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

January 27, 2012

Mr. David A. Heacock
President and Chief Nuclear Officer
Virginia Electric and Power Company
Innsbrook Technical Center
5000 Dominion Boulevard
Glen Allen, VA 23060-6711

SUBJECT: NORTH ANNA POWER STATION, UNIT NO. 1 (NORTH ANNA UNIT 1), RELIEF REQUEST (RR) N1-I4-CMP-001, REGARDING THE USE OF WELD OVERLAYS AS AN ALTERNATIVE REPAIR TECHNIQUE (TAC NO. ME5965)

Dear Mr. Heacock:

By letter dated March 30, 2011, as supplemented by letters dated June 29, 2011, and November 10, 2011, Virginia Electric and Power Company (the licensee), submitted relief request (RR) N1-I4-CMP-001. This RR proposed an alternative to certain requirements of the American Society of Mechanical Engineers, *Boiler and Pressure Vessel Code* (ASME Code), Section XI, for repairing the Alloy 82/182 dissimilar metal (DM) welds if cracking is detected by the inservice inspection (ISI) for North Anna, Unit 1 steam generator (SG) hot leg nozzles. This alternative requested approval will allow the application of full structural weld overlay onto the Alloy 82/182 DM weld of the steam generator (SG) hot leg nozzles.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(a)(3)(i), the licensee requested to use the proposed alternative, RR N1-I4-CMP-001, on the basis that the alternative provides an acceptable level of quality and safety.

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the licensee's request, as supplemented. As set forth in the enclosed safety evaluation, the NRC staff has determined that the proposed alternative described in RR N1-I4-CMP-001, provides an acceptable level of quality and safety and provides reasonable assurance that the SG hot leg nozzles are operationally ready. Accordingly, the NRC staff has concluded that the licensee has adequately addressed all of the regulatory requirements set forth in 10 CFR 50.55a(a)(3)(i).

Therefore, the NRC staff authorizes the alternative noted above, at North Anna, Unit 1, for full structural weld overlay onto the Alloy 82/182 DM weld of the steam generator (SG) hot leg nozzles for the spring 2012 refueling outage of the fourth 10-year ISI interval that commenced on May 1, 2009, and will end on April 30, 2019.

All other ASME Code, Section XI requirements for which relief was not specifically requested and approved, remain applicable including third-party review by the Authorized Nuclear Inservice Inspector.

Please contact me at (301) 415-2942, or the Project Manager Dr. Sreenivas at (301) 415-2597, if you have any questions.

Sincerely,

Nancy L. Salgado

Nancy L. Salgado, Chief
Plant Licensing Branch II-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-338

Enclosure:
Safety Evaluation

cc w/encl: Distribution via Listserv

UNITED STATES
NUCLEAR REGULATORY COMMISSION
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELIEF REQUEST N1-I4-CMP-001, USE OF WELD OVERLAYS AS AN ALTERNATIVE REPAIR TECHNIQUE FOR STEAM GENERATOR HOT LEG NOZZLES

NORTH ANNA POWER STATION, UNIT NO. 1

VIRGINA ELECTRIC AND POWER COMPANY

DOCKET NO. 50-338

1.0 INTRODUCTION

By letter dated March 30, 2011 (Agencywide Documents and Access Management System (ADAMS) Accession No. ML110900566), as supplemented by letters dated June 29, 2011, (ADAMS Accession No. ML11187A323), and November 10, 2011 (ADAMS Accession No. ML113180296), Virginia Electric and Power Company, (the licensee) submitted Relief Request (RR) N1-I4-CMP-001 for the U.S. Nuclear Regulatory Commission (NRC) review and approval. The licensee requested relief from certain requirements of the American Society of Mechanical Engineers, *Boiler and Pressure Vessel Code* (ASME Code), Section XI, for repairing the Alloy 82/182 dissimilar metal (DM) welds if cracking is detected by the inservice inspection (ISI). RR N1-I4-CMP-001 pertains to the installation of full structural weld overlay (FSWOL) onto the Alloy 82/182 DM weld of the steam generator (SG) hot leg nozzles at the North Anna Power Station, Unit No. 1, (North Anna, Unit 1) during the spring 2012 refueling outage. The licensee requested RR N1-I4-CMP-001 for the North Anna, Unit 1, fourth 10-year ISI interval that commenced on May 1, 2009, and will end on April 30, 2019.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR), Part 50, Section 50.55a(a)(3)(i), the licensee proposed an alternative repair technique, by installing FSWOL on the nickel-based alloy DM welds, in lieu of repair and/or replacement provisions of Article IWA-4000 of the ASME Code, Section XI. The licensee requested to use the proposed alternative on the basis that the alternative provides an acceptable level of quality and safety.

2.0 REGULATORY REQUIREMENTS

Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(g)(4) specifies that 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, "Rules for In-service Inspection (ISI) of Nuclear Power Plant Components," to the extent practical within the limitations of design, geometry, and materials of construction of the components. The regulations require that inservice examination 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(g)(6)(ii), the Commission may require the licensee to follow an augmented ISI program for systems and components for which the Commission deems that added assurance of structural reliability is necessary.

10 CFR 50.55a(a)(3), states that "proposed alternatives to the requirements of paragraphs (c), (d), (e), (f), (g) and (h) of this section or portions thereof may be used when authorized" by the NRC, if the licensee "demonstrates that (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(b)(2)(xv), "Appendix VIII specimen set and qualification requirements," states that "the following provisions may be used to modify implementation of Appendix VIII of Section XI, 1995 Edition through the 2001 Edition. Licensees choosing to apply these provisions shall apply all of the provisions under this paragraph except for those in 10 CFR 50.55a(b)(2)(xv)(F) which are optional. Licensees who use later editions and addenda than the 2001 Edition of the ASME Code shall use the 2001 Edition of Appendix VIII."

10 CFR 50.55a(g)(6)(ii)(F), "Examination requirements for class 1 piping and nozzle dissimilar-metal butt welds" incorporates by reference ASME Code Case N-770-1, "Alternative Examination Requirements and Acceptance Standards for Class 1 PWR [Pressurized-Water Reactor] Piping and Vessel Nozzle Butt Welds Fabricated with UNS N06082 or UNS W86182 Weld Filler Material with or without Application of Listed Mitigation Activities." Paragraph (g)(6)(ii)(F)(1), states that "licensees of existing and operating pressurized-water reactors as of July 21, 2011, shall implement the requirements of ASME Code Case N-770-1, subject to the conditions specified in Paragraphs (g)(6)(ii)(F)(2) through (g)(6)(ii)(F)(10), by the first refueling outage after August 22, 2011."

3.0 TECHNICAL EVALUATION

ASME Code Components Affected

ASME Code Class:	Class 1
Examination Category:	B-F in Table IWB-2500-1
Item No.	B5.70
Component:	Steam Generator Hot Leg Nozzle To Safe-End Dissimilar Metal Welds
System:	Reactor Coolant System

The components at North Anna, Unit 1, for which a relief is requested, are listed in Table 1.

Table 1. Component List

Weld No.	Description	Nominal Inner Diameter (ID) in.	Material
11715-WMKS-RC-E-1A.2 / 29-RC-1 / N-SE29 IN.	Steam Generator Hot Leg Nozzle to Safe-End Weld	29	Low Alloy Steel Hot Leg Nozzle / Alloy 82/182 Weld / Stainless Steel Safe-End
11715-WMKS-RC-E-1B.2 / 29-RC-4 / N-SE29 IN.	Steam Generator Hot Leg Nozzle to Safe-End Weld	29	Low Alloy Steel Hot Leg Nozzle / Alloy 82/182 Weld / Stainless Steel Safe-End
11715-WMKS-RC-E-1C.2 / 29-RC-7 / N-SE29 IN.	Steam Generator Hot Leg Nozzle to Safe-End Weld	29	Low Alloy Steel Hot Leg Nozzle / Alloy 82/182 Weld / Stainless Steel Safe-End

The SG hot leg nozzle is a low alloy steel (SA-508 Class 3) that is buttered with Alloy 82/182 weld material and welded by Alloy 82/182 to the austenitic stainless steel safe-end (SA-336, Class F316LN). The nozzle is internally cladded with austenitic stainless steel.

Applicable Code Edition and Addenda

The Code of Record for the fourth 10-year ISI interval at North Anna, Unit 1, is the 2004 Edition with no Addenda of the ASME Code, Section XI.

Applicable Code Requirements

IWA-4411 of the 2004 Edition with no Addenda of the ASME Code, Section XI, states, "Welding, brazing, and installation shall be performed in accordance with the Owner's Requirements and, except as modified below, in accordance with the original Construction Code of the item."

IWA-4411(a) of the 2004 Edition with no Addenda of the ASME Code, Section XI, states, in part, "Later Editions and Addenda of the Construction Code, or a later different Construction Code, either in its entirety or portions thereof, and Code Cases may be used, provided the substitution is as listed in IWA-4221(c)."

IWA-4411(b) of the 2004 Edition with no Addenda of the ASME Code, Section XI, states, "Revised Owner's Requirements may be used, provided they are reconciled in accordance with IWA-4222."

IWA-4411(e) of the 2004 Edition with no Addenda of the ASME Code, Section XI, states, "The requirements of IWA-4600(b) may be used when welding is to be performed without the postweld heat treatment required by the Construction Code."

The 2001 Edition with no Addenda of the ASME Code, Section XI, Appendix VIII, Supplement 11, "Qualification Requirements for Full Structural Overlaid Wrought Austenitic Piping Welds," provides requirements for performance demonstration for ultrasonic testing (UT) examination procedures, equipment, and personnel used to detect and size flaws.

The 2001 Edition with no Addenda of the ASME Code, Section XI, Appendix VIII, Supplement 10, "Qualification Requirements for Dissimilar Metal Piping Welds," is applicable to the DM piping welds examined from either the inside or outside surface.

Licensee's Reason for Relief Request

The licensee, states that, "Dissimilar metal welds (DMWs) containing nickel welding alloys 82 and 182 have experienced primary water stress corrosion cracking (PWSCC) in components operating at pressurized water reactor temperatures." The licensee proposed, "to mitigate the [PWSCC] susceptibility of the North Anna Unit 1 Steam Generator Hot Leg Nozzle dissimilar metal welds by installing a full structural weld overlays (FSWOL) on each of the DMWs. This approach provides an alternative to inspection alone as a means to assure the structural integrity of these locations."

There are no generically accepted criteria currently available for applying a FSWOL to DM welds constructed of Alloy 82/182 weld material. For repair/replacement activities, the ASME Code, Section XI, applicable to North Anna, Unit 1, does not contain requirements for FSWOL installation.

Licensee's Proposed Alternative

As an alternative to the requirements of the ASME Code, Section XI, (Articles IWA-4410 and IWA-4611), the FSWOL is proposed to be installed on each of the North Anna, Unit 1, SG hot leg nozzle to safe-end DM welds. The proposed alternative will mitigate the PWSCC susceptibility of these welds. The FSWOL will be installed based on the ASME Code Case N-740-2, "Full Structural Dissimilar Metal Weld Overlay for Repair or Mitigation of Class 1, 2, and 3 Items, methodology." The ASME Code Case N-740-2 methodology is described in Attachment 1 of Enclosure 1 of RR N1-I4-CMP-001.

For weld overlay application on the North Anna, Unit 1, SG hot leg nozzles DM weld, an increase of up to 1000 square inches for the temperbead surface area over the ferritic nozzle material is proposed.

The Electric Power Research Institute (EPRI) Performance Demonstration Initiative (PDI) program is proposed for the qualification of UT examinations for detection and sizing of flaws in the FSWOL in lieu of the requirements in Supplement 11 of Appendix VIII of the 2004 Edition and

no Addenda of the ASME Code, Section XI. Supplement 11 specifies the requirements for performance demonstration of UT examination procedures, equipment, and personnel for detection and sizing flaws in the FSWOL of wrought austenitic piping welds.

Licensee's Basis for Proposed Alternative

The proposed alternative (i.e., installation of FSWOL) provides an acceptable methodology for mitigating PWSCC susceptibility of subject DM welds. It also reduces defects that may be observed in the subject welds to an acceptable size. The FSWOL is applied using weld overlay filler metals (i.e., Alloy 52/52M) that are potentially resistant to PWSCC. Weld overlay procedures create compressive residual stress profiles within the original weld. In addition, the post overlay preservice inspection (PSI) and the ISI requirements provide assurance that structural integrity is maintained for the life of the plant.

An FSWOL using Alloy 52M weld material will be installed on each of the subject Alloy 82/182 DM welds in accordance with ASME Code Case N-740-2 methodology. The licensee stated that an alternative is desired because ASME Code Case N-504-4, "Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping," is written specifically for stainless steel pipe-to-pipe weld FSWOL and ASME Code Case N-638-4, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temperbead Technique," contains additional restrictions and requirements. Attachment 3 of Enclosure 1 of RR N1-I4-CMP-001 documents comparison of the licensee's proposed alternative, (i.e. ASME Code Case N-740-2), with the ASME Code Case N-504-4 and Appendix Q requirements.

ASME Code Case N-504-4 provides requirements for installing weld overlay on austenitic stainless steel piping to reduce a defect to a flaw of acceptable size as an alternative to defect removal. The NRC has approved for use, ASME Code Case N-504-4 in Regulatory Guide (RG) 1.147, Revision 16, with condition that the provisions of ASME Code, Section XI, Nonmandatory Appendix Q, weld overlay repair of Class 1, 2, and 3 austenitic stainless steel piping weldments, must be met. The licensee stated that the provisions of RG 1.147, Revision 16, will be met.

ASME Code Case N-638-4 requirement limits the temperbead surface area over the ferritic nozzle material up to 500 square inches. The NRC has approved for use, ASME Code Case N-638-4 in RG 1.147, Revision 16, with conditions. In addition, the NRC has approved extending of the temperbead surface area limitation to 700 square inches in the Davis-Besse relief request (ADAMS Accession No. ML100080573).

ASME Code Case N-638-4 provides requirements for preheat or postweld heat treatment of temperbead techniques on the ASME Code Class 1 components. The NRC has approved for use, ASME Code Case N-638-4 in RG 1.147, Revision 16, with conditions related to nondestructive examination (NDE) and interpass temperature measurement.

FSWOL design and analyses

The licensee stated that the design and flaw evaluation provisions in the proposed alternative are the same as ASME Code Case N-504-4 as supplemented in Appendix Q of the ASME Code, Section XI, with the proposed exceptions. Section "Design and Crack Growth Considerations" of Attachment 3 of Enclosure 1 of RR N1-I4-CMP-001 documents the licensee's proposed exceptions. The proposed design and flaw evaluation provisions are based on postulated flaws

or as-found flaws. The licensee stated that for weld overlay crack growth evaluations, a flaw with a depth of 10 percent and a circumference of 360 degrees will be assumed or the as-found flaw size will be used. The size of the flaws will be projected to the end of the design life of the overlay. Crack growth including both stress corrosion and fatigue crack growth will be evaluated in the materials in accordance with the requirements of IWB-3640 of the ASME Code, Section XI. If the flaw is at or near the boundary of two different materials, evaluation of flaw growth in both materials is required.

The FSWOL design for the steam generator nozzles at North Anna, Unit 1, will meet the applicable stress limits from the ASME Code, Section III. Crack growth evaluations for PWSCC and fatigue of as-found (or postulated) flaws will demonstrate that structural integrity will be maintained. The analyses and verifications specified in items 1 through 6 of Subsection "Analyses and Verifications" of Section 5 of Enclosure 1 of RR N1-I4-CMP-001 will be performed for the proposed weld overlays. The summary of the results from items 1 through 3 will be submitted to the NRC following completion of the weld overlays prior to entry into Mode 4, while the results from items 4 through 6 will be included in the design modification package closure documents and made available to the NRC for review.

NDE examinations

Section 5, Section A1.4 of Attachment 1, Attachment 2, and Attachment 3 of Enclosure 1 of RR N1-I4-CMP-001 document the proposed NDE examinations for FSWOL installation. The licensee indicated that the NDE examinations will be performed in accordance with the requirements of IWA-2200 of the ASME Code, Section XI, except as specified in RR N1-I4-CMP-001. The NDE personnel will be qualified in accordance with IWA-2300 the ASME Code, Section XI.

As a part of design of weld overlay, the weld length and the surface finish and flatness are specified to allow a qualified UT examination to be performed on the weld overlay, the required volume of the base material, and the original weld. The licensee stated that the procedures and personnel qualifications for the UT examinations will be performed in accordance with the requirements of the PDI Program. Attachment 2 of Enclosure 1 of RR N1-I4-CMP-001 documents comparison between the requirements of Supplement 11 and the PDI program. The licensee stated that the UT examinations qualified by the PDI Program are more sensitive for detection of defects, either from fabrication or service induced, than the ASME Code, Section III, radiographic testing (RT) or UT methods. Further, the construction flaws have been included in the PDI qualification sample sets for evaluating procedures and personnel.

Ambient temperature temperbead technique

The guidance of ASME Code Cases N-504-4 and N-638-4 as modified by ASME Code Case N-740-2 will be used for application of FSWOL to the steam generator nozzle to safe-end DM welds at North Anna, Unit 1. The proposed overlays will be performed using ambient temperature temperbead welding process in accordance with the requirements in Attachment 1 of Enclosure 1 of RR N1-I4-CMP-001 in lieu of the post-weld heat treatment requirements of the ASME Code, Section III. The EPRI and other organizations have conducted research on the use of an ambient temperature temperbead process using the machine gas tungsten arc welding (GTAW) process and documented their findings in EPRI Technical Report GC-111050, "Ambient Temperature Preheat for Machine GTAW Temperbead Application." The licensee stated that according to the EPRI report, repair welds performed with an ambient temperature temperbead procedure utilizing the GTAW process exhibit mechanical properties equivalent to or better than those of the

surrounding base material. Laboratory testing, analysis, successful procedure qualifications, and successful repairs have demonstrated the effectiveness of this process.

Section 5, and A2.1 of Attachment 1, of Enclosure 1 of RR N1-I4-CMP-001 addresses the effects of the ambient temperature temperbead welding process on mechanical properties of repair welds, hydrogen cracking, cold restraint cracking, and extent of overlay coverage of ferritic base metal.

Licensee's Commitments

Enclosure 2 of RR N1-I4-CMP-001 documents the licensee's commitments. Prior to entry into Mode 4 following the completion of the weld overlays, it commits to provide to the NRC the results of its analysis (e.g., stress analyses that establish residual stress profiles, fracture mechanics analysis that predict crack growth, and analyses that demonstrate FSWOL does not impact the existing nozzle stress) described in Sections 1.a., 1.b., and 1.c. of Enclosure 2 of RR N1-I4-CMP-001. In addition, within 14 days of completion of the final UT examinations of the FSWOL, the license is committed to provide to the NRC the results of the UT examinations of FSWOL described in Section 2 of Enclosure 2 of RR N1-I4-CMP-001.

Duration of Relief

The FSWOL installed in accordance with the provisions of the proposed alternative shall remain in place for the design life of the repair. The proposed alternative is applicable to the fourth 10-year ISI interval of North Anna, Unit 1, which commenced on May 1, 2009, and will end on April 30, 2019.

4.0 NRC STAFF (STAFF) EVALUATION

The staff has evaluated the information provided in RR N1-I4-CMP-001, as supplemented by letters of response to the staff's request for additional information (RAI) dated June 29, 2011, and November 10, 2011. The licensee proposes to use the provisions of ASME Code Case N-740-2 to install FSWOL on the DM welds listed in Table 1 as an alternative to the repair and/or replacement requirements of the ASME Code, Section XI. ASME Code Case N-740-2 was approved by the ASME Code Committee and it specifically addresses requirements for installation of the FSWOL for repair or mitigation of DM welds containing nickel-based alloy (e.g., Alloy 82/182) weld materials. However, the NRC has not approved for use, ASME Code Case N-740-2 in Regulatory Guide (RG) 1.147, Revision 16.

The staff recognizes that the nickel-based alloy (e.g, Alloy 82/182) DM welds in components (e.g., SG hot legs) that are subjected to combinations of primary coolant environments, higher operating temperatures, and sustained high tensile stresses have shown a propensity for PWSCC degradation. FSWOL of nickel-based alloy DM welds is an acceptable methodology for preventing potential failures due to PWSCC based on the use of filler metals (e.g., Alloy 52 or Alloy 52M) that are less susceptible to PWSCC. FSWOL is a deposition of weld reinforcement on the surface of outer diameter (OD) of DM weld and its associated components (e.g., on the low-alloy steel portion of the nozzle across the DM weld onto the attached safe-end) to form a new pressure boundary. Preemptive (mitigative or repair) weld overlay could be used as an approach in addressing PWSCC degradation of DM welds. By installing weld overlay, any potential future cracking is mitigated because of the resulting favorable post-overlay residual stresses at the weld location. In addition, weld overlay enhances joint inspectability during ISI.

To evaluate RR N1-I4-CMP-001, the staff utilizes ASME Code Cases N-504-4 and N-638-4, Appendix Q to the ASME Code, Section XI, and the NRC approved EPRI Technical Report (TR) MRP-169, Rev. 1-A, "Technical Basis for Preemptive Weld Overlay for Alloy 82/182 Butt Welds in Pressurized Water Reactors (PWRs)," as guidance. ASME Code Case N-504-4 establishes requirements for repair of ASME Code Class 1, 2, and 3 austenitic stainless steel piping by depositing weld reinforcement (weld overlay) on the OD surface of the pipe as an alternative to the provisions of either the Construction Code or the ASME Code, Section XI. ASME Code Case N-638-4 establishes requirements for performing ambient temperature temperbead welding as an alternative to preheat and post-weld heat treatment requirements of the Construction Code. The NRC has approved for use, ASME Code Cases N-504-4 and N-638-4 in RG 1.147, Revision 16, with conditions. TR MRP-169, Rev. 1-A, details design analysis, materials, and examination requirements for weld overlay installation on the nickel-based Alloy 82/182 DM welds. The NRC safety evaluation of TR MRP-169, Rev. 1-A, provide additional requirements.

10 CFR 50.55a(b)(2)(xv), "Appendix VIII specimen set and qualification requirements," states in part, licensees who use later editions and addenda than the 2001 Edition of the ASME Code shall use Appendix VIII of the 2001 Edition.

The 2001 Edition and no Addenda of the ASME Code, Section XI, Appendix VIII, Supplement 11 and Supplement 10, provide requirements for performance demonstration for ultrasonic testing (UT) examination procedures, equipment, and personnel used to detect and size flaws. The staff issued RAI requesting the licensee clarify which edition and addenda of the ASME Code, Section XI, will be used for Appendix VIII. By letter dated June 29, 2011, in response to the staff RAI, the licensee confirmed that the 2001 Edition and no Addenda for Appendix VIII, will be used. 10 CFR 50.55a(g)(6)(ii)(F) delineates examination requirements for class 1 piping and nozzle DM butt welds. 10 CFR 50.55a(g)(6)(ii)(F)(1) requires licensees of existing and operating PWRs as of July 21, 2011, implement the requirements of ASME Code Case N-770-1, subject to the conditions specified in paragraphs (g)(6)(ii)(F)(2) through (g)(6)(ii)(F)(10), by the first refueling outage after August 22, 2011. ASME Code Case N-770-1 describes alternative examination requirements and acceptance standards for the ASME Code Class 1 piping and vessel nozzle DM butt welds fabricated with Alloy 82/182 material.

General Requirements

The staff reviewed the licensee's proposed general requirements for FSWOL documented in Section 5 and Attachments 1 and 3 of Enclosure 1 of RR N1-I4-CMP-001. The staff notes that the general requirements for FSWOL reinforcement include the minimum requirements for chromium content of weld overlay filler metals (e.g., Alloy 52 or Alloy 52M) and the requirements for delta ferrite content of weld overlay filler metals as well as the buffer layer(s) weld deposit. The specifics are discussed below.

The licensee will use the weld overlay filler metal that consists of austenitic nickel alloy (ERNiCrFe-7/7A) with chromium content of at least 28 percent by weight (i.e. 28 wt. % Cr) applied 360 degrees around the circumference of the DM welds and associated components. The licensee stated that if a stainless steel buffer layer is used, the delta ferrite content of the filler material will be 5-I5 FN as required by the Construction Code. Credit for the first weld layer may not be taken toward the required thickness unless it has been shown to contain at least 24 wt. % Cr. The staff has determined that the proposed filler metals contain significantly high chromium composition (i.e. 28 wt. % Cr to 30 wt. % Cr). Thus, the installed weld overlay will be

less susceptible to PWSCC and meets the requirements specified in TR MRP-169, Rev. 1-A.

To address hot cracking, the licensee stated that one or more weld barrier layer(s) will be installed over the stainless steel base material to prevent potential hot cracking in Alloy 52M weld overlay. The licensee stated that if a stainless steel buffer layer is used, as permitted by ASME Code Case N-740-2, the ferrite content of the filler material shall be 5 FN - I5 FN per the Construction Code requirements. The staff issued an RAI requesting the licensee discuss whether the delta ferrite requirements of Paragraph (e) of ASME Code Case N-504-4 and Subarticle Q-2000(d) of Appendix Q of the ASME Code, Section XI, for buffer layer(s) will be met.

By letter dated June 29, 2011, in response to the staff's RAI, the licensee stated that the stainless steel filler material will be applied only as a buffer layer, thus, the ASME Code Case N-504-4 requirements do not apply. The licensee also added that the buffer layer will neither be considered weld reinforcement nor counted toward the design thickness requirements for weld overly. The staff has determined that the licensee did not adequately address the requirements of Article Q-2000(d) regarding the chemical analysis and the carbon content of deposited stainless steel weld metal, therefore, the staff issued another RAI asking the licensee for clarification and technical justification.

By letter dated November 10, 2011, in response to the staff's RAI, the licensee stated that the austenitic stainless filler metal used to reduce the potential for hot cracking in Alloy 52M weld overlay will also have sufficient delta ferrite to minimize the potential for hot cracking in the austenitic stainless weld deposit. Specifically for the wire to be used for the North Anna, Unit 1, SG hot leg nozzles overlay, the certified material test report (CMTR) documents a bare wire chemistry of 0.02% Carbon and the Weld Research Council (WRC)-1992 Diagram delta ferrite of 9 FN. This wire when tested using the magnetic delta ferrite determination method, as required by the ASME Code, Section III, NB-2433.1, produced a gas tungsten arc weld deposit containing 9 FN. The staff finds the licensee's response acceptable because the ASME Code, Section XI, Appendix Q, limitations on the delta ferrite and the carbon content for stainless steel filler metals that would be used as buffer layer(s) deposit are met.

Design and Analysis Requirements

The staff reviewed Subsection "Analyses and Verifications" of Section 5.0, Section A1.3 of Attachment 1, and Attachment 3, of Enclosure 1 of RR N1-I4-CMP-001 that document requirements for design of the FSWOL repair for the subject DM welds. For the purpose of structural sizing the weld overlay, the licensee assumed in the underlying base material or weld the limiting circumferential and axial flaws that results maximum required overlay thickness. An assumed 360° circumferential flaw is 100% through the original wall thickness of the DM weld. An assumed axial flaw is 100% through-wall thickness with length of 1.5 inches, or the combined width of the weld plus buttering plus any stress-corrosion cracking (SCC) susceptible material, whichever is greater. The licensee stated that the following is a list of specific analyses and verifications to be performed in the event preemptive FSWOL need to be installed on the subject welds.

- Nozzle-specific stress analyses will be performed to establish a residual stress profile in each nozzle. Inside diameter (ID) weld repairs will be assumed in these analyses that effectively bound any actual weld repairs that may have occurred in the nozzles. The analysis will then simulate application of the weld overlays to determine the final residual

stress profile. Post-weld overlay residual stresses at normal operating conditions will be shown to result in an improved compressive stresses on the inner portion of the component that reduces the probability for further crack propagation due to PWSCC.

- Fracture mechanics analyses will be performed to predict crack growth for assumed flaws. Crack growth due to PWSCC and fatigue crack growth in the original DM weld will be evaluated. The crack growth analyses will consider all design loads and transients plus the post-weld overlay through-wall residual stress distributions. It will demonstrate that the assumed cracks will not grow beyond the design basis for the weld overlays (i.e., through the original DM weld thickness and any additional allowance for crack growth within the weld overlay) for the time period until the next scheduled ISI.

- The stress analyses will demonstrate that the application of the weld overlays does not impact the conclusions of the existing nozzle stress reports. The ASME Code, Section III, stress and fatigue criteria shall be met for the regions of the overlays remote from observed (or assumed) cracks.

- Axial shrinkage will be measured before and after the weld overlay application. Shrinkage stresses arising from the weld overlays at other locations in the piping systems will be demonstrated to not have an adverse effect on the systems. Clearances of affected supports and restraints will be checked after the overlay repair, and will be reset within the design ranges as required.

- The total added weight on the piping systems due to the overlays shall be evaluated for potential impact on piping system stresses and dynamic characteristics.

- The as-built dimensions of the weld overlays shall be measured and evaluated to demonstrate that they meet (or exceed) the minimum design dimensions of the overlays.

By letter dated June 29, 2011, in response to the staff RAI regarding the ID repaired (construction) flaw size assumption in stress analysis, the licensee stated that the stress analysis conservatively assumes an original construction repair weld that extended from the ID surface 50% through-wall for 360 degrees. The staff finds the licensee's assumption for a repaired flaw size acceptable because in accordance with the analysis results documented in TR MRP-169, Rev. 1-A, the resulting residual stresses from weld overlay bounds any repairs that may have been made during plant construction.

The staff recognizes that the weld overlay full thickness length is intended to provide the coverage on both sides of the susceptible material and the observed crack in the DM weld to allow for adequate transfer and redistribution of axial loads between the pipe and weld overlay (i.e., from the pipe into the weld overlay and back into the pipe). The staff issued RAI requesting the licensee clarify whether the weld overlay full thickness length of at least $0.75\sqrt{Rt}$, where R is the outer pipe radius and t is the nominal pipe thickness, will be applied axially to both sides of the susceptible material (e.g. DM weld, buttering, and safe-end) and the observed crack. By letter dated June 29, 2011, in response to the staff RAI, the licensee confirmed that the weld length of at least $0.75\sqrt{Rt}$ will be applied to both sides of the susceptible weld. The licensee stated that the axial length and end slope of the weld overlay shall cover the weld and heat affected zones (HAZ) on each side of the weld as well as any SCC susceptible base material adjacent to the weld. The axial length also provides for load redistribution from the item into the weld overlay and back into

the item without violating applicable stress limits of Article NB-3200 of the ASME Code requirements. The staff finds the licensee's response acceptable because the requirement of ASME Code Case N-504-4 and Subarticle Q-3000(b)(1) of Appendix Q of the ASME Code, Section XI, are met.

The staff finds the licensee's proposed FSWOL design, stress analysis, and crack growth evaluation for the subject welds meet (or exceed) the requirements specified in ASME Code Case N-504-4, and Appendix Q to the ASME Code, Section XI and Article NB-3000 of the ASME Code, Section III, and therefore acceptable.

Examination Requirements

The staff reviewed Section 5.0, A1.2.2(c), A1.2.2(d), and A1.4 of Attachment 1, and Attachment 3, of Enclosure 1 of RR N1-I4-CMP-001 that document the proposed examination requirements for FSWOL. The staff notes that the nondestructive examination (NDE) of FSWOL include the pre-weld overlay (WOL) deposition examinations, the acceptance examinations of competed WOL, the pre-service inspection (PSI) examinations, the subsequent ISI examinations, and any additional examinations. The specifics are discussed below.

Pre-WOL deposition examination

The licensee stated that the surface to be weld overlaid will be examined using the pressure-temperature (PT) method. Unacceptable indications with major dimensions greater than 1/16 inch will be repaired with or without excavation per requirements specified in A1.2.2(d) of Attachment 1 of Enclosure 1 of RR N1-I4-CMP-001. The thickness of the layer(s) of weld metal applied to seal unacceptable indications in the area to be repaired with or without excavation will not be used in meeting the weld reinforcement design thickness requirements. The area repaired will be reexamined to ensure free of unacceptable indication prior to application of FSWOL. The staff finds the licensee's proposed pre-WOL examination requirements satisfy the ASME Code Case N-504-4 and ASME Code, Section XI, Appendix Q, requirements, therefore acceptable.

Acceptance examination

The staff reviewed Section A1.4(a) of Attachment 1, and Section "Examinations and Inspections" of Attachment 3, of Enclosure 1 of RR N1-I4-CMP-001 that documented the proposed acceptance examination requirements. The specifics are discussed below.

The licensee stated that the weld overlay will have a surface finish of 250 μ-inches root mean square (RMS) or better. This permits the UT examinations to be performed in accordance with the ASME Code, Section XI, Appendix VIII, qualification requirements.

The licensee proposed that the weld overlay and the adjacent base material for at least ½ inch from each side of the overlay will be examined using the PT method. The weld overlay shall satisfy the surface examination acceptance criteria for welds of the Construction Code or NB-5300 of ASME Code, Section III. The adjacent base material shall satisfy the surface examination acceptance criteria for base material of the Construction Code or NB-2500 of ASME Code, Section III. For ambient temperature temperbead welding process that will be discussed in detail later, the PT examinations of completed weld overlay will be conducted no sooner than 48 hours following completion of the three tempering layers over the ferritic steel.

The licensee proposed that the examination volume A-B-C-D in Figure A1-1(a) of Section A1.4 of Attachment 1 of Enclosure 1 of RR N1-I4-CMP-001 be examined by UT to ensure adequate fusion (bond) with the base material and to detect welding flaws, such as interbead lack of fusion, inclusions, or cracks. The interface C-D between the overlay and weld includes the bond and heat-affected zone from the overlay. For ambient temperature temperbead welding process, the UT examination will be conducted no sooner than 48 hours following completion of the three tempering layers over the ferritic steel. Planar flaws detected in the weld overlay acceptance examination shall meet the PSI standards of IWB-3514 of the ASME Code, Section XI. In applying the acceptance standards to planar indications, the thickness t_1 or t_2 defined in Figure A1-1(b) of Section A1.4 of Attachment 1 of Enclosure 1 of RR N1-I4-CMP-001 will be used as the nominal wall thickness in IWB-3514 of the ASME Code, Section XI, provided the base material beneath the flaw (i.e., safe end, nozzle, or piping material) is not susceptible to SCC. For susceptible material, thickness t_1 will be used. If a flaw in the overlay crosses the boundary between the two regions, the more conservative of the two dimensions (thickness t_1 or t_2) will be used.

The licensee stated that "the acceptance standards of IWB-3514 of the ASME Code, Section XI will be met with the additional limitation that the total laminar flaw area shall not exceed 10% of the weld surface area and that no linear dimension of the laminar flaw area shall exceed the greater of 3 inches or 10% of the pipe circumference." The licensee will not use the radiographic testing (RT) alternative. The licensee stated that "the UT examinations performed in accordance with the PDI Program are more sensitive for detection of defects, either from fabrication or service-induced, than the ASME Code, Section III, prescribed RT or UT." Furthermore, the construction type flaws have been included in the PDI Program sample sets for qualifying procedures and personnel. The staff finds the proposed acceptance examinations are consistent with (or exceed) the Appendix Q to the ASME Code, Section XI, and ASME Code Case N-504-4, requirements including the conditions specified in RG 1.147, Revision 16, and therefore acceptable.

Preservice (PSI) examination

The staff recognizes that pursuant to 10 CFR 50.55a(g)(6)(ii)(F)(1), the licensee is required to comply with the examination requirements of ASME Code Case N-770-1 for FSWOL, subject to the conditions, by the first refueling outage after August 22, 2011. The staff also recognizes that the PSI examination requirements for FSWOL are specified in Paragraph -2220 and Note 9 of Table 1 of ASME Code Case N-770-1. To ensure compliance, the staff issued RAI requesting the licensee clarify whether the requirements in ASME Code Case N-770-1 for the PSI of FSWOL will be met. By letter dated November 10, 2011, in response to the staff RAI, the licensee acknowledged that the ASME Code Case N-770-1 required PSI examinations and its associated acceptance standards for FSWOL will be met.

In addition, the licensee stated that a system leakage test in accordance with Article IWA-5000 of the ASME Code, Section XI, will be performed. The licensee will also perform the surface examinations of the FSWOL in accordance with the requirements of Article Q-4100 of Appendix Q of the ASME Code, Section XI, and ASME Code Case N-504-4.

The staff finds the proposed PSI examinations of FSWOL acceptable because the licensee will follow ASME Code Case N-770–1, as required by 10 CFR 50.55a(g)(6)(ii)(F)(1).

Inservice (ISI) examinations

For the ISI examinations of FSWOL, the staff recognizes that in accordance with 10 CFR 50.55a(g)(6)(ii)(F)(1), the licensee is required to comply with the requirements of ASME Code Case N-770-1, subject to the conditions, by the first refueling outage after August 22, 2011. The staff also recognizes that Paragraph -2400 and Note 8 of Table 1 of ASME Code Case N-770-1 specified the ISI examination requirements for FSWOL. To ensure compliance, the staff issued RAI requesting the licensee clarify whether the requirements in ASME Code Case N-770-1 for the ISI of FSWOL will be met. By letter dated November 10, 2011, in response to the staff RAI, the licensee acknowledged that the ASME Code Case N-770–1 requirements for the ISI examinations of FSWOL and its associated acceptance standards will be met.

The staff finds the proposed ISI examinations for FSWOL acceptable because the licensee will follow ASME Code Case N-770–1, as required by 10 CFR 50.55a(g)(6)(ii)(F)(1).

Ambient Temperature Temperbead Welding

The use of an ambient temperature temperbead process utilizing the machine gas tungsten-arc welding (GTAW) is documented in EPRI Technical Report (TR) GC-111050, "Ambient Temperature Preheat for Machine GTAW Temperbead Application," and EPRI TR 1013558, "48-Hour Hold Requirements for Ambient Temperature Temperbead Welding." According to the above reports, this welding technique eliminates the need for minimum preheat requirements and post weld heat treatment (PWHT) or post weld hydrogen bakeout requirements of the ASME Code, Section XI, Article IWA-4600. In addition, repair welding performed with this technique exhibit mechanical properties equivalent to or better than those of the surrounding base material. The effectiveness of this process has been demonstrated by laboratory testing, analysis, successful procedure qualifications, and successful repairs.

The effects of the ambient temperature temperbead welding process on mechanical properties of welds, hydrogen induced cracking, cold restraint cracking, and extent of overlay coverage of ferritic base metal are addressed in Section 5, and A2.1 of Attachment 1, of Enclosure 1 of RR N1-I4-CMP-001. The licensee also provided the proposed requirements for the ambient temperature temperbead welding that follows the requirements of ASME Code Case N-638-4. The staff's review of the licensee's proposed requirements and modifications is discussed below.

The staff recognizes that for weld overlay application on DM weld, ASME Code Case N-638-4, Paragraph 1.0(b), limits the maximum area of an individual weld to 500 square inches. As documented in A2.2 of Attachment 1 of Enclosure 1 of RR N1-I4-CMP-001, the licensee's proposed alternative expands the maximum area of an individual weld, based on the finished surface over the ferritic (nozzle) base material to greater than 600 square inches, but not exceeding 1000 square inches. The licensee's reason for this alternative was due to application of FSWOL on a large diameter and thick SG hot leg nozzles. In addition, FSWOL will extend to the transition taper of the ferritic low alloy carbon steel nozzle to provide a weld geometry that allows qualified UT examination of the required examination volume.

For technical justifications regarding the increase in temperbead area, the licensee stated that EPRI TR 1021073 "Justification for Extension of the Temper Bead Limit to 1000 Square Inches for WOL of P1 and P3 Materials," dated June 21, 2010, cites evaluations of a 28-inch diameter large bore pipe weld overlay. The licensee stated that the analysis results from EPRI TR 1021073 (Ref. 5) show that larger scale temperbead weld repairs could be performed on low alloy steel components. Specifically, repairs that included weld overlays on vessel nozzles and similar components could be expanded to an area of 1000 square inches without creating deleterious residual stress levels and still maintain the structural integrity of the component. In addition, the licensee stated that the NRC has approved extending of the temperbead surface area limitation to 700 square inches in the Davis-Besse relief request (ADAMS Accession No. ML100080573). The staff issued an RAI requesting the licensee provide a copy of EPRI TR 1021073 (Ref. 5) for NRC review and evaluation.

By letter dated June 29, 2011, in response to the staff RAI, the licensee submitted a copy of nonproprietary EPRI TR 1021073 to the NRC for review. The licensee stated that the stress analyses for the FSWOL for the North Anna, Unit 1, SG nozzles have not been completed to date, however, the EPRI TR 1021073 results serve just as the basis for acceptability of increasing the weld overlay area to greater than 700 square inches, but not exceeding 1000 square inches. The staff noted from the review of EPRI TR 1021073 that a series of finite element based residual stress analysis was performed. These analyses served as sensitivity studies to support increasing the temperbead weld overlay repair area of large bore ferritic piping components up to a repair area of 1000 square inches. The results of analyses demonstrated favorable residual stress distribution on the inside surface of the pipe with minimal radial shrinkage and distortion. It also revealed that increasing the area of the tempbead weld overlay over ferritic material improves the residual stresses on the inside surface of the pipe. Based on the above evaluation, the staff finds the licensee's proposed increasing weld overlay area upto but not exceeding 1000 square inches on ferritic material using ambient temperature temper bead welding for the North Anna, Unit 1, SG nozzles, acceptable.

Performance Demonstration Initiative Program

The staff recognizes that the ASME Code, Section XI, Appendix VIII, Supplement 11, specifies qualification requirements for the FSWOL of wrought austenitic piping welds. The licensee proposed to use the qualification requirements of the PDI program in lieu of the Appendix VIII, Supplement 11. The licensee identified and evaluated the differences between the PDI program and the ASME Code, Section XI, Appendix VIII, Supplement 11, as shown in Attachment 2 of Enclosure 1 of RR N1-I4-CMP-001.

The U.S. nuclear utilities created the PDI program to implement performance demonstration requirements contained in Appendix VIII of Section XI of the ASME Code. To this end, the PDI program has developed a program for qualifying equipment, procedures, and personnel in accordance with the UT criteria of Appendix VIII, Supplement 11. Prior to the Supplement 11 program, EPRI was maintaining a performance demonstration program (the precursor to the PDI program) for weld overlay qualification under the Tri-party Agreement with the NRC, BWR Owner's Group, and EPRI, in the NRC letter dated July 3, 1984 (ADAMS Accession No. ML8407090122). Later, the NRC staff recognized the EPRI PDI program for weld overlay qualifications as an acceptable alternative to the Tri-party Agreement in its letter dated January 15, 2002, to the PDI Chairman (ADAMS Accession No. ML020160532).

The PDI program is routinely assessed by the staff for consistency with the current ASME Code and proposed changes. The PDI program does not fully comport with the existing requirements of Appendix VIII, Supplement 11. PDI presented the differences at public meetings in which the NRC participated (Memorandum from Donald G. Naujock to Terence L. Chan, "Summary of Public Meeting Held January 31 – February 2, 2002, with PDI Representatives," March 22, 2002, (ADAMS Accession No. ML010940402), and Memorandum from Donald G. Naujock to Terence L. Chan, "Summary of Public Meeting Held June 12 through June 14, 2001, with PDI Representatives," November 29, 2001, (ADAMS Accession No. ML013330156)). Based on the discussions at these public meetings, the staff determined that the PDI program provides an acceptable level of quality and safety.

The staff finds the differences and associated justifications the licensee provided in Appendix 2 of RR N1-I4-CMP-001 acceptable because the PDI program satisfies the intent of the Supplement 11 requirements.

Summary

Finally, the staff finds that the requirements of RR N1-I4-CMP-001 for design and installation of FSWOL are either consistent with (or exceed) the intent of the provisions of ASME Code Cases N-504-4 and N-638-4 and Appendix Q of the ASME Code, Section XI. In addition, the licensee will follow the PSI and ISI examinations requirements and associated acceptance standards of ASME Code Case N-770-1, as required by 10 CFR 50.55a(g)(6)(ii)(F). Therefore, the licensee's proposed alternative is acceptable.

5.0 CONCLUSION

As set forth above, the NRC staff determines that the proposed alternative in RR N1-I4-CMP-001 provides an acceptable level of quality and safety. Accordingly, the NRC staff concludes that the licensee has adequately addressed all of the regulatory requirements set forth in 10 CFR 50.55a(a)(3)(i), and therefore, the NRC staff authorizes the alternative noted above, at North Anna, Unit 1, for full structural weld overlay onto the Alloy 82/182 DM weld of the steam generator hot leg nozzles by installing FSWOL for the fourth 10-year ISI interval that commenced on May 1, 2009, and will end on April 30, 2019. The design portion of RRN1-I4-CMP-001 is authorized for the remaining life of the component including future plant life extension.

All other ASME Code requirements for which relief was not specifically requested and approved, remain applicable including third-party review by the Authorized Nuclear inservice inspector.

Principal Contributor: Ali Rezai

Date: January 27, 2012

All other ASME Code, Section XI requirements for which relief was not specifically requested and approved, remain applicable including third-party review by the Authorized Nuclear inservice inspector.

Please contact me at (301) 415-2942, or the Project Manager Dr. Sreenivas at (301) 415-2597, if you have any questions.

Sincerely,

/RA/

Nancy L. Salgado, Chief
Plant Licensing Branch II-1
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Office of Nuclear Reactor Regulation

Docket No. 50-338

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