03 Edition. WBN-1 was in the third period of the first 10-year interval at the time of the initial request and transitioned to the second 10-year interval on May 27, 2007, with the ASME Code, Section XI ISI Programs written to meet the 2001A03 Edition.

In accordance with the ASME Code, Section XI, 2001A03 Edition, IWA-4220 requirements; R&R activities must meet the owner's requirements and the construction codes applicable during original item construction. Accordingly, consideration was given to the original COR in the IDTB designs and the development of the individual R&R plans and associated installation of the RPVH repair activities. The original plant component fabrication and installation COR are:

ORIGINAL DESIGN COR			
PLANT/UNIT	**RPVH ASSEMBLY**	**CRDM PENETRATION TUBE**	**INCORE INSTRUMENT and THERMOCOUPLE TUBE**
WBN-1	ASME III, 1971W71*	ASME III, 1971W72	ASME III, 1971W72

*1972 Edition through 1971 Winter Addenda.

Alternatively, the R&R plan may meet all or portions of the requirements of different Editions and Addenda of the Construction Code, or ASME Code, Section III when the Construction Code was not ASME Code, Section III, provided the Code to be used for the activities is reconciled with the owner's requirements, in accordance with the reconciliation requirements of IWA-4200 of the ASME Code, Section XI, 2001A03 Edition.

Along with the IWA-4000 R&R requirements, the ASME Code allows the use of approved alternatives in the ASME Code, Section XI, Code Case N-638-1 (CC N-638-1). However, NRC Regulatory Guide (RG) 1.147, "Inservice Inspection Code Case Acceptability, ASME Code, Section XI, Division 1," Revision 14, also imposes additional limitations of the use of this code case. TVA has incorporated consideration of these limitations into the proposed IDTB repair processes.

3.3 Code Requirements from which Relief is Requested

TVA is requesting relief from meeting the requirements of ASME Code, Section XI, 2001A03 Edition, Article IWA-4000. Paragraph IWA-4220 requires that R&R performed on Code Class boundary components, at a minimum, meet the design, fabrication, and installation requirements of the original applicable Construction Code. For WBN-1, for the proposed repairs to the RPVH penetrations, paragraph NB-2539 of the 1971W71 Edition of ASME Code, Section III requires postweld heat treatment (PWHT) of repairs in accordance with paragraph NB-4640.

Certain aspects of the preweld and postweld repair NDE requirements and flaw characterization requirements are not practical. Specifically, TVA is also requesting relief from meeting certain requirements of ASME Code, Section XI, IWA-3300(b), IWB-3142.4, IWB-3420, and IWB-3612 of the 2001A03 Edition.

IWA-3300(b) contains a requirement for flaw characterization.

IWB-3142.4 allows for analytical evaluation to demonstrate that a component is acceptable for continued service.

IWB-3142.4 also requires that components found acceptable for continued service by analytical evaluation be subjected to successive examination.

IWB-3420 requires the characterization of flaws in accordance with the rules of IWA-3300.

IWB-3612(a) requires that, for normal conditions, the ratio of the maximum applied stress intensity factor (K_I) to the available fracture toughness based on crack arrest (K_{Ia}) for the corresponding crack tip temperature be less than $1/\sqrt{10}$.

IWB-3612(b) requires that, for emergency and faulted conditions, the ratio of the maximum applied stress intensity factor (K_I) to the available fracture toughness based on crack initiation (K_{Ic}) for the corresponding crack tip temperature be less than $1/\sqrt{2}$.

3.4 Duration of the Alternative

TVA requests approval of G-RR-2 for use during the remainder of the current 10-year ISI Program interval at WBN-1, as indicated in G-RR-2 and the Section 3.2 table above. Once the J-groove weld repairs are made or modifications are installed, they will remain in place for the design life of the repair that is defined in accordance with the evaluation requirements for WBN-1.

3.5 Proposed Basis and Alternatives

TVA stated that the PWHT requirements, as indicated above, are unreasonable and impractical to attain under field conditions on a RPVH. In addition to possible distortion of the RPVH, significant personnel dose would be expended to set up and remove the PWHT equipment. Because of the risk of damage to the RPVH material properties or dimensions and the additional dose that would be required, it is not practical to apply the PWHT requirements of paragraph NB-4620 of the ASME Code, Section III, 2001A03 Edition to the RPVH, nor the elevated temperature preheat and post weld soak required by the alternative temper bead method offered by ASME Code, Section XI, IWA-4600.

In addition, TVA stated that if inspection of the RPVH nozzle penetrations reveals flaws affecting the J-groove attachment welds, it may be unreasonable to characterize these flaws by NDE and it may be unreasonable to perform any successive examinations of these flaws. The original nozzle to RPVH weld configuration is difficult to examine using an ultrasonic test (UT) due to the compound curvature and fillet weld radius. The configuration is not conducive to UT due to the configuration and dissimilar metal interface between the R&R weld and the low alloy steel RPVH. Furthermore, due to limited accessibility from the RPVH outer surface and the proximity of adjacent nozzle penetrations, it is unreasonable to scan from this surface on the RPVH base material to detect flaws in the vicinity of the original J-groove welds. These conditions preclude ultrasonic coupling and control of the sound beam in order to perform flaw sizing with reasonable confidence in the measured flaw dimension. Therefore, TVA is also requesting relief from meeting specific requirements of ASME Code, Section XI, Article IWA-4000 governing this R&R and the associated requirements of IWA-3300(b), IWB-3142.4, IWB-3420, and IWB-3612.

TVA stated further that for application of the IDTB repairs, an automatic or machine GTAW ambient temperature temper bead welding technique will be implemented in accordance with CC N-638-1, with certain exceptions. For WBN-1, automatic or machine GTAW is allowed in accordance with the provisions of the ASME 2001A03 Edition, paragraphs IWA-4633.2(a) through (e). However, CC N-638-1 is also appropriate to be used with the 2001A03 Edition in order to allow the qualification and use of the ambient temperature temper bead weld technique. Use of CC N-638-1 for the IDTB R&R, as it is proposed in this request, is compatible with the ASME Code, Section XI, 2001A03 Edition provisions in paragraph IWA-4623.2. Attachment 1 to Enclosure 1 of G-RR-2 provides a listing of the basic process steps involved in the IDTB R&R activities. Figures 1 and 2 in Attachment 1 are sketches of the approximate end configurations for the ICI tube and the CDRM nozzle configurations, respectively. Configuration sketches of the HV line configuration will be provided if R&R of those nozzles, or their associated J-groove welds, are required.

3.5.1 Alternative R&R Design, Fabrication Considerations

The following proposed alternative requirements provide a general description of the proposed alternative design, welding and examination, and the flaw characterization processes. For a detailed description and a comparison of the applicable code requirements to proposed alternative processes see G-RR-2.

TVA requested relief to use an ambient temperature temper bead method of repair as an alternative to the requirements of the 2001A03 Edition of ASME Code, Section III, NB-3300, NB-4453, NB-4622, NB-5245, and NB-5330. Approval is also requested to use filler materials, ERNiCrFe-7A (Alloy 52M, UNS06054), or ERNiCrFe-7 (Alloy 52, UNS06052), which are endorsed by Code Case 2142-2, "F-Number Grouping for NiCrFe Filler Metals Section IX (Applicable to all Sections, including Section III, Division 1, and Section XI)," for the weld repair. CC N-638-1, which has been approved in RG 1.147, Revision 14, has also been used as a template for this application.

TVA stated that repairs to the RPVH nozzle penetration J-groove attachment welds, which are required when a 1/8-inch or less non-ferritic weld deposit exists above the original fusion line, will be made in accordance with the requirements of IWA-4000, of the ASME Code, Section XI, 2001A03 Edition. The requirements of paragraphs NB-4622, NB-3300, NB-4453, and NB-5245, of ASME Code, Section III, 2001A03 Edition, and QW-256 of the latest edition of ASME Code, Section IX are also applicable to the potential RPVH penetration tube and J-groove weld repairs. Alternatives to these requirements will be used in accordance with the requirements of the alternative welding process described below. Specifically, the following alternatives are being proposed for the ASME Code, Section III, Section IX, and Section XI requirements:

NB-4622.1 establishes the requirement for PWHT of welds including repair welds. The alternative will utilize an ambient temperature temper bead weld procedure CC N-638-1. Throughout the remainder of this section CC N-638-1 will be referred to as the alternative.

NB-4622.11 addresses temper bead weld repair to dissimilar metal welds or buttering and certain sub-paragraphs would apply to the proposed repairs as follows:

Paragraph (c) addresses the repair welding procedure and welder qualification in accordance with ASME Code, Section IX and the additional requirements of Article NB-4000. The alternative will satisfy paragraph (c) requirements except for the stipulations of paragraph QW-256 of ASME Code, Section IX.

Paragraph (c)(2) requires the use of the shielded metal-arc welding (SMAW) process with covered electrodes meeting either the A-No. 8 or F-No. 43 classification. The alternative will utilize a GTAW process with bare electrodes and bare filler metal meeting the F-No. 43 classification.

Paragraph (c)(5) requires preheat of the weld area and 1-1/2 times the component thickness or 5-inch band, whichever is less, to a minimum temperature of 350 degrees Fahrenheit (°F) prior to and during repair welding, and a maximum interpass temperature of 450 °F. It also requires that thermocouples and recording instruments be used to monitor the metal temperature during welding. The alternative uses an ambient temperature temper bead weld process. Preheat temperature verification will be performed by use of a contact pyrometer on accessible areas of the RPVH. Interpass temperature measurements cannot be accomplished due to inaccessibility in the weld region on the inner surfaces of the penetration tube area.

Paragraph (c)(8) requires welding be done with a minimum preheat of 100 °F and maximum interpass temperature of 350 °F subsequent to the hydrogen bake out of NB-4622.11(c)(7). The alternative limits the maximum interpass temperature to 350 °F and requires the area preheat to be at least 50 °F prior to GTAW welding and does not require hydrogen bake out.

Paragraph (d)(1) requires a liquid penetrant (PT) examination after the hydrogen bake out described in NB-4622.11(c)(7). The alternative does not require the hydrogen bake out.

Paragraph (d)(2) requires PT and radiographic (RT) examinations of the repair welds and the preheated band after a minimum time of 48 hours at ambient temperature. Paragraph (d)(2) also requires UT examination, if practical. The alternative will use PT and UT examination of the final weld a minimum of 48 hours after the weld has cooled to ambient temperature.

Paragraph (d)(4) requires that all NDE be in accordance with NB-5000. The alternative will use PT and UT examination of the final weld.

Paragraph (f) establishes requirements for the procedure qualification test plate relative to the P-Number, group Number and the PWHT of the materials to be welded. The alternative stipulates that the root width and included angle of the cavity are to be no greater than the minimum specified for the repair.

Paragraph (g) establishes requirements for welder performance qualification relating to physical obstructions that might impair the welder's ability to make sound repairs, which is pertinent to the Shielded Metal Arc Welding (SMAW) manual welding process. The alternative will utilize a machine GTAW process and require welding operators be qualified in accordance with ASME Code, Section IX.

NB-4453.4(a) requires examination of the repair welds in accordance with the requirements for the original weld. The alternative will use PT and UT examination of the final weld a minimum of 48 hours after the weld has cooled to ambient temperature.

NB-5331(b) does not allow any cracks, lack of fusion, or incomplete penetration regardless of length. A linear indication often occurs at the intersection of the RPVH, the nozzle, and the first intersecting weld bead (triple point). The alternative will allow the triple point indication to remain.

QW-256/QW-406.3, of ASME Code, Section IX, requires that the maximum interpass temperature during procedure qualification be no more than 100 °F below that used for actual welding. The alternative specifies that the maximum interpass temperature during welding is to be 350 °F.

The welding technique proposed by TVA differs from and modifies Sections 1.0 through 4.0 of the proposed alternative as follows:

Section 2.1(j) requires the average values of the three heat-affected zones (HAZ) impact tests be equal to or greater than the average values for the unaffected base material tests. The alternative will use an adjustment temperature of +5 °F to the nil ductility reference temperature (RT_{NDT}) for base material on which welding is performed.

Section 3.0(d) specifies that the maximum interpass temperature for field applications shall be 350 °F regardless of the interpass temperature during procedure qualification. Section 2.1(e) specifies that the maximum interpass temperature for the first three layers of the test assembly shall be 150 °F. QW-256 specifies maximum interpass temperature as a supplementary essential variable that must be held within 100 °F above that used during procedure qualification. The alternative will use a maximum interpass temperature of 350 °F during welding.

Paragraph 4.0(b) requires the final weld surface and band around the area defined in paragraph 1.0 (d) to be examined using surface and UT methods. The alternative will use an examination area which includes the weld and adjacent base material to be examined by PT and UT methods.

Paragraph 4.0(c) requires areas which had weld-attached thermocouples to be ground and examined using a surface examination. The alternative will use contact pyrometers to monitor interpass temperatures.

Paragraph 4.0(e) requires UT acceptance criteria to be in accordance with IWB-3000. No acceptance criteria in IWB-3000 directly apply for this configuration. The alternative will use the required conditional UT acceptance criteria in accordance with NB-5330 of the ASME Code, Section III which is consistent with the original construction code requirements.

Potential corrosion concerns of the RPVH low alloy steel include general, galvanic, crevice, stress corrosion cracking (SCC), and hydrogen embrittlement. Galvanic corrosion, crevice corrosion, SCC, and hydrogen embrittlement of the RPVH low alloy steel are not significant concerns based on previous operational experience with low alloy steel exposed to primary coolant. The general corrosion rate for the RPVH low alloy steel, under the anticipated exposure conditions, is 0.0032 inch/year, based on an 18-month operating cycle followed by a 2-month refueling cycle.

Detailed stress and fatigue analyses of the IDTB CRDM/ICI nozzle weld repair were performed demonstrating that the IDTB CRDM/ICI weld repair design meets the stress and fatigue requirements set by ASME Code, Section III, 2001A03 Edition. Conservative fatigue analyses conclude that the maximum cumulative fatigue usage factor for 40 years of operation is 0.336 for the CRDM weld repair and the Alloy 690 replacement nozzle and 0.263 for the ICI weld repair and Alloy 690 replacement nozzle. The maximum allowed ASME Code fatigue usage factor is 1.0. The fatigue analyses included the normal and upset operating transients. The life expectancy of the IDTB CRDM/ICI weld repair was also evaluated with respect to the PWSCC concerns of the remaining Alloy 600 CRDM nozzle portion affected by the IDTB weld repair. The Alloy 690 replacement nozzle and Alloy 52/52M IDTB weld are not considered susceptible to PWSCC. The life expectancy of the IDTB weld repair relative to PWSCC is conservatively estimated at 2.7 effective full power years with a nonabrasive water jet machining remediated IDTB weld for repair of a CRDM nozzle, or an ICI nozzle. The PWSCC life was based on the Electric Power Research Institute (EPRI) MRP-55 PWSCC crack growth model. The PWSCC propagation path was conservatively assumed to follow the highest hoop tensile stress. The crack tip stress intensity factor was calculated for each increment of crack growth.

The results of the triple point flaw analyses demonstrate that a 0.100-inch weld anomaly is acceptable for 40 years of operation following the CRDM/ICI nozzle IDTB weld repair. Flaw acceptance is based on the criteria for limit load ASME Code, Section XI, IWB-3644, 2001A03 Edition. Fatigue crack growth is minimal along each flaw propagation path with the maximum calculated final flaw size being only 0.1003-inch for both the CRDM nozzle and the ICI nozzle. For the CRDM nozzle IDTB weld repairs and the ICI thermocouple guide column nozzle weld repairs, the minimum limit load margins are 3.21, compared to the required safety factor of 2.7, in accordance with IWB-3644 of the ASME Code, Section XI, 2001A03 Edition.

3.5.2 Alternative Welding Process Considerations

TVA has contracted with Framatome Advanced Nuclear Products (FANP/AREVA) to examine the RPVH penetration tube and J-Groove weld examinations and to perform any needed R&R. During the performance of the IDTB R&R in accordance with CC N-638-1, monitoring of the weld preheat and interpass temperatures is required to meet the requirements of Article IWA-4000 of the R&R Program (i.e., IWA-4610(a) of the ASME Code, Section XI, 2001A03 Edition). The IWA-4000 requirements stipulate that the temperatures are to be monitored with the use of thermocouples. In lieu of the thermocouples, contact pyrometers and manual records of the temperatures will be used to document the monitoring of these temperatures in order to preclude the need of attaching the thermocouples, thereby reducing the amount of personnel radiation exposure. The pyrometers will be calibrated in accordance with TVA's, or the contractor's, Measuring and Test Equipment Program and will be capable of monitoring at least the required process temperature range from the minimum preheat temperatures of 50 °F to the maximum interpass temperatures of 350 °F. In addition to the requirements of CC N-638-1 (with its modifications), and in accordance with the provisions of ASME Code, Section IX, Code Case 2142-2, the welding metal to be used as the filler wire will be either ERNiCrFe-7A (Alloy 52M, UNS06054), or ERNiCrFe-7 (Alloy 52, UNS06052). Use of these weld filler materials is supported by ASME Code Case 2142-2, "F-Number Grouping for Ni-Cr-Fe Filler Metals ASME Code, Section IX (Applicable to all Sections, including ASME Code, Section III, Division 1, and ASME Code, Section XI)," which was approved for use with ASME Code, Section IX on August 7, 2003. TVA plans to perform RPVH, CRDM/ICI and HV nozzle penetration repairs by welding the RPVH (P-No.3 base material) and the RPVH nozzle penetrations (P-No.43 base material) with filler material F-No.43, as described above. The general repair outline is shown in Attachment 1 to Enclosure 1 of G-RR-2.

TVA committed to provide NRC with FANP's summary report with initial supporting analyses in the event that the required examinations of RPVH penetration tubes and J-groove welds reveal indications that require repair. FANP's bounding analysis will be reviewed for the impact of indications found to determine if there is a need to revise the supporting analyses. In the event that the FANP bounding analyses require revision, TVA will submit the revised summary report once it becomes available.

3.5.3 Alternative Flaw Characterization Considerations

In accordance with the directives of NRC Order EA-03-009, TVA plans to perform examinations of the CRDM penetration tubes and associated RPVH J-groove welds. In the event that unacceptable indications are found during these examinations, R&R of the CRDM penetration tubes and/or the associated J-groove weld areas may be performed. As part of this process, it may be necessary to allow indications to remain in place in the original J-groove weld areas which have been removed from the pressure boundary function. In accordance with the basic ASME Code, Section XI requirements, characterization of any such flaws must be performed.

The applicable code requirement for the RPVH penetration tube R&R is ASME Code, Section XI, 2001A03 Edition. In accordance with this code, the inservice examination of the RPVH is performed during the normal VT-2 visual examinations conducted as part of the Class 1 system/component pressure tests. Evidence of leakage found during the VT-2 examination will precipitate evaluation and investigations into the source of the leakage. Thus, paragraphs IWA-3300, IWB-3142.4, and IWB-3420 would be applicable to any flaws identified as the result of inservice examinations such as the VT-2 visual examination. IWB-3612 provides acceptance criteria for the analytical evaluation of flaws that, in the case of this analytical analysis, are assumed to exist in the remnant of the J-groove weld material.

The paragraphs referred to above would require characterization of a flaw existing in the remnant of the J-groove weld that would be left on the RPVH if a penetration tube nozzle must be partially removed.

If inspection of the RPVH nozzle penetrations reveals flaws affecting the J-groove attachment welds, exact characterization of these flaws by NDE is unobtainable. Therefore, the full assurance that the future performance of any successive examinations in accordance with the requirements of the code is also unobtainable because of the inability to properly compare the two sets of results. The original nozzle to RPVH weld configurations are difficult to UT examine due to the compound curvature and fillet radius. The configuration is not conducive to UT due to the configuration and dissimilar metal interface between the NiCrFe weld and the low alloy steel RPVH. Furthermore, due to limited accessibility from the RPVH outer surface and the proximity of adjacent nozzle penetrations, it is not possible to perform an ASME Code required scan from the outer surface on the RPVH base material to detect flaws in the vicinity of the original welds. These conditions preclude UT coupling and control of the sound beam in order to perform flaw sizing which results in reasonable confidence of the accuracy of the measured flaw dimensions. Therefore, TVA requested relief from ASME Code, Section XI, IWA-3300(b), IWB-3142.4, IWB-3420, IWB-3612 with the following proposed alternative requirements:

IWA-3300(b) contains a requirement for flaw characterization. In lieu of this requirement, a conservative worst-case flaw shall be assumed to exist in this weld that extends from the weld surface to the RPVH low alloy steel base material interface. TVA has performed appropriate fatigue crack growth analyses based on that flaw to establish the minimum remaining service life of the RPVH.

IWB-3142.4 allows for analytical evaluation to demonstrate that a component is acceptable for continued service. It also requires that components found acceptable for continued service by analytical evaluation be subject to successive examination in accordance with IWB-2420(b) and (c). TVA has performed analytical evaluation of the worst-case flaw referred to above to demonstrate the acceptability of continued operation. However, because of the impracticality of performing any subsequent inspection that would be able to characterize any remaining flaw, successive examination will not be performed.

IWB-3420 requires the characterization of flaws in accordance with the rules of IWA-3300. TVA has assumed a conservative worst-case flaw to exist and performed appropriate fatigue crack growth analyses based on that flaw.

IWB-3612 provides acceptance criteria based upon applied stress intensity factors. IWB-3612(a) requires that, for normal conditions, the ratio of the maximum applied stress intensity factor (K_1)and the available fracture toughness based on crack arrest (K_b) for the corresponding crack tip temperature be less than $1/\sqrt{10}$.

Based on a determination that the flaw failure mechanism is ductile tearing, TVA proposes to consider the use of elastic plastic fracture mechanics (EPFM) and two different safety factors for primary and secondary loads, in keeping with industry practice. In the December 6, 2006, submittal, TVA proposed to use safety factors of 3 on primary (pressure) stresses and 1.0 on secondary stresses (residual plus thermal) for flaw stability under ductile tearing for the normal and upset conditions. The crack driving force will be calculated using safety factors of 1.5 and 1.0 for primary and secondary stresses, respectively. For EPFM analysis of faulted conditions, safety factors of 1.5 and 1.0 will be used for flaw stability assessments and factors of 1.25 and 1.0 for evaluations of crack driving force. These safety factors will be applied for both the CRDM and the ICI penetration tube configuration analysis.

By letter dated December 14, 2007, TVA proposed a new set of safety factors for its flaw evaluations as shown below. The flaw evaluation is discussed further in Section 4.3 of this safety evaluation.

Operating condition	Evaluation Method	Safety factors on Primary Stresses	Safety Factors on Secondary Stresses
Normal	J/T based flaw stability	3.0	1.5 and 1.33*
Faulted	J/T based flaw stability	1.5	1.0
Normal	$J_{0.1}$ limited flaw extension	1.5	1.0
Faulted	$J_{0.1}$ limited flaw extension	1.5	1.0

* Note: The safety factor of 1.5 is used on the CRDM nozzle and the safety factor of 1.33 is used on the thermocouple column nozzle

4.0 STAFF EVALUATION

4.1 Proposed Alternative/Modifications to PWHT Requirements

The following discussion evaluates TVA's proposed alternative CC N-638-1 with modifications in lieu of ASME Code, Section III, IX and XI PWHT requirements.

ASME Code, Section III, NB-4622.1 specifies all welds shall be PWHT, including repair welds. The alternative, CC N-638-1, utilizes an ambient temperature temper bead weld procedure, which excludes the need for PWHT, elevated preheat and post weld soak. TVA states that significant personnel dose would be expended to set up and remove the PWHT equipment and distortion of the RPVH is possible. The staff notes that the area below the RPVH is typically a high radiation area and that high radiation doses to workers are possible. Reducing the amount of time working in this location is consistent with ALARA (as low as reasonably achievable) guidelines when an acceptable alternative is available. Research performed by EPRI, Report GC-1 11050, demonstrates that carefully controlled heat input and bead placement allow subsequent welding passes to relieve stress and temper the HAZ of the base material and preceding weld passes. The GTAW ambient temperature temper bead process has been shown effective by research, successful procedure qualifications, and many successful repairs since development of the technique. Procedure qualification work indicates that the ambient temper bead process produces sound and tough welds. The NRC staff notes that the ambient temperature temper bead process is suitable because the heat penetration of subsequent weld layers is carefully applied to produce overlapping thermal profiles that develop an acceptable degree of tempering in the underlying HAZ. The staff notes that repair welds performed with an ambient temperature temper bead procedure and utilizing the machine GTAW welding process exhibit mechanical properties equivalent to or better than those of the surrounding base material. Further, laboratory testing, analysis, successful procedure qualification and successful repairs have all demonstrated the effectiveness of this process. Therefore, based on the preceding cited research and proven inservice performance, the NRC staff concludes that the use of alternative ASME CC N-638-1 is acceptable.

ASME Code, Section III, NB-4622.11(c) and ASME Code, Section IX, QW-256/QW-406.3 require the following, respectively: 1) the repair welding procedure and welder qualification to be in accordance with ASME Code, Section IX and Section III, NB-4000 and 2) the maximum interpass temperature during procedure qualification to be no more than 100 °F below that used for actual welding. TVA stated that the alternative CC N-638-1 will satisfy NB-4622.11(c) requirements except for the condition of ASME Code, Section IX, QW-256, because an interpass temperature increase greater than 100 °F is a supplementary essential variable. TVA states that this requirement is not applicable to field applications. A 350 °F maximum interpass temperature is required for field applications per CC N-638-1. TVA concluded that the higher interpass temperature is permitted because it would only result in slower cooling rates that could be helpful in producing more ductile transformation products in the HAZ. The NRC staff notes that these limitations have been demonstrated to be adequate to produce sound welds and are similar to the limits in Code Case N-638, which has been endorsed by the staff in Draft RG DG-1091, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1." Therefore, the staff accepts the 350 °F maximum interpass temperature for field applications due to the reasonable likelihood of offsetting undesirable heat sink effects and as an attempt to promote a beneficial metallurgical transformation.

ASME Code, Section III, NB-4622.11(c)(2) requires the use of the SMAW process with covered electrodes meeting either the A-Number 8 or F-Number 43 classification. TVA states the alternative CC N-638-1 will utilize a GTAW process with electrodes and filler metal meeting the F-43 classification. TVA states that these electrodes have been proven to demonstrate equivalent physical and micro structural characteristics. Moreover, the proposed CC N-638-1 ambient temperature temper bead process is inherently free of hydrogen. The NRC staff notes that in the proposed welding atmosphere (high purity argon gas), the electrodes will make a weld exhibiting the same physical and micro structural characteristics as one made with the SMAW process. Unlike the SMAW process, GTAW welding filler metals do not rely on flux coverings that are susceptible to moisture absorption from the environment. Conversely, the GTAW process utilizes dry, inert shielding gases that protect the molten weld pool from oxidizing atmospheres. Any moisture on the surface of the component being welded will be vaporized ahead of the welding torch. The vapor is prevented from being mixed with the molten weld pool by the inert shielding gas that blows the vapor away before it can be mixed. The NRC staff notes further that modern filler metal manufacturers produce wires which have very low residual hydrogen. This is important because filler metals and base materials are the most realistic sources of hydrogen for automatic or machine GTAW welding. The staff agrees that the GTAW process meets and/or exceeds code requirements and is acceptable based on in-service performance.

ASME Code, Section III, NB-4622.11(c)(5) requires preheat to a minimum temperature of 350 °F prior to and during repair welding, and a maximum interpass temperature of 450 °F to an area 1.5 times the component thickness or a 5-inch band, whichever is less. It also requires that thermocouples and recording instruments be used to monitor the metal temperature during welding. TVA states that the alternative CC N-638-1 does not require an elevated temperature preheat and that preheat temperature verification by use of a contact pyrometer on accessible areas of the RPVH is sufficient. TVA states that interpass temperature measurements cannot be accomplished due to inaccessibility in the weld region on the inner surfaces of the penetration tube area. TVA verified maximum interpass temperatures based on mockup results and analytical calculations that show that the maximum interpass temperature will not be exceeded based on a maximum allowable welding heat input, weld bead placement, travel speed, and conservative preheat temperature assumptions. TVA stated that the maximum interpass temperature used during the welding of the procedure qualification record test assembly was less than 150 °F, as required in CC N-638-1 for the first three layers. Heat input beyond the third layer will not have a metallurgical effect on the low alloy steel HAZ, but will affect austenitic grain growth and UT. This takes precedence over the requirements of QW-256 and QW-406.3 of ASME Code, Section IX. The NRC staff notes that the maximum interpass temperature will not exceed the maximum allowable temperatures due to low welding heat input, weld bead placement, travel speed and conservative preheat temperature assumptions. The staff believes that the physical aspects of manipulating equipment following completion of one layer and adjusting for the next layer should lower significantly or return the weld to near ambient temperature. The staff notes further the heat input beyond the third layer will not have a metallurgical effect on the low alloy steel HAZ, but will affect austenitic grain growth and UT.

The NRC staff notes further that contact pyrometers avoid subsequent NDE of removal areas when using weld attached thermocouples as required by the proposed alternative. Therefore, the staff concurs with the proposed alternate methods of verifying minimum preheat and maximum interpass temperature due to inaccessibility, mockup and analytical results.

ASME Code, Section III, NB-4622.11(c)(8) and (d)(1) require the following, respectively: 1) that welding is to be performed using a minimum preheat of 100 °F and a maximum interpass temperature of 350 °F subsequent to a hydrogen bake out, and 2) that a PT examination is required following a hydrogen bake out. TVA states that the alternative CC N-638-1 limits the maximum interpass temperature to 350 °F, requires the area preheat to be at least 50 °F prior to GTAW welding, requires a PT examination and does not require a hydrogen bake out. TVA has demonstrated this method to be adequate by producing tough and sound welds through the procedure qualification process, which has been endorsed by the NRC staff in Draft RG DG-1091, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1." TVA also states that hydrogen bake out is unnecessary for the extremely low hydrogen GTAW ambient temperature temper bead weld process and that a PT examination will be performed as part of the post weld examination process. TVA states that the GTAW process is inherently free from hydrogen as it uses bare electrodes and shields the molten puddle with high purity argon gas. TVA states that bare filler metal does not require special storage conditions due to the absence of welding fluxes and atmosphere, the repair area is essentially free from hydrocarbons and moisture. TVA stated that the surfaces to be welded, filler metal and shielding gas shall be suitably controlled. The NRC staff notes that the GTAW process uses bare electrodes and shields the molten puddle with high purity argon gas. In the absence of welding fluxes and air, the repair area is essentially free of hydrocarbons and moisture. In addition, combined effects from the confined welding location and hydrogen crack resistant austenitic weld metal contribute to the reduction of dissolved hydrogen in the metal, thus lessening the likelihood of hydrogen cracking. Therefore, the staff finds the proposed alternatives acceptable based on the procedure qualification results, the service proven ability of the GTAW process and the surface NDE that will be performed. Also, see ASME Code, Section III, NB-4622.11(c) discussion above.

ASME Code, Section III, NB-4622.11(d)(2)/(d)(4) and NB-4453.4(a) require the following, respectively: 1) a PT and RT examination of the repair welds following a minimum of 48 hours at ambient temperature and a UT examination, if practical, 2) all NDE to be in accordance with

NB-5000 and 3) NDE of the repair welds to be in accordance with original weld requirements. TVA stated that the alternative CC N-638-1 will use PT and UT examination of the final weld a minimum of 48 hours after the weld has cooled to ambient temperature. TVA stated that the proposed repair welds cannot be RT inspected due to limitations on access for source and film placement coupled with the probability of unacceptable geometric un-sharpness. Additionally, the radiation field on contact with the RPVH would result in fogging of the RT film and affect interpretation of the results. Furthermore, adjoining RPVH nozzles inhibit placement of the film and maintaining radioactive source alignment prevents achievement of a meaningful RT. The staff concurs that the access limitations of the CRDM penetrations prevent meaningful RT of the repair welds. TVA states that although industry experience with UT examination of austenitic weld materials such as the J-groove weld does not provide meaningful results due to the attenuative properties of the weld metal, the repair weld is suitable for UT and a final PT can be performed in this case. TVA states for these partial penetration welds, ASME Code, Section III, NB-5245 requires a progressive surface PT or Magnetic Particle Test (MT) examination be at the lesser of one-half the maximum weld thickness or 1/2-inch. The surface of the finished welded joint shall also be examined by either method. TVA states that the final examination of the new weld repair and immediate surrounding area within the band will be sufficient to verify that defects have not been induced in the low alloy steel RPVH material due to the welding process. The NRC staff notes that the access limitations of the CRDM penetrations prevent meaningful RT of the repair welds. The weld configuration and geometry of the penetration in the RPVH provide an obstruction for the RT and limit interpretation of the film. Placement of the film and maintaining radioactive source alignment are impractical due to the near proximity of adjoining nozzles. In addition, the staff notes that TVA will utilize a PT and UT examination in lieu of the ASME Code-required progressive PT and RT. The staff notes that the progressive examinations would be difficult to conduct because of interferences caused by the presence of the automatic GTAW welding equipment. The surface PT examinations will identify any surface to slight subsurface penetrating flaws. The volumetric UT examinations should find construction and repair related flaws. Therefore, the staff agrees that the alternative volumetric examination coupled with surface examination will provide a sufficient degree of confidence in verifying the soundness of the proposed welds.

ASME Code, Section III, NB-4622.11(f) and (g) require the following, respectively: 1) establishing the procedure qualification test plate relative to the P-Number, group Number and the PWHT of the materials to be welded and 2) welder performance qualification relating to physical obstructions that might impair the welder's ability to make sound repairs, pertaining to the SMAW manual welding process. TVA states that the alternative CC N-638-1 requires that the root width and included angle of the cavity are to be no greater than the minimum specified for the repair. TVA also states that CC N-638-1 uses a machine GTAW process and requires welding operators to qualify in accordance with ASME Code, Section IX requirements. TVA states that the GTAW machine process eliminates concerns about obstructions that might interfere with the welder's ability to weld as all such obstructions will be eliminated to accommodate the welding machine. The NRC staff believes this restriction on root width and included angle is imposed to further ensure reproducibility of production or field welds. The staff notes that this requirement ensures that the welding procedure is only used in repair cavity configurations where it has demonstrated sufficient access to deposit root passes, tie-in to the beveled or tapered walls of the repair cavity, provide appropriate tempering and ensure complete weld fusion. The staff also notes that the proposed alternative and elimination of obstructions exceeds ASME Code requirements and is acceptable.

ASME Code, Section III, NB-5331(b) does not allow cracks, lack of fusion, or incomplete penetration regardless of length. A linear indication often occurs at the triple point intersection of the RPVH, the nozzle, and the first weld bead. The alternative CC N-638-1 will allow the triple point indication to remain, based on TVA's postulated 0.100-inch flaw assumed to propagate, via fatigue crack growth, in each of the two directions on the uphill and downhill sides of the nozzle. TVA states that results of the analysis demonstrate that the weld anomaly is acceptable for a 40-year design life of the IDTB weld repair for both the CRDM and ICI nozzles. The NRC staff concurs with the alternative because the performed fatigue analysis demonstrates a reasonable assurance these repairs would restore long-term stability to the penetration tube repair of the RPVH assembly. Also, see Section 4.3 below regarding the alternative to flaw evaluation.

4.1.1 Proposed Modifications to Code Case N-638-1 Requirements

TVA proposed welding technique differs from/modifies Sections 1.0 through 4.0 of the alternative CC N-638-1 as follows:

Section 2.1(j) requires the average values of the three HAZ impact tests be equal or greater than the average values for the unaffected base material tests. TVA stated that the reference temperature for Nil Ductility Transition (RT_{NDT}) was determined to be -30 °F for the Charpy impact testing portion of the IDTB qualification process. TVA stated at RT_{NDT} + 60 °F temperature (+30 °F), the average of the HAZ absorbed energy Charpy impact tests was greater than the average of the unaffected base material in accordance with ASME Code, Section III, NB-2331. However, the average of the mils lateral expansion for the HAZ was less than the average values for the unaffected base material. TVA conducted additional Charpy V-notch tests on the HAZ material as permitted by ASME Code, Section III, NB-4335.2 to determine an additive temperature to the RT_{NDT} temperature. TVA stated that the average mils lateral expansion for the HAZ at +35 °F was equivalent to the unaffected base material at +30 °F. These test results require an adjustment temperature of +5 °F to the RT_{NDT} temperature for base material on which welding is performed (i.e., RT_{NDT} +5 °F). TVA concluded that the CC N-638-1 will be modified to use an adjustment temperature of +5 °F to the RT_{NDT} temperature for base material on which welding is performed (i.e., RT_{NDT} +5 °F) as required by test results. The NRC staff accepts the modified alternative adjustment temperature based on the above extensive testing of the HAZ, as permitted by the ASME Code.

Section 3.0(d) requires the maximum interpass temperature for field applications to be 350 °F regardless of the interpass temperature during qualification. TVA states that the alternative CC N-638-1, section 2.1(e) specifies that the maximum interpass temperature for the first three layers of the test assembly shall be 150 °F. However, ASME Code, Section IX, QW-256 specifies maximum interpass temperature as a supplementary essential variable that must be held within 100 °F above that used during procedure qualification. TVA states that CC N-638-1 restricts base metal heating during qualification that could produce slower cooling rates which are not achievable during field applications. TVA concludes that CC N-638-1 modifies the QW-256 requirement as the maximum interpass temperature of 350 °F will be used during production/field welding. See discussion on ASME Code, Section III, NB-4622.11(c)(5) above. The NRC staff agrees the 350 °F maximum interpass temperature may prove beneficial for a favorable metallurgical transformation during field applications by producing slower cooling rates. Also, see discussion on ASME Code, Section III, NB-4622.11(c)(5) above.

Sections 4.0(b) and 4.0(e) require the following, respectively: 1) the final weld surface and band around the area defined in section 1.0(d) to be examined using surface and UT methods and 2) UT acceptance criteria to be in accordance with IWB-3000. The purpose for the examination of the band is to assure all flaws associated with the weld repair area have been removed or addressed. TVA states that the band around the area defined in paragraph 1.0(d) cannot be examined due to the physical configuration of the partial penetration weld. The alternative will use an examination area that includes the weld and adjacent base material to be examined by PT and UT methods in the regions shown in Figure 1 of Attachment 1 to G-RR-2. TVA stated that the final examination of the new weld and immediate surrounding area of the weld within the band will be sufficient to verify that defects have not been induced in the low alloy steel RPVH material due to the welding process, and will assure integrity of the nozzle and the new weld. TVA states that it is unreasonable to examine the band required due to the head configuration and interference from adjacent nozzles, as well as the configuration of the partial penetration welds. TVA states the PT area includes the weld surface and extends upward on the original nozzle inside surface to include the rolled expansion area including the rolled transition area (approximately 2.7 inches on the CRDM nozzles and approximately 3.1 inches on the ICI nozzles) and at least 1/2-inch below the new weld on the lower nozzle inside surface. TVA states UT will be performed by scanning from the inner diameter surface of the weld and the volume of interest for UT extends from at least 1 inch above and below the new weld into the RPVH low alloy steel base material to at least 1/4-inch depth. TVA stated that the UT is qualified to detect flaws in the repair weld and base metal interface in the repair region. TVA states that for this configuration, there are no acceptance criteria in ASME Code, Section XI, IWB-3000 that directly apply. UT acceptance criteria will be in accordance the CC N-638-1 conditional requirement ASME Code, Section III, NB-5330. The conditional requirements are generally more restrictive than ASME Code, Section XI standards, and do not permit many common welding flaws such as lack of fusion, incomplete penetration, or cracks regardless of length. IWB-3000 standards allow acceptance of these types of fabrication indications based on dimensioned flaw boundaries.

The NRC staff notes that application of the alternative examination area is impractical due to the physical configuration and proximity of this specially designed weld in relation to the surrounding nozzle and RPVH. The location of adjacent nozzle expansion transitions, J-groove weld and RPVH material would interfere with the alternative defined examination area. Due to the configuration of this specially designed weld, TVA proposed to use the examination area defined above. The staff notes that this proposed examination area consists of the weld repair and the fusion zone or base metal interface and that effectiveness was demonstrated on a full-size mockup similar to the RPVH. The staff agrees with proposed extent of the modified examination area based on use of the alternative weld process and difficulty created by the weld configuration and surrounding RPVH. Also, see Section 4.3 below regarding the alternative to flaw evaluation.

Section 4.0(c) requires areas which had weld-attached thermocouples to be ground and examined using a surface examination. TVA states that the proposed alternative CC N-638-1 modifies Section 4.0 requirement as it will use contact pyrometers to monitor interpass temperatures in lieu of thermocouples. TVA stated that the RPVH preheat temperature will be essentially the same as the reactor building ambient temperature during power operation and therefore, RPVH preheat temperature monitoring and the use of thermocouples is unnecessary which would result in additional personnel dose associated with placement and removal. TVA states that preheat temperature verification by use of a contact pyrometer on accessible areas of the RPVH will be sufficient. See discussion ASME Code, Section III, NB-4622.11(c)(5) above.

The NRC staff notes that the maximum interpass temperatures required for this welding can easily be measured with this type of device. The NRC staff notes further that contact pyrometers maintain a more accurate and consistent temperature reading due to physical contact with the component; however, they avoid the welding, subsequent NDE of removal areas and increased radiation exposure required with utilizing thermocouples. Therefore, this type of temperature measurement is acceptable. The staff concurs with the modification to use contact pyrometers based on the undesirability of using welded thermocouples and NDE of removal sites. Also, see discussion of ASME Code, Section III, NB-4622.11(c)(5) in Section 4.1 above.

The staff concludes, based on the justifications presented in the preceding discussion, that 1) TVA's proposed alternative to use CC N-638-1 ambient temperature temper bead process with modifications in lieu of the ASME Code required temper bead process, PWHT, elevated preheat and postweld soak, will produce a permanent repair weld and provide reasonable assurance of structural integrity, 2) TVA's proposed alternative to perform postrepair PT and UT examinations in lieu of the ASME Code required postrepair RT examination requirements are acceptable due to the physical limitations of adjacent components preventing access of source/film placement, and 3) ASME Code, Section XI requirements concerning PWHT are impractical and TVA's attempt to comply with these requirements would result in an unnecessary increase in radiological dose.

4.2 Alternative to ASME Code IWA-3300(b), IWB-3142.4, and IWB-3420

ASME Code, Section XI, IWA-3300(b) requires that potential flaws in a component are to be characterized by inspection. ASME Code, Section XI, IWB-3142.4 requires that components containing relevant conditions shall be acceptable for continued service if an analytical evaluation demonstrates acceptability of the components. Components accepted for continued service, based on an analytical evaluation, shall be subsequently examined. ASME Code, Section XI, IWB-3420 requires that each detected flaw, or group of flaws, shall be characterized by the requirements of IWA-3300 to establish the dimensions of the flaws. In lieu of these requirements, TVA assumed a conservative worst-case flaw to exist in the J-groove weld of the CRDM/ICI nozzles due to PWSCC. The postulated radial crack was assumed to extend from the weld surface to the interface between the butter and the base metal of the RPVH. TVA also calculated the appropriate fatigue crack flaw growth into the base metal of the RPVH to determine the minimum remaining service life. The staff has determined that characterization of any cracks in the original J-groove weld region is exceptionally difficult to perform from inside the vessel by UT methods due to dissimilar materials and geometry. The compound curvature of the RPVH, the acoustical interference inherent within base and weld metals, and the interference between these varying metals prohibit ultrasonic coupling and control of the sound beam necessary for sizing cracks with any degree of confidence. The angle of incidence from the outer surface of the RPVH base material does not permit perpendicular interrogation by UT examination using shear wave techniques for circumferentially oriented flaws. In addition, the physical proximity of the nozzle does not allow for longitudinal scrutiny of the area of interest. Cladding provides an acoustic interface which will severely limit a positive examination of the weld material and characterization of an existing flaw. Furthermore, RT examination of this area is impractical because flaws oriented perpendicular to gamma and x-rays are difficult to detect and the triple point anomaly would mask any flaws behind it. PT examination will show linear surface growth, however, the linear growth can only indicate if there is volume growth.

TVA stated that subsequent NDE of the J-groove weld and buttering to satisfy successive examination requirements is impractical. The postulated flaws are not in a pressure-retaining weld and, based on industry experience, they would arrest at the butter-to-low alloy base material interface. TVA has analyzed the postulated flaw as acceptable for continued service based on the flaw growing to the butter-to-low alloy base material interface and blunting. TVA has also analyzed postulated fatigue cracks in the RPVH base material in conjunction with PWSCC in the J-groove weld and buttering and has determined that the ASME Code, Section XI evaluation criteria are satisfied.

Therefore, the staff agrees that characterization of flaws and successive examinations described above are impractical due to the physical geometry and material composition of the RPVH and weld material. The staff has reviewed the TVA proposed alternatives to ASME Code, Section XI, IWA-3300(b), IWB-3142.4, and IWB-3420 requirements and finds them to be acceptable based on TVA performing a flaw evaluation using a conservative worst-case flaw existing in the J-groove weld caused by PWSCC and performing fatigue analysis which demonstrated a reasonable assurance that the structural integrity of the RPVH is acceptable for 3 calendar years.

4.3 Alternative to Flaw Evaluation Requirements of ASME Code IWB-3612

TVA is required to perform flaw evaluations in accordance with ASME Code, Section XI, IWB-3612, to demonstrate that the final flaw size is acceptable. As an alternative, TVA stated that fracture mechanics evaluations were performed to determine that degraded J-groove weld material could remain in the RPVH, with no examination to size any flaws that might remain following repairs. TVA analyzed the remaining non-chamfered J-groove welds in the CRDM nozzles by postulating that the entire J-groove weld and butter is cracked and the flaw propagates into the RPVH by fatigue.

Although a crack propagating through the J-groove weld by PWSCC would eventually grow to the interface between the weld and low alloy steel RPVH, continued growth by PWSCC into the low alloy steel is not expected to occur. SCC of carbon and low alloy steel is not a problem under pressurized water reactor conditions. SCC of steels containing up to 5-percent chromium is most frequently observed in caustic and nitrate solutions and in media containing hydrogen sulfide. Based on this information, SCC is not expected to be a concern for low alloy steel exposed to primary water. Therefore, an interdendritic crack propagating from the J-groove weld area is expected to blunt and cease propagation.

TVA first determined crack stress intensity factors for initial “as-left" flaws using three-dimensional finite element analysis. Crack size was incremented based on the fatigue crack growth model provided in ASME Code, Section XI, IWA-4300, 2001A03 Edition. Stress intensity factors were increased by the square root of the ratio of flaw sizes for each increment of crack growth. This approximation is conservative considering both the residual and the thermal gradient stresses decrease in the direction of crack propagation.

TVA stated that the RPVH does not have sufficient fracture toughness to satisfy the specified safety margins based on the stress intensity factor for the final flaw size in accordance with ASME Code, Section XI, IWB-3612. The NRC staff notes that the flaw evaluation of IWB-3612 is based on linear elastic fracture mechanics, which is conservative for the flaw evaluation of the low alloy steel such as WBN-1 RPVH. As an alternative, TVA proposed EPFM to evaluate the final flaw sizes after 10 years of crack growth for all propagation paths based on a determination that ductile tearing is the failure mechanism for the final flaw under the conditions being evaluated. The 10-year period corresponds to the ISI interval and the RPV head is required to be examined at least once every 10 years. In the December 6, 2006, submittal, TVA reported that the postulated flaw was evaluated using the safety factors as discussed in Section 3.5.3 of this safety evaluation. In the EPFM evaluation, TVA used J-integral/Tearing modulus (J-T) approach and J-integral limited flaw extension approach.

However, the NRC staff questioned some of the safety factors that TVA used in its EPFM calculations because they are lower (not as conservative) than the safety factors that the NRC has approved for other nuclear plants. For the J-T based flaw stability analysis, the NRC staff has approved the use of a safety factor of 3.0 for primary stresses and 1.5 for secondary (residual plus thermal) stresses for normal operating conditions in CRDM repair relief requests. For the J-integral limited flaw extension of 0.1-inch analysis, the NRC staff has approved the use of a safety factor of 1.5 on primary stresses and 1.0 on secondary stresses for the normal and faulted conditions. TVA stated that it used the safety values in ASME Code Case N-749, which the NRC has not endorsed. The NRC staff suggested that the NRC previously-approved safety factors be used in the flaw stability analysis.

In its letter dated December 14, 2007, TVA reported that using safety factors previously-approved by the NRC, a repaired RPV upper head CRDM nozzle would be acceptable for 3 years instead of 10 years of operation. TVA also reported that a repaired thermocouple column nozzle would be acceptable for 3 years of operation if the safety factor of 1.33 is used on secondary stresses in lieu of the NRC recommended 1.5. The above results were obtained based on the upper shelf Charpy V-notch impact energy of 79.1 ft-lb and deleting the turbine roll test and 2485 psig hydrotest transients from analytical consideration. In the February 7, 2008, letter, TVA committed to revise WBN-1 Updated Final Safety Report (UFSAR) Section 5.2.1.5 to prohibit the future performance of the turbine roll test and hydrotest transients if an IDTB repair to the CRDM and thermocouple column nozzles is made. TVA stated that there are currently no plans and does not anticipate the need to perform these tests over the remaining life of the facility.

The NRC staff does not have a concern that the final size flaw is acceptable for 3 years instead of 10 years. If TVA does not find any unacceptable indications in the RPVH penetrations during the spring 2008 refueling outage, TVA would not need this relief request, no repair will be made, and the flaw calculation would be moot. If an unacceptable flaw is detected in the RPVH penetration nozzles, TVA will perform the proposed IDTB repair in accordance with this relief request. After the repair is made, TVA is required to perform RPVH inspection every refueling outage per NRC Order EA-03-009. The refueling outage at WBN-1 is about every 1.5 years. The calculated 3-year period for the postulated flaw is not a concern because the flaw acceptance period of 3 years is longer than the inspection frequency of every 1.5 years. Even if TVA were to adopt a longer refueling cycle at WBN-1, it would probably not be longer than 2 years. Thus, within the 3-year period, there would be at least one periodic inspection to confirm the structural integrity of the RPVH and to demonstrate that any flaw will not exceed the maximum analyzed flaw size. TVA reported that the postulated flaw that is assumed to be propagated into the RPVH is 1.3 inches. The thickness of the RPVH is 6.5 inches. Comparing the flaw size to the RPVH thickness, there is sufficient safety margin for RPVH structural integrity.

As stated above, TVA used the safety factor of 1.33 because it cannot satisfy the NRC-approved safety factor of 1.5 on secondary stresses for the thermocouple column nozzle. The NRC staff does not have a concern on the use of the safety factor of 1.33 in this particular flaw evaluation.

TVA has performed various flaw stability analyses using various safety factors and 1.33 is a safety factor that would show the acceptability of the RPVH for 3 years. TVA has included various conservative assumptions as stated above. The use of the safety factor of 1.33 is restricted for 3 calendar years. The NRC staff notes that the safety factor of 1.33 is not allowed for general use.

The NRC staff concludes that the proposed alternative for flaw evaluation would not significantly affect the structural integrity of the CRDM nozzle or RPVH. The staff's conclusion is based on the following observations:

1. TVA's fracture mechanics evaluation assumes conservatively that the entire remnant J-groove weld is cracked, and that the crack propagates into the RPVH.

2. The proposed flaw evaluation alternative of using lower safety factors than the ASME Code, Section XI, IWB-3612, is limited in application because it is applicable only to the fracture mechanics analysis of the postulated flaw in the CRDM J-groove weld propagating into the RPVH.

3. The maximum cumulative fatigue usage factors of 0.336 and 0.263 for CRDM and ICI weld repair/Alloy 690 replacement nozzles, respectively, are lower than and within the maximum allowed ASME Code fatigue usage factor of 1.0 based on 40 years of operation.

4. The proposed safety factors of 3.0 on primary stresses, and 1.5 on secondary stresses, are acceptable for WBN-1 when compared to the normal/primary safety factor of 3.16, which is required by IWB-3612(a), because TVA's fracture mechanics analysis revealed the following:

    A. The applied tearing modulus remains less than the material tearing modulus and the applied J-integral remains less than the material J-integral at the 0.1-inch crack extension for the final flaw size on both the uphill and downhill sides under all operating conditions with the above safety factors incorporated.

    B. TVA conservatively modeled the weld residual stresses in its flaw evaluation.

5. The proposed alternate flaw evaluation is limited for 3 calendar years from the time of the completed repair.

The NRC staff concludes that the proposed alternative provides reasonable assurance of structural integrity and is appropriate for the final configuration of the RPVH penetration nozzles based on the analysis demonstrating that the postulated flaw will arrest and that the structural integrity of the RPVH will be maintained. This assurance is obtained without the removal of existing flaws in the remaining original J-groove weld material and without performing flaw characterization in accordance with ASME Code, Section XI, IWA-3300 (b), IWB-3142.4, IWB-3420, and IWB-3612 of the 2001A03 Edition.

TVA's fracture mechanics analysis demonstrated that in the case of a nozzle repair, based on a discovered flaw remaining within the existing J-groove weld, the RPVH structural integrity is acceptable for 3 calendar years following the completion of the repair. As authorized by 10 CFR 50.55a(g)(6)(i), the staff imposes the following additional requirement. If a nozzle is repaired (i.e., establishing a new pressure boundary weld), TVA is required to submit to the NRC for review and approval any plans for corrective actions on the existing J-groove weld and/or the RPVH to demonstrate acceptable RPVH soundness beyond 3 calendar years.

5.0 LIST OF COMMITMENTS

In the submittal dated December 6, 2006, and in supplements dated December 14, 2007, and February 7, 2008, TVA committed to the following:

1. TVA will provide the NRC with FANP's summary report with initial supporting analyses in the event that the required examinations of RPVH penetration tubes and J-groove welds reveal indications that require repair. This summary report would be submitted prior to unit restart for the associated outage.

2. The FANP bounding analysis will be reviewed for the impact of any indications found to determine if there is a need to revise the supporting analyses. In the event that the FANP bounding analyses requires revision, TVA will submit the revised summary report in conjunction with item 1 above, as needed.

3. If an IDTB repair to the CRDM and/or thermocouple column nozzles is made, TVA will revise WBN-1 UFSAR Section 5.2.1.5 to prevent use of the turbine roll test and hydrostatic test.

6.0 CONCLUSION

Based on the above discussion, the NRC staff concludes the following: (1) that compliance with the ASME Code required in-process and postrepair examinations, flaw characterization and successive examinations of the remnant J-groove welds are impractical for WBN-1, (2) that the ASME Code, Section XI required PWHT, elevated preheat and post weld soak are impractical and the proposed alternative to use the ambient temperature temper bead process of CC N-638-1, with modifications, would produce a permanent repair weld and promote reasonable assurance of structural integrity, and (3) that the proposal to leave cracks in the non-pressure boundary portion of the remaining J-groove partial penetration weld and to evaluate crack growth using the appropriate ASME Code, Section XI criteria for a worst-case crack growth scenario is acceptable for 3 calendar years from the time of completing the RPVH repair. The NRC staff concludes that the proposed alternative will provide a reasonable assurance of structural integrity for the planned RPVH penetration repairs.

Therefore, pursuant to 10 CFR 50.55a(g)(6)(i), the proposed relief is granted for the remainder of the second 10-year ISI Interval at WBN-1, which ends on May 26, 2016, subject to the following requirement. If a nozzle is repaired (i.e., establishing a new pressure boundary weld), the grant of relief is limited to 3 calendar years from the time of completing the repair and TVA is required to submit to the NRC for review and approval any plans for corrective actions on the existing J-groove weld and/or the RPVH to demonstrate acceptable RPVH soundness beyond 3 calendar years.

This granting of relief pursuant to 10 CFR 50.55a(g)(6)(i) is authorized by law and will not endanger life or property or the common defense and security, and is otherwise in the public interest giving due consideration to the burden upon the licensee that could result if the requirements were imposed on the facility.

All other requirements of the ASME Code, Sections III and XI, for which relief has not been specifically requested and approved, remain applicable, including third party review by the Authorized Nuclear Inservice Inspector.

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Date: February 8, 2008