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

March 15, 2013

Mr. Christopher R. Costanzo
Vice President Nine Mile Point
Nine Mile Point Nuclear Station, LLC
P.O. Box 63
Lycoming, NY 13093

SUBJECT: NINE MILE POINT NUCLEAR STATION, UNIT NO. 1 RE: RELIEF FROM THE REQUIREMENTS OF THE ASME CODE, SECTION XI, REQUEST NO. 1ISI-004, REVISION 1, REPAIR OF CONTROL ROD DRIVE HOUSING PENETRATIONS (TAC NO. ME5789)

Dear Mr. Costanzo:

By letter dated March 4, 2011 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML110680291), as supplemented by letters dated March 25, 2011, September 29, 2011, April 9, May 22, June 7, and October 31, 2012 (ADAMS Accession Nos. ML110950302, ML11279A037, ML121020213, ML12152A173, ML12160A349, and ML123120285, respectively), Nine Mile Point Nuclear Station, LLC (NMPNS, the licensee) pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(a)(3)(i), submitted the request to the U.S. Nuclear Regulatory Commission (NRC), Request Number 1ISI-004, "Request to Utilize an Alternative to the Requirements of 10 CFR 50.55a(g) for the Repair of Control Rod Drive Housing Penetrations for the Remainder of the License Renewal Period of Extended Operation." In its letter dated April 9, 2012, the licensee submitted Revision 1 to the Request No. 1ISI-004. In the subject relief request, the licensee requested the use of an alternative to the requirements of certain American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI requirements and the ASME Code Case N-606-1 as approved by the NRC, at NMPNS, Unit No. 1 (NMP1).

Specifically, pursuant to 10 CFR 50.55a(a)(3)(i), the licensee requested an alternative to the requirements of the ASME Code, Section XI for the NMP1 to utilize ASME Code Case N-606-1, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW [Gas Tungsten-Arc Welding] Temper Bead Technique for Boiling Water Reactor (BWR) Control Rod Drive (CRD) Housing/Stub Tube Repairs," with modifications in several areas of the NRC-Approved Code Case N-606-1. The licensee requested to use the proposed alternative for use during the remaining term of the NMP1 renewed operating license, which expires on August 22, 2029, and on an contingency basis, if a weld repair is necessary to meet its licensing bases with respect to "zero leakage permanent repair strategies for CRD housing penetrations" that has been roll-repaired in accordance with the ASME Code Case N-730, and on the basis that the alternative provides acceptable level of quality and safety.

The NRC staff has completed its review of the subject request. As set forth in the enclosed safety evaluation (SE), the NRC staff determines that the alternatives proposed in NMPNS Relief Request 1ISI-004, Revision 1 to perform a repair of CRD housing penetrations at NMPNS will provide 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

pursuant to 10 CFR 50.55a(a)(3)(i), the NRC staff authorizes NMPNS Relief Request 1ISI-004, Revision 1 for the repair of CRD housing penetrations at NMPNS. This relief request is authorized for use during the remaining term of the NMP1 renewed operating license, which expires on August 22, 2029. It should be noted that (a) the licensee must perform inservice inspection (ISI) on the repair area within 12 years of implementing the repair, as detailed in Section 3.5.3 of this SE, (b) the relief request is authorized for use with all the applicable conditions and limitations of the Code Case N-606-1, and (c) The maximum allowable flaw size at the triple point is 0.1 inch long for the full circumference of the repair weld at the triple point.

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

Please contact me at (301) 415-1711, or the Project Manager, Bhalchandra K. Vaidya at (301) 415-3308, if you have any questions.

Sincerely,

Sean Meighan, (Acting) Branch Chief
Plant Licensing Branch I-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket Nos. 50-220

Enclosures:
Safety Evaluation

cc w/encl: Distribution via Listserv

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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELIEF REQUEST NO. 1ISI-004, REVISION 1

REGARDING REQUEST FOR THE ALTERNATIVE FOR

REPAIR OF CONTROL ROD DRIVE HOUSING PENETRATIONS

NINE MILE POINT NUCLEAR STATION, LLC

NINE MILE POINT NUCLEAR STATION, UNIT 1

DOCKET NOS. 50-220

1.0 INTRODUCTION

By letter dated March 4, 2011 (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML 110680291, Reference 1), Nine Mile Point Nuclear Station, LLC (NMPNS, the licensee) submitted for Nuclear Regulatory Commission (NRC) staff's review and approval Relief Request 1ISI-004. By letter dated March 25, 2011 (ADAMS Accession No. ML110950302, Reference 2), the licensee submitted corrected Request No. 1ISI-004, which superseded the March 4, 2011 submittal in its entirety. Subsequently, the licensee supplemented its March 25, 2011 submittal by letters dated September 29, 2011 (ADAMS Accession No. ML11279A037, Reference 3), April 9, 2012 (ADAMS Accession No. ML121020213, Reference 4), May 22, 2012 (ADAMS Accession No. ML12152A173, Reference 5), June 7, 2012 (ADAMS Accession No. ML12160A349, Reference 6), and October 31, 2012 (ADAMS Accession No. ML123120285, Reference 7). In the subject relief request, pursuant to the regulation in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(3)(i), the licensee requested an alternative to the requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI for the Nine Mile Point Nuclear Station, Unit 1 (NMP1) to utilize ASME Code Case N-606-1, "Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW [gas tungsten arc welding] Temper Bead Technique for Boiling Water Reactor (BWR) Control Rod Drive (CRD) Housing/Stub Tube Repairs," with several modifications. In Attachment 2 to April 9, 2011, submittal (Reference 4), the licensee provided Revision 1 of the subject relief request which revised the relief request to require both heat transfer calculations and measurement of interpass temperatures on a test coupon, in lieu of direct measurement of the interpass temperatures during welding. The licensee's proposed alternative in Relief Request 1ISI-004, Revision 1 would be used for the repair of CRD housing penetrations at NMP1 only if a CRD housing penetration that was roll repaired in accordance with Code Case N-730, should resume leaking. In addition, in Reference 6, the licensee withdrew its request for relief from the restriction in Paragraph 1(f) of Code Case N-606-1 that prohibits rotary peening of the final weld surface. The NRC staff's August 3, 2009 safety evaluation (SE) of the licensee's request for alternative to use Code Case N-730 to perform permanent roll repair (Ref. 8) contains an

Enclosure

evaluation of the potential growth of `flaws in the partial penetration welds of the stub tube to the reactor vessel (RV), stub tube to CRD housing, and in the CRD housing base material. Therefore, Relief Request 1ISI-004, Rev. 1 did not include a request for relief from the requirement to characterize detected flaws of IWA-3300, IWA-4340, or IWB-3420.

2.0 REGULATORY REQUIREMENTS

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, "Rules for Inservice 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. The Code of Record for the current fourth NMP1 ISI interval is the ASME Code, Section XI, 2004 Edition, no Addenda.

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. The licensee submitted the subject relief request, pursuant to 10 CFR 50.55a(a)(3)(i), which proposed an alternative to the implementation of the ASME Code, Section XI requirements based on ASME Code Case N-606-1 as modified by the licensee for the repair of CRD housing penetrations at NMP1. Regulatory Guide (RG) 1.147, Inservice Inspection Code Case Acceptability, ASME Code, Section XI, Division 1, lists the Code Cases that are acceptable to the NRC for application in a licensee's ASME Code, Section XI ISI programs. A licensee may use a Code Case specified in the RG without prior approval by the NRC if it meets the conditions specified for the Code Case.

The ASME Code Case N-606-1 provides alternative requirements for the repair of CRD housing penetrations using the ambient temperature temper bead technique. The NRC has conditionally approved this Code Case in RG 1.147, Revision 16 with the following condition: "Prior to welding, an examination or verification must be performed to ensure proper preparation of the base metal, and that the surface is properly contoured so that an acceptable weld can be produced. The surfaces to be welded, and surfaces adjacent to the weld, are to be free from contaminants, such as, rust, moisture, grease, and other foreign material or any other condition that would prevent proper welding and adversely affect the quality or strength of the weld. This verification is to be required in the welding procedures."

3.0 TECHNICAL EVALUATION

3.1 ASME Code Component Affected

RV Bottom Head and CRD Housing Penetrations

3.2 ASME Code Requirements

The ASME Code Section XI, 2004 Edition, no Addenda, IWA-4221(a) states: "An item to be used for repair/replacement activities shall meet the Owner's Requirements. Owner's Requirements may be revised, provided they are reconciled in accordance with IWA-4222. Reconciliation documentation shall be prepared."

The ASME Code Section XI, 2004 Edition, no Addenda, IWA-4221(b) states: "An item to be used for repair/replacement activities shall meet the Construction Code specified in accordance with (1), (2), or (3) below."

The ASME Code Section XI, 2004 Edition, no Addenda, IWA-4221(c) states in part: "As an alternative to (b) above, the item may meet all or portions of the requirements of different Editions and Addenda of the Construction Code, or Section III when the Construction Code was not Section III, provided the requirements of IWA-4222 through IWA-4226, as applicable, are met."

The ASME Code Section XI, 2004 Edition, no Addenda, IWA-4400 provides welding, brazing, metal removal, and installation requirements related to repair/replacement activities.

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

The ASME Code Section XI, 2004 Edition, no Addenda, IWA-4411(a) 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)."

The ASME Code Section XI, 2004 Edition, no Addenda, IWA-4610(a) states in part: "Thermocouples and recording instruments shall be used to monitor the process temperatures ..."

The ASME Code Section III, 2004 Edition, no Addenda, NB-5331 states: "All imperfections which produce a response greater than 20% of the reference level shall be investigated to the extent that the operator can determine the shape, identity, and location of all such imperfections and evaluate them in terms of acceptance standards given in (a) and (b) below."

The ASME Code Section III, 2004 Edition, no Addenda, NB-5331(b) states: "Indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length."

Code Case N-606-1, paragraph 1(f) states: "Peening may be used, except on the initial and final layers."

Code Case N-606-1, paragraph 3(d) states: "The maximum interpass temperature for field applications shall be 350 °F regardless of the interpass temperature during qualification."

Code Case N-606-1, last sentence in the "Reply" states in part: "... welds, may be made by the automatic or machine gas tungsten arc welding (GTAW) temper bead technique...., and without the nondestructive examination requirements of the Construction Code, provided the requirements of Para. 1 through Para. 5, and all other requirements of IWA-4000, are met."

Code Case N-606-1, paragraph 4(a) states: "The final weld surface and the band around the area defined in Para. 1(d) shall be examined using a surface and ultrasonic methods when the completed weld has been at ambient temperature for at least 48 hours. The ultrasonic examination shall be in accordance with Appendix I."

3.3 Duration of the Alternative

The licensee requested that the repair performed using this Relief Request is applicable for use during the remaining term of the NMP1 renewed operating license, which expires on August 22, 2029.

3.4 Licensee's Proposed Alternatives and Basis

3.4.1 Acceptance Examination Area

3.4.1.1 Proposed Alternative (as stated by the licensee in Ref. 4, Attachment 2)

> [The ASME] Code Case N-606-1, Paragraph 4(a), requires the final weld surface and the preheated band around the area defined in paragraph 1(d) of Code Case N-606-1 to be examined using surface and ultrasonic (UT) methods.
>
> [The ASME] Code Case N-606-1, Paragraph 1(d) defines the area to be welded and the band around the area (at least 1½ times the component thickness or 5 inches, whichever is less) to be preheated.
>
> [The] NMPNS requests relief from examination of the area defined in Code Case N-606-1, Paragraph 4(a). In lieu of Code Case N-606-1 Paragraph 4(a), final examination of the new weld and immediate surrounding area within the bore will be performed.
>
> Figure 2 [in the relief request] depicts the areas for liquid penetrant (PT) examination and UT of the modified CRD penetration.

3.4.1.2 Basis for Relief (as stated by the licensee in Ref. 4, Attachment 2)

> [The ASME] Code Case N-606-1, Paragraph 1(d), defines the area to be welded and the band around the area (at least 1½ times the component thickness or

5 inches, whichever is less) to be preheated. The band around the repair weld area, as defined in Code Case N-606-1, Paragraph 1(d), cannot be examined as specified in Code Case N-606-1, Paragraph 4(a). Access restrictions and the final configuration of the repair weld do not allow UT examination or PT examination of the ferritic steel 5 inch band. This is illustrated in Figures 1 and 2 [of the relief request], which show that the surface of the ferritic steel vessel bottom head penetration is blocked by the CRD housing and the completed weld, such that access for PT examination and UT examination of the vessel surface is not possible.

The band includes an annular area extending 5 inches above and below the area to be welded in the penetration bore that extends onto the outside surface of the RV bottom head. This examination requirement was intended for situations wherein the original flaw creating the leak path is being repaired and it is necessary to confirm complete removal of the original flaw. For the proposed weld repair method the original flaw remains as-is and the repair creates a new pressure boundary weld remote from the original flaw locations.

The exposed ferritic steel portion of the CRD housing penetration at the root of the repair weld and the weld preparation bevel on the end of the remaining portion of the CRD housing lower section are PT examined prior to welding. This examination provides assurance that no flaws exist on the surfaces in the bore in the region to be welded.

The final examination of the new weld and immediate surrounding area within the bore will be sufficient to verify that defects have not been induced in the low alloy steel bottom head material due to the welding process and will assure the integrity of the CRD housing and the new weld. Figure 2 [of the relief request] depicts the areas for PT examination and UT examination of the modified CRD housing penetration. The PT area includes the new weld surface and ½ inch minimum distance below the weld. UT will be performed by scanning from the inner diameter (ID) surface of the CRD housing and weld. The UT examination is qualified to detect flaws in the new weld and base metal interface beneath the new weld. UT acceptance criteria are in accordance with NB-5331, as modified by BWRVIP-58-A. The extent of the examination is consistent with Construction Code requirements. The volume of interest for UT examination includes the new weld, the bottom head low alloy steel base material heat affected zone (HAZ), the CRD housing to weld interface, and the CRD housing base material beneath the weld. Limited UT coverage of the low alloy steel volume beneath the weld taper or the weld taper volume can be accomplished due to the weld geometry and the ultrasonic beam angles that are used for examination.

The basis for excluding surface and volumetric examination of the region around the final weld surface [compared to that required by Paragraph 4(a) of Code Case N-606-1] is BWRVIP-58-A, which has been approved by the NRC. The NDE [nondestructive examination] procedures were developed and demonstrated to provide an acceptable level of quality for the CRD internal

access weld repair. The alternative proposes to perform similar NDE as was approved in BWRVIP-58-A.

3.4.2 48-Hour Hold

3.4.2.1 Proposed Alternative (as stated by the licensee in Ref. 4, Attachment 2)

[The ASME] Code Case N-606-1, Paragraph 4(a), requires the surface and volumetric examinations to be performed at least 48 hours after the completed weld has been at ambient temperature.

[The] NMPNS requests relief from the 48-hour hold defined in Code Case N-606-1, Paragraph 4(a). In lieu of the Code Case N-606-1, Paragraph 4(a) requirement, the final examination of the new weld and immediate surrounding area within the bore will occur at least 48 hours after the completion of the third temper bead layer.

3.4.2.2 Basis for Relief (as stated by the licensee in Ref. 4, Attachment 2)

Hydrogen cracking is a form of cold cracking which typically occurs within 48 hours of welding. It is produced by the action of internal tensile stresses acting on low toughness material weld heat affected zones. The internal stresses are produced from localized build-ups of monatomic hydrogen. Monatomic hydrogen forms when moisture or hydrocarbons interact with the welding arc and molten weld pool. The monatomic hydrogen can be entrapped during weld solidification and tends to migrate to transformation boundaries or other microstructure defect locations. As concentrations build, the monatomic hydrogen recombines to form molecular hydrogen, thus generating localized internal stresses at these internal defect locations. If these stresses exceed the fracture toughness of the material, hydrogen induced cracking occurs. This form of cracking requires the presence of hydrogen and low toughness materials. It is manifested by intergranular cracking of susceptible materials and typically occurs within 48 hours of welding.

The machine GTAW process is inherently free of hydrogen. Unlike the shielded metal arc welding process, GTAW filler metals do not rely on flux coverings that may be susceptible to moisture absorption from the environment. The GTAW process utilizes dry inert shielding gases that cover the molten weld pool from oxidizing atmospheres. Any moisture on the surface of the component being welded is 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. Furthermore, modern filler metal manufacturers produce weld wires having very low residual hydrogen. This is important because filler metals and base materials are the most realistic sources of hydrogen for the automatic or machine GTAW temper bead process. Therefore, the potential for hydrogen-induced cracking is greatly reduced by using the machine GTAW process. Extensive research has been performed by the Electric Power Research Institute (EPRI). EPRI Report 1013558, "Repair and

Replacement Applications Center: Temperbead Welding Applications 48-Hour Hold Requirements for Ambient Temperature Temperbead Welding" provides justification for starting the 48-hour hold after completing the third temper bead weld layer rather than waiting for the weld overlay to cool to ambient temperature.

3.4.3 Acceptance NDE

3.4.3.1 Proposed Alternative (as stated by the licensee in Ref. 4, Attachment 2)

[The ASME] Code Case N-606-1, Paragraph 4(a), requires UT examination to be in performed in accordance with Appendix I, and Paragraph 4(d) specifies acceptance criteria in accordance with ASME Code Section XI, IWB-3000.

[The] IWB-3000 does not have any acceptance criteria that directly apply to the partial penetration weld configuration. Therefore, NMPNS requests relief from examination requirements as specified in Code Case N-606-1 Paragraphs 4(a) and 4(d). The alternative proposes to perform NDE in accordance with ASME Code Section III similar to that specified in BWRVIP-58-A, except that the 2004 Edition with no Addenda will be used in lieu of the 1995 Edition, including Addenda through 1995.

3.4.3.2 Basis for Relief (as stated by the licensee in Ref. 4, Attachment 2)

The acceptance criteria of NB-5331 in ASME Code Section III, 2004 Edition with no Addenda, will apply to all flaws identified within the new weld volume, as modified by and similar to that specified in BWRVIP-58-A.

Section III, NB-5245 requires incremental and final surface examination of partial penetration welds. Due to the welding layer disposition sequence (i.e., each layer is deposited parallel to the penetration centerline), the specific requirements of NB-5245 cannot be met. The Construction Code requirement for progressive surface examination is because volumetric examination is not practical for conventional partial penetration weld configurations.

The new weld is suitable for UT examination, and a final surface PT examination will be performed. UT examination will be performed by scanning from the inner diameter surface of the housing and weld. The UT examination is qualified to detect flaws in the new weld and base metal interface beneath the new weld. UT examination acceptance criteria are in accordance with NB-5331 as modified by BWRVIP-58-A. The extent of the examination is consistent with Construction Code requirements and similar to that specified in BWRVIP-58-A, as discussed in Attachment 2 [to the March 25, 2011 letter.

The volume of interest for UT examination, which will be covered to the maximum extent practical, includes the new weld, the bottom head low alloy steel base material heat affected zone beneath the weld, the CRD housing to weld interface, and the CRD housing base material beneath the weld. Limited UT coverage of the low alloy steel volume beneath the weld taper or the weld taper volume can

be accomplished due to the weld geometry and the ultrasonic beam angles that are used for examination.

The final examination of the new weld and immediate surrounding area will be sufficient to verify that defects have not been induced in the ferritic low alloy reactor vessel bottom head due to the welding process. UT examination will be performed by scanning from the inner diameter (ID) surface of the weld and the adjacent portion of the CRD housing. The UT examination is qualified to detect flaws in the new weld and base metal interface in the modified configuration, to the maximum extent practical.

3.4.4 Triple Point Anomaly

3.4.4.1 Proposed Alternative (as stated by the licensee in Ref. 4, Attachment 2)

[The] UT examination is proposed to be performed in accordance with ASME Code Section III, 2004 Edition with no Addenda. ASME Section III NB-5330 acceptance criteria [see 3.5.3 below] apply, including NB-5331(b), which states that indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

....in some cases a solidification anomaly has been observed at the weld root and may be detected when performing the UT examination. Analyses described in BWRVIP-58-A ["BWR Vessel and Internals Project, CRD Internal Access Weld Repair," EPRI, Palo Alto, CA, October, 2005, 1012618] concluded that these anomalies are not detrimental to the repair weld design if they are less than 0.05 inches extending from the triple point. NMPNS requests relief to permit anomalies in the weld not exceeding 0.10 inches long for the full circumference at the triple point. If these anomalies are determined to be less than or equal to 0.10 in. long emanating in any direction from the weld root triple point and extending around the penetration for the full circumference or less, they will be acceptable and repair will not be required.

3.4.4.2 Basis for Relief (as stated by the licensee in Ref. 4, Attachment 2)

An artifact of the ambient temperature temper bead repair weld is an anomaly in the weld at the triple point. The triple point is where there is a confluence of three materials: the stainless steel CRD housing, the stainless steel weld, and the low alloy steel RV bottom head. The location of the triple point anomaly is shown in Figure 2. This anomaly consists of an irregularly shaped very small void. Mock-up testing has verified that the anomalies may exist and do not exceed 0.10 inch in length.

A fracture mechanics analysis has been performed to provide justification, in accordance with the ASME Code Section XI, for operating with the postulated triple point anomaly. The anomaly is modeled as a 0.10 inch, "crack like" defect, extending 360° around the circumference at the triple point location. The analysis includes a prediction of fatigue crack growth in an air environment, since the

anomaly is located on the outside surface of the new weld. Several potential flaw propagation paths are considered in the flaw evaluation. The results of the analysis demonstrate that the 0.10 inch weld anomaly is acceptable. In accordance with ASME Section XI, IWB-3134(b), the results of the analysis are provided in Attachment 3 (non-proprietary) and Attachment 5 (proprietary)[to the relief request].

3.4.5 Interpass Temperature Monitoring

3.4.5.1 Proposed Alternative (as stated by the licensee in Ref. 4, Attachment 2)

[The] ASME Code Section XI, IWA-4610(a), requires the use of thermocouples and recording instruments to monitor process temperatures.

NMPNS requests relief from using thermocouples for interpass temperature monitoring as specified in IWA-4610(a). In lieu of using thermocouples to monitor and verify process temperatures, maximum interpass temperature verification is proposed to be accomplished by performing heat transfer calculations and by performing temperature measurement on a test coupon that is no thicker than the bottom head and CRD housing wall thickness. The test coupon welding would use the maximum heat input permitted by the applicable welding procedure specification.

3.4.5.2 Basis for Relief (as stated by the licensee in Ref. 4, Attachment 2)

Direct interpass temperature measurement is impractical to perform during welding operations from inside the CRD housing penetration bores. Interpass temperature measurements cannot be accomplished due to the physical configuration and the inaccessibility of the weld region during welding.

For this repair, the maximum interpass temperature will be determined by both of the following methods:

(1) Heat-flow calculations, using at least the variables listed below:

(a) Welding heat input

(b) Initial base material temperature

(c) Configuration, thickness, and mass of the item being welded

(d) Thermal conductivity and diffusivity of the materials being welded

(e) Arc time per weld pass and delay time between each pass

(f) Arc time to complete the weld

(2) Measurement of the maximum interpass temperature on a test coupon that is no thicker than the item to be welded. The maximum heat input of the welding procedure shall be used in welding the test coupon.

These methods are consistent with the associated requirements specified in Code Case N-638-4. Regulatory Guide 1.147, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1," Revision 16, dated October 2010, lists ASME Code Case N-638-4 as a conditionally accepted ASME Code Section XI Code Case. The approval conditions noted in the regulatory guide do not impact requirements for performing maximum interpass temperature verification as described in Code Case N-638-4 and herein. Use of the two methods provides adequate assurance that interpass temperatures will remain below 350°F.

3.4.6 Rotary Peening

The Licensee's letter dated June 7, 2012 (Ref. 6), which supplements their request for additional information (RAI) response dated April 9, 2012, withdrew item 6A "Proposed Alternative: Rotary Peening" and item 6B "Basis for Relief" from the relief request. Thus the request for relief from paragraph 1(f) in ASME Code Case N-606-1 is withdrawn from all versions of this relief request.

3.5 NRC staff Evaluation of Alternatives to Code Case N-606-1

Under the rules of ASME Code, Section XI, repairs shall be performed in accordance with the Owner's Requirements and the original Construction Code. Later editions and addenda of the Construction Code or of ASME Code, Section III, either in their entirety or portions thereof, and ASME Code Cases may be used. Code Case N-606-1, as modified by the identified alternatives, will be used by the licensee for installation of a weld overlay on the RV Bottom Head and CRD Housing Penetrations. Code Case N-606-1 was conditionally approved by the NRC staff for use under RG 1.147, Revision 16. This condition states, "Prior to welding, an examination or verification must be performed to ensure proper preparation of the base metal, and that the surface is properly contoured so that an acceptable weld can be produced. The surfaces to be welded, and surfaces adjacent to the weld, are to be free from contaminants, such as, rust, moisture, grease, and other foreign material or any other condition that would prevent proper welding and adversely affect the quality or strength of the weld. This verification is to be required in the welding procedures." The Licensee has stated that they will comply with this condition. Therefore, the use of Code Case N-606-1 as an alternative to the mandatory ASME Code repair provisions is acceptable to the NRC staff, provided that all conditions and provisions specified in RG 1.147, Revision 16 are complied with.

3.5.1 Acceptance Examination Area

The licensee proposed to use PT on the new weld surface and ½ inch minimum distance below the repair as an alternative to the requirement of Code Case N-606-1 to examine a band around this area at least 1-1/2 times the component thickness or 5 inches, whichever is less. The licensee also stated in their basis for this alternative that UT would be performed on the repair weld, and the HAZ of the low alloy steel base metal and stainless steel CRD housing.

The licensee's proposed area to be examined by PT is different than the area to be examined by PT specified in BWRVIP-58-A, which called for the PT examination to include the weld surface and the CRD housing base metal surface ½ inch above and below the weld. Due to the weld configuration for the NMP1 CRD repair, in which there is a gap between the top and bottom portions of the original CRD housing, the upper weld toe is not directly contiguous with the upper portion of the CRD housing but ends in a taper region on the exposed bottom head base metal. The narrow gap of exposed RV bottom head low alloy steel above this taper region is within the scope of the PT examination. The repair weld, low-alloy steel heat affected zone beneath the repair weld, and the heat affected zone of the bottom portion of the stainless steel CRD housing are examined by UT to the maximum extent possible. The UT examination is qualified to detect flaws in the new weld and base metal interface beneath the new weld. Since Figure 2 of the relief request did not show the dimensions of the areas and volumes to be examined, in RAI C (Ref. 9) the NRC staff requested a clarification to the areas and volumes for the PT and UT examination and a revision to Figure 2. In response to RAI C, the licensee provided detailed descriptions and figures clearly showing the inspection volumes and surfaces, as well as illustrations depicting the estimated achievable coverage for both the surface and volumetric examinations. The figures in the licensee's RAI response show that the UT examination achieves complete coverage of the repair weld and low alloy steel HAZ when all beam angles are considered in the aggregate. However, as shown in Table 3 of Attachment 2 to the Reference 2, when considered individually, certain probe angles are unable to provide 100 percent examination area coverage. Therefore, in RAI J (Ref. 9), detailed in SE Section 3.5.3, the NRC staff requested additional information on the licensee's basis for acceptability of the coverage limitations.

The NRC staff evaluated the licensee's proposed acceptance examination area and finds that the examination area is equivalent to the examination area specified in NRC-approved topical report BWRVIP-58-A, within the limits of the different geometry for the NMP1 repair design. The examinations for the NMP1 and the BWRVIP-58-A repair designs both specify PT examination of the weld surface and adjacent base metal surfaces, and UT examination of the repair weld volume, underlying low-alloy steel HAZ and CRD housing HAZ. Therefore, both the BWRVIP-58-A and NMP1 examination areas cover the regions most likely to have flaws induced by the welding process, and examination of the full extent of material required by Code Case N-606-1 is not necessary. Examination of the upper portion of the CRD housing is not necessary for the NMP1 design since it is not metallurgically connected to the repair weld thus would not have a HAZ from the weld. Therefore, based on the above, the NRC staff finds the licensees proposed alternative examination area is acceptable pursuant to 10 CFR 50.55a (a)(3)(i).

3.5.2 <u>48-Hour Hold</u>

The ASME Code Case N-606-1, Paragraph 4(a), specifies that the final weld surface shall be examined using surface and volumetric examinations no sooner than 48 hours after the completed weld reaches ambient temperature. Code Case N-606-1 is acceptable subject to the following conditions specified in Regulatory Guide 1.147, Revision 16: Prior to welding, an examination or verification must be performed to ensure proper preparation of the base metal, and that the surface is properly contoured so that an acceptable weld can be produced. The surfaces to be welded, and surfaces adjacent to the weld, are to be free from contaminants, such as, rust, moisture, grease, and other foreign material or any other condition that would

prevent proper welding and adversely affect the quality or strength of the weld. This verification is to be required in the welding procedures.

The EPRI Report 1013558 (Ref. 10) provides a technical basis for starting the 48-hour hold after completion of the third temper bead weld layer rather than waiting 48 hours after the weld overlay cools to ambient temperature. After evaluating the issues relevant to hydrogen cracking, such as microstructure of susceptible materials, availability of hydrogen, applied stresses, temperature, and diffusivity and solubility of hydrogen in steels, EPRI concluded that "...there appears to be no technical basis for waiting the 48 hours after cooling to ambient temperature before beginning the NDE of the completed weld. There should be no hydrogen present, and even if it were present, the temper bead welded component should be very tolerant of the moisture ..." EPRI also notes that over 20 weld overlays and 100 repairs have been performed using temper bead techniques on low-alloy steel components over the last 20 years. During this time, there has never been an indication of hydrogen cracking by the NDEs performed after the 48-hour hold or by subsequent ISIs. The industry experience with weld overlays documented in the EPRI Report was mainly based on A 533 Grade B plate and A 508 forgings. The NRC staff compared the chemical composition ranges of A 302B (material of the NMP1 bottom head) with other low-alloy steel materials on which temper bead weld techniques are performed (A 533 Grade B, A508) and finds that the chemical compositions are sufficiently similar that it can be concluded that the behavior of A302 B material, with respect to hydrogen retention and diffusion, should be very similar to that of A 533 Grade B plate and A 508 forgings. In its response to RAI B (Ref. 7), the licensee provided the following information to further support applicability of the EPRI Report to the A 302B bottom head material and the use of Code Case N-606-1:

> The delayed cold cracking mechanisms are identical for all low alloy and carbon steels and are: (a) the presence of diffusible hydrogen; (b) susceptible microstructure; and (c) sustained tensile stress (residual or applied). Each of these mechanisms is discussed below for the NMP1 RV SA-302 Grade B material.
>
> (a) Sources for Hydrogen
>
> The machine Gas Tungsten-Arc Welding (GTAW) process is inherently a low-hydrogen process. The GTAW process utilizes dry inert gases that shield the molten weld pool and increase the relative partial pressure between atmospheric elements and the molten weld pool. Furthermore, in the GTAW process, any moisture on the surface of the component being welded is vaporized ahead of the welding. Additionally, austenitic weld materials are being used for the proposed repair as directed by Code Case N-606-1. Austenite has a higher solubility for hydrogen than ferrite, and therefore acts as a sink for any existing diffusible hydrogen. After the third tempering layer, no path exists for additional hydrogen to diffuse into the ferritic base material.
>
> (b) Microstructure
>
> Upon welding, a small region of the heat affected zone in SA-302 Grade B material is increased to above the upper transformation temperature. Due to the rapid heating and relatively low ambient temperature of the surrounding base material, cooling rates are high in this area and result in a microstructure of primarily martensite intermixed with small amounts of bainite, pearlite, and ferrite. As subsequent passes are welded, as in the temperbead repair outlined in Code

Case N-606- 1, the martensite is tempered to a high strength/high toughness microstructure that exceeds the toughness of the unwelded base material as required by ASME Section III, NB-4335.2 (c)-4. The ambient temperature temperbead process used for this repair (as directed by Code Case N-606) is proven to produce high toughness tempered martensite in the procedure qualification (see ASME Section III, NB-4335.2 (c)-4), and is extremely resistant to hydrogen cracking. No microstructure changes occur to the ferritic base material after the third tempering layer.

(c) Tensile Stress and Temperature

The proposed repair plan consists of a groove weld joining the reactor vessel material to the roll expanded CRD housing [Type] 304 SS [stainless steel] material. Since the upper portion of the weld does not tie in to the upper section of the CRD housing, residual stresses are reduced from typical groove weld geometries. Additionally, the EPRI report's discussion on "Tensile Stress and Temperature" includes all P-No. 3 steels (including SA-302 Grade B), and therefore applies to this discussion.

Code Case N-606-1 Applicability Code Case N-606 was written specifically for the purpose of the CRD housing penetration repair being proposed. EPRI Report 1013558 is applicable to Code Case N-606 for the reasons discussed above under the "SA-508, Class 2 vs. SA-302 Grade B" heading. Additionally, the technical aspects of Code Case N- 638 (specifically mentioned in EPRI Report 1013558) and Code Case N-606 were identical in Revision 1 of both Code Cases. While Code Case N-638 has been revised to include the revised 48 hour hold requirement, Code Case N-606 has not been updated with the same frequency as Code Case N-638. However, since the technical details discussed in Item 1 apply to all P-No. 3 base materials, the technical basis for applying the modified 48-hour hold allowance is equally applicable for a Code Case N-606.

Therefore, based on analysis and review of EPRI Report 1013558 and the RAI B response, the NRC staff determines that the conclusions of the EPRI Report are applicable to the A 302B material of the NMP1 bottom head. The basis for the NRC staff's conclusion is the similar chemical composition and material type of the A 302 B material to the materials evaluated in the EPRI report. The NRC staff also notes that all these materials are categorized as P-3 with respect to welding properties by the ASME Code.

An ASME Technical Basis Paper (Ref. 11), supporting the proposed revision to the 48-hour hold time requirement for Code Case N-638, indicates that the introduction of hydrogen to the ferritic HAZ is limited to the first weld layer, because this is the only weld layer that makes contact with the ferritic base material. The Technical Paper states that while the potential for the introduction of hydrogen to the ferritic HAZ is negligible during subsequent weld layers, these layers provide a heat source that accelerates the dissipation of hydrogen from the ferritic HAZ in non-water-backed applications. The Technical Basis Paper concludes that there is sufficient delay time to facilitate the detection of potential hydrogen cracking when NDE is performed 48 hours after completion of the third weld layer. Furthermore, the solubility of hydrogen in austenitic stainless steel weld materials is much higher than that of ferritic materials, while the diffusivity of hydrogen in austenitic materials is lower than that of ferritic materials. As a result, hydrogen in the ferritic HAZ tends to diffuse into the austenitic weld metal, which has a much

higher solubility for hydrogen. This diffusion process is enhanced by heat supplied in subsequent weld layers.

Based on the information summarized above, the NRC staff finds that starting the 48-hour hold time after completion of the third temper bead weld layer is acceptable. This finding is based on the inherent low-hydrogen nature of the weld process, the cracking-resistant microstructure produced in the HAZ, and the design of the weld which minimizes tensile stresses, which minimize the likelihood of hydrogen cracking. Further, based on our review of the ASME technical basis paper, the NRC staff finds that it is not necessary to wait until 48 hours after the completed overlay has reached ambient temperature to perform NDE, because any delayed hydrogen cracking, were it to occur, would be expected to occur within the 48 hours following completion of the third temper bead weld layer. The NRC staff find's the licensees proposed alternative to the 48-hour hold requirements of Code Case N-606-1 is acceptable pursuant to 10 CFR 50.55a (a)(3)(i).

3.5.3 Acceptance NDE

Code Case N-606-1, Paragraph 4(a) requires UT examination to be performed in accordance with Appendix I, and Paragraph 4(d) specifies acceptance criteria in accordance with ASME Code, Section XI, IWB-3000. However, IWB-3000 does not have acceptance criteria that directly apply to the partial penetration weld configurations. As such, the licensee requested relief from the examination requirements as specified in Code Case N-606-1, Paragraphs 4(a) and 4(d). The licensee proposed alternative was to perform NDE in accordance with ASME Code, Section III, 2004 Edition with no Addenda, similar to that specified in BWRVIP-58-A. The BWRVIP-58-A documents the qualification of a UT examination technique for CRD housing repair welds that includes scanning from the entire weld face and from the inside surface of the CRD housing which interrogates the weld and most of the low-alloy steel bottom head heat affected zones. The UT was performed on a mockup to qualify the technique using the NDE requirements of Section V, Article 5, 1995 Edition/Addenda, and the Acceptance Standards of ASME Code, Section III, NB-5000, 1995 Edition with 1995 Addenda. In RAI D (Ref. 9), the NRC staff noted that the UT technique described in BWRVIP-58-A was only demonstrated on two stub tube mock-ups with implanted flaws, and of the four fatigue cracks in these mock-ups, three were documented as "not detected" by the UT technique. It was unclear to the NRC staff as to how the results presented in Table 4-3 on page 4.12 of BWRVIP-58-A show that "satisfactory performance for detection of the flaws was accomplished." Therefore, the NRC staff requested the licensee to provide details on how the UT technique described in 1ISI-004 was qualified.

In their response to RAI D (Ref. 7), the licensee explained that in 2009, AREVA completed a project to evaluate and compare the effectiveness of UT inspection of three component forms including the CRD housing modified BWRVIP-58 inner diameter temper bead (IDTB) weld repair that is proposed for NMP1. The work, performed after the publication date for BWRVIP-58-A, was performed independently from BWRVIP-58-A. The RAI response provides details of the 2009 AREVA work, including descriptions and figures that detail the mockups used in the work, the UT technique used, and the results from all the UT examinations of the mockups. The licensee notes that the transducers selected for the proposed NMP1 repair configuration are those used successfully in the examination of repairs of PWR RV closure head penetrations and include: a 0-degree search unit for weld profiling and detection; 45-degree refracted longitudinal (RL) search unit, scanned axially "up" and "down," for detection of flaws parallel to the weld;

70-degree RL search unit, scanned axially "up" and "down," for detection of flaws parallel to the weld; and 45-degree RL search units, clockwise and counterclockwise, used for detection of flaws perpendicular to the weld.

The licensee's RAI response presents a table of results from the UT examinations of all mockup standards. The table lists the detection results for each flaw and for each angle of detection in all of the mockups inspected, and uses color codes to depict estimated signal-to-noise ratio (SN) for each indication. The repair mockups with the configuration relevant to NMP1 (modified from BWRVIP-58) contained welds with a smooth machined ID surface along with a groove machined adjacent to the weld. The presence of the groove limited the amount of surface available for inspection when inspecting with the beam directed down the tube (or away from the groove). Unlike the BWRVIP-58 repair mockups, the modified repair mockups had machined ID surfaces that did not present coupling problems when inspecting over the top of the weld. The conventional probes were capable of detecting all flaws, both axial and circumferential, with good signal-to-noise ratios. The results shown by the licensee in their RAI response demonstrate that proposed ultrasonic examination method will have adequate sensitivity to detect unacceptable flaws when the weld ID has a smooth surface. Since the procedures proposed for the NMP1 weld repair result in a smooth ID surface, the NRC staff is satisfied that the proposed UT is capable of detecting flaws in the repair zone.

Relief Request 1ISI-004 states that UT examination acceptance criteria are in accordance with NB-5331 as modified by BWRVIP-58-A. In RAI E (Ref. 9), the NRC staff requested the licensee to provide details of how the acceptance criteria of NB-5331 are modified by BWRVIP-58-A, and justify any modifications. The criteria in NB-5331 rejects indications characterized as cracks, lack of fusion, or incomplete penetration, regardless of length. In their response to RAI E (Ref. 7), the licensee indicated that the modification is to allow an indication of up to 0.10-inch in the triple point region, which would be rejectable per the criteria of NB-5331. The licensee further states that the triple point anomaly is analyzed independently and considered benign when sized less than 0.10 inch in the through-thickness direction. In RAI F (Ref. 9), the NRC staff requested that the licensee provide details of how it was determined that the UT is able to detect and size an unacceptable triple point anomaly. In their response to RAI F (Ref. 7), the licensee provided a description of a Triple Point mockup that contained artificial flaws that simulate the weld solidification anomalies that occur where the weld material, stainless steel CRD tube material, and carbon steel vessel material are joined. This mockup, constructed to simulate the typical UT signal responses obtained for triple point solidification anomalies, contained a series of electro-discharge machining (EDM) notches with differing depths that were squeezed shut via hot isostatic pressing (HIP). The results of the UT examinations of this Triple Point mockup showed that all flaws were detected using one or more of the conventional UT probes used. Additionally, the licensee presented results of length and depth sizing, which were used to define the accuracy of the UT technique. Based on the results presented, the NRC staff is satisfied that, if a rejectable triple point anomaly were to be present, it would be detected and sized appropriately.

The ASME Code, Section III acceptance criteria requires discrimination of flaw type such that cracks, lack of fusion, and incomplete penetration greater than 20% distance amplitude correction are rejected. In RAI G, the NRC staff thus asked the licensee to explain how flaw type is determined by the UT procedure such that this criterion may be applied. In its response to RAI G, the licensee explained that the analysis section of the UT procedure provides

guidance via procedural steps to the data analyst based on reflector features for flaw classification. The licensee further provided examples of this guidance. The NRC staff review of this guidance finds that it is appropriate and acceptable for discrimination of flaw types when implementing the acceptance criteria of ASME Code, Section III.

The NRC staff notes that at least two vendors in the United States have performance demonstration initiative (PDI) qualified UT techniques for inspecting upper head control rod drive mechanism (CRDM) nozzles in pressurized water reactors (PWRs). The NRC staff further notes the statement found in Table 1 on page 7 of 13 of Attachment 2 to Ref. 2, "The CRDM nozzle penetration repair configuration is very similar to the dissociated configuration for NMP1; therefore the same beam angles will be used." Therefore, in RAI H, the NRC staff asked the licensee to discuss whether, in addition to using the same beam angles, the personnel, procedures, and equipment used for the qualified PWR upper head exams will be used for NMP1 CRD housings repairs. In its response, the licensee stated that the procedures and equipment for performing the UT exams will be the same as those used in PWR IDTB repair upper head examinations. The licensee stated further, "Approximately 70% of the AREVA NDE analysis NRC staff who are eligible for deployment, possess the PWR upper head CRDM [Personnel Demonstration Qualification Statements] PDQS. Though not required for this examination, the examination personnel involved with the NMP1 CRD housing repair will possess the PWR upper head CRDM PDQS or an equivalent BWR bottom head PDQS, should one become available in the future." The NRC staff is thus satisfied that the licensee will be implementing PDI qualified personnel, equipment and procedures for examinations of the NMP1 IDTB repair, thus this concern is resolved.

In RAI I (Ref. 9), the NRC staff noted that in Table 1 on page 8 of 13 of Attachment 2 to Reference 2, the licensee stated that UT examination at the end of the defined ISI interval will confirm acceptance for the subsequent interval. However, the licensee did not address ISI NDE qualifications in the relief request or BWRVIP-58A. As such, the NRC staff asked the licensee to describe the UT that will be used for ISI. In their response, the licensee stated, "The UT examination used for inservice inspection will be equivalent to the technique used for the preservice inspections to be performed following completion of the weld repair." Since the licensee will implement an inservice inspection technique equivalent to the technique used for the preservice inspections (i.e., personnel, procedures and equipment qualified through the PDI process), the NRC staff found the response to RAI I acceptable.

Item 4 of Attachment 2 to indicates that in or beneath the tapered region of the weld, limited UT coverage exists in both the weld and the low alloy steel (LAS) HAZ for the radial beam scan direction (which detects laminar-type flaws) and for the circumferential beam direction (which detects axially oriented flaws). Therefore, it is possible that there could be undetected laminar or axially oriented flaws in either the weld or LAS HAZ in this region. In its justification for the coverage limitations of the UT examination, the licensee indicated that they performed a flaw evaluation considering flaw growth from fatigue, stress corrosion cracking (SCC) and stress-induced corrosion cracking (SICC), which demonstrated that flaws would remain within acceptable limits for the defined ISI interval. In RAI J, the NRC staff requested the licensee submit this flaw evaluation (Reference 18 to Attachment 2 of the relief request). In response to RAI J, the licensee provided the flaw evaluation, entitled "NMP1 LAS [Low-Alloy Steel] SCC [Stress Corrosion Cracking]/SICC[Stress-Induced Corrosion Cracking] Analysis (Ref. 12), as Attachment 4 to Reference 7. The reference contains a fracture mechanics analysis of a

postulated initial flaw located at the upper toe of the repair weld, at the interface between the repair weld and the underlying low-alloy steel RV bottom head material. The flaw lies in a cylindrical surface 360 degrees around the circumference of the CRD housing, and is assumed to propagate through the low-alloy steel. In the response to RAI J the licensee indicated that this is the most probable propagation path for a flaw initiating at this location due to the high residual stresses that will be present in the low-alloy steel as a result of the installation of the repair weld, and that other propagation paths are less likely. In support of this assertion, the licensee further cited "BWRVIP-60-A, BWR Vessel and Internals Project Evaluation of Stress Corrosion Crack Growth in Low Alloy Steel Vessel Materials in the BWR Environment," which concludes that both initiation and growth of intergranular stress corrosion cracking (IGSCC) in low-alloy steels in a BWR environment is extremely unlikely. Based on this the licensee concluded that IGSCC crack growth would be possible only in a region of high residual stress such as the weld HAZ. The licensee also cited a previous flaw evaluation of a postulated flaw in the Alloy 182 stub tube to RV weld that included consideration of the flaw penetrating into the RV base metal. The evaluation concluded that even if cracking were to continue into the vessel the postulated flaw does not pose any structural concerns for the RV. The NRC staff agreed with this conclusion in an SE dated August 3, 2009 (Ref. 8). The NRC staff reviewed this SE and concludes that it supports the assertion that undetected flaws in the LAS HAZ of the CRD repair will not pose a threat to the integrity of the RV.

The analysis of Reference 12 addresses only laminar flaws in the LAS HAZ. Since laminar or axial flaws could also exist in the weld filler metal in the weld taper region, and axial flaws could exist in the LAS HAZ, the NRC staff further evaluated this issue. The NRC staff finds that undetected axial flaws in the tapered region of the weld would necessarily be small due to the small size of the tapered region, and axial flaws extending beyond the weld taper region would be detected by the UT examination. The NRC staff further finds that no surface-breaking flaws should exist in the taper region of the repair weld or the exposed low-alloy steel above the weld because the entire inside surface of the repair weld and the low-alloy steel above it is subject to a PT examination after welding. However, if any embedded flaws exist in the taper region, these flaws would be small. Since the same material and stresses are involved, the NRC staff finds that propagation of such flaws (including laminar flaws in the weld metal) should be bounded by the crack growth and stability analyses of the "NMP-1 CRD Housing Weld Anomaly Analysis," (Ref. 14), which evaluated growth by fatigue of a 0.10 inch 360 degree cylindrical defect at the intersection of the repair weld, low alloy steel vessel, and CRD housing material. (The NRC staff's evaluation of Reference 14 is in Section 3.5.4 of this SE). The crack types and crack propagation paths evaluated in Reference 14 are axial and circumferential cracks growing in the radial direction through the stainless steel repair weld from the outer diameter inwards, and a cylindrical flaw growing vertically in either the low-alloy steel or the stainless steel repair weld. The NRC staff also finds that an axial flaw that propagated through the entire height of the repair weld would lead to leakage, which would be detectable via routine VT-2 visual examination conducted under the ASME Section XI ISI Program, and would not lead to ejection of the CRD housing. Therefore, although the licensee's evaluation of a postulated flaw in the region of the repair area that cannot be effectively examined by UT did not consider all possible propagation paths and initial flaw locations, the NRC staff concludes that the possibility of undetected flaws having a significant impact on the structural integrity of the CRD housing is remote. The NRC staff therefore found the licensee's response to RAI J acceptable.

Reference 12 concludes that a 0.10 inch postulated flaw in the exposed LAS is acceptable for 12 years of operation following a CRD housing temper bead weld repair. Therefore, ISI must be performed on the repair area within 12 years of implementation of the repair.

The NRC staff finds the proposed acceptance NDE acceptable for the following reasons:

- The licensee will perform UT examination qualified to detect defects in the repair weld, the low-alloy steel HAZ, and CRD housing HAZ, to the maximum extent possible;

- Based on the licensee's evaluation as augmented by the NRC staff's evaluation, potential undetected flaws in the weld taper region or the adjacent HAZ will not grow to a size that would affect the structural integrity of the RV during the remaining life of the plant (or prior to the scheduled follow-up UT examination, as applicable)

- The licensee will apply the acceptance criteria of the ASME Code, Section III, NB-5331, as modified to allow a lack of fusion type flaw at the triple point. This type of flaw has been justified analytically.

- PT examination will be performed on the final surface which will detect surface flaws.

Based on ASME Code Section XI, IWA-4411(a) states, "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," the NRC staff finds the use of a later Code Edition acceptable.

Based on the above, the NRC staff find's the licensees proposed acceptance NDE is acceptable pursuant to 10 CFR 50.55a (a)(3)(i).

3.5.4 Triple Point Anomaly

The new weld that joins the remnant nozzle to the RV head penetration bore may result in a weld solidification anomaly at the junction (weld root), (i.e., the triple point) of the ASME SA-182 F304 CRD stub tube, the LAS of the RV head, and the new weld metal. The phenomenon that the licensee refers to as a triple point anomaly is not uncommon in weld fabrications involving a partial penetration or lap joint type welds comprised of ferritic material, stainless steel, and stainless steel filler metal using the GTAW process. It is sometimes unavoidable under the best fabrication circumstances. In the case of the licensee's request, it plans to perform a UT examination that is qualified to detect triple point anomalies greater than or equal to 0.10-inch in depth, and evaluate them for acceptance under ASME Code Section XI. The NRC staff is satisfied the proposed UT techniques can detect and size triple point flaws equal or greater than 0.10 inches in depth, as documented in Section 3.5.3 of this SE.

The licensee performed a fracture mechanics analysis, in accordance with the ASME Code, Section XI, to justify operating with the postulated weld anomaly at the triple point. The weld anomaly is modeled as a 0.10-inch, circular, crack-like defect, extending 360 degrees around

the circumference of the nozzle at the triple point location. Mock-up testing has verified that the anomalies may exist and do not exceed 0.10 inch in length. A fracture mechanics analysis has been performed to provide justification, in accordance with the ASME Code Section XI, for operating with the postulated triple point anomaly. Therefore, if these anomalies are determined to be less than or equal to 0.10 in. long emanating in any direction from the weld root triple point and extending around the penetration for the full circumference or less, they will be acceptable and repair will not be required.

Fracture Mechanics Evaluation

The NRC staff reviewed the licensee's fracture mechanics analysis of the triple point anomaly, for which non-proprietary (Ref. 13) and proprietary (Ref. 14) versions were provided in Attachments 3 and 5 to Reference 2. The licensee's evaluation uses the methods of the ASME Code, Section XI, 2004 Edition with No Addenda.

The general steps to the fracture mechanics analysis are as follows:

- Postulate initial flaw orientation, location, size, and possible propagation paths
- Determine growth of each type of flaw along each applicable path by fatigue
- Determine flaw stability at end of life based on design basis loading

The licensee's evaluation postulated several different potential crack propagation paths starting from the triple point anomaly. These are 1) propagation of a circumferential flaw horizontally from the outer diameter to the inner diameter of the repair weld, 2) propagation of a cylindrical axial flaw horizontally from the outer diameter to the inner diameter of the repair weld, and 3) propagation of the flaw axially along the fusion line of the repair weld with the RV base material. Since the vessel is hemispherical, the CRD housings penetrate the vessel at an angle to the vessel surface resulting in "uphill" and "downhill" locations around the penetration. For the flaw at the fusion line, the analysis considered the cases of propagation through either the repair weld material or the RV base material, on both the uphill and downhill side, resulting in 4 crack paths. For the axial or circumferential flaws propagating in the axial direction, either type of flaw could propagate either on the downhill or uphill path. Therefore, there are a total of 6 paths defined.

The licensee determined the stress intensity factors (SIFs) using two different methods. For the axial and circumferential flaws growing in the horizontal direction through the repair weld, the SIFs were determined using the weight function method implemented in a proprietary computer code. For the cylindrical flaw growing vertically, the licensee used the SIF solutions for a continuous surface crack in a flat plate from Appendix A of the 2004 Edition of the ASME Code, Section XI.

Fatigue Crack Growth

For the fatigue crack growth evaluation, the analysis considered stresses from plant transients for normal, upset and emergency conditions (service Levels A, B and C). The stresses due to external loads on the CRD housing were determined via a finite element analysis (FEA). Residual stresses associated with the weld repair were determined via a separate FEA.
The fatigue crack growth evaluation used the number of cycles for the various transients for

40 years. The NRC staff reviewed the transients considered and finds the transients and the numbers of occurrences of each are generally consistent with those listed in Table V-2, "Operating Cycles and Transient Analysis Results," in Section V, "Reactor Coolant System," of the Updated Final Safety Analysis Report (UFSAR) for NMP1, Rev. 20 dated October 2007. However, for two specific transients, the number of occurrences used differs from those listed in the UFSAR, therefore in RAI L (Ref. 9) the NRC staff requested an explanation of this discrepancy. In its response to RAI L (Ref. 7), the licensee indicated that the number of occurrences for these transients was based on the original number of cycles for the 40-year design life from the original General Electric (GE) loading cycle diagram. The licensee further noted that since the repair has not been installed yet and the remaining plant design life for NMP1 is less than 40 years, the number of cycles is conservative relative to the remaining years for plant operation. The licensee also stated this conclusion was based on a projection of the number of these transients that may occur over a 40-year period based on the last ten years of operating history which indicates the expected number of cycles will be far less than the number of cycles used in the calculation. The NRC staff reviewed the number of these transients listed in the NMP1 UFSAR and observed that the numbers of cycles used in Reference 14 are at least 50% of the 40-year value. Therefore, since less than 20 years remains in the NMP1 period of extended operation, the NRC staff finds the numbers of cycles used in the evaluation are conservative. Therefore, the NRC staff found the licensee's response to RAI L acceptable.

The licensee used the fatigue crack growth rates from the ASME Code Section XI, Article A-4300 for the low-alloy steel RV head material, and Article C-8410 for the austenitic stainless steel weld material. Fatigue crack growth rates for an air environment were used for both materials. The NRC staff reviewed the fatigue crack growth rates used and finds they are appropriate. Use of the air crack growth rates is appropriate because all the postulated flaws are growing from the non-wetted side of the CRD housing or weld.

The results of the fatigue crack growth evaluation for the circumferential flaw growing horizontally showed the downhill path had greater flaw growth.

End-of-Life Stability Evaluation

In RAI K (Ref. 9), the NRC staff requested additional information to clarify the following issues related to the end-of-life stability evaluation:

1. Explain which transients and load combinations were used for the end-of-life evaluation for each type of flaw, and how these transients and load combinations were determined to be limiting.
2. Identify which Service Levels the limiting loads provided in the response to Item 1 represent. If the end-of-life flaw stability evaluation did not consider each Service Level (A, B, C, and D), justify why only certain service level conditions were considered.
3. Identify the source in the NMP1 design basis for the transients and loading combinations used to determine fatigue crack growth and to evaluate end-of-life flaw stability. Describe how the transients listed were derived from the plant design basis.

With respect to Item 1, the response to RAI K (Ref. 7) indicates that the highest pressure stress for all the applicable transients was used in the flaw evaluation for both axial and circumferential flaw cases. For the circumferential flaw, external axial loads due to deadweight, stuck control

rod and seismic were considered. The axial loads from Service Level B were used. For the axial flaws, only pressure stresses were considered. The NRC staff finds this reasonable since external piping loads would be mostly in the axial, or vertical direction (parallel to the CRD housing), or bending loads. Axial loads would have no effect on an axial crack, and any flaws in the CRD repair area would see little bending load since the housing is backed up by the thick RV bottom head shell. The safety factor for Service Level A was used for conservatism since Service Level A (normal operation) requires the highest safety factor. For the cylindrical flaws, margins for normal, upset, emergency and faulted conditions were determined for the circumferential flaws (Service Levels A, B, C and D) in accordance with IWB-3612. Stress intensities for all these conditions were determined via FEA. The margins were calculated for the final flaw length with the most limiting temperature (with regard to fracture toughness) and stress intensity from any of the transients.

With respect to Item 2 of RAI K, the licensee's response indicates all Service Level conditions (normal, upset, faulted and emergency) were considered for the cylindrical flaw. Service Level B conditions were limiting for the circumferential flaw. For the axial flaw, only pressure loading is considered. The response indicated the highest pressure loading for any transient was considered. For the cylindrical flaw, the response indicated that all Service Levels were considered and the limiting margins were given in Table 5-12 of Reference 14.

With respect to RAI K Item 3, the response indicated the source of the loading combinations was the original GE cycle loading diagram for the NMP1 RV. The response additionally indicated previous NMP1 vessel, CRD penetration, and nozzle stress analyses were reviewed to determine if the thermal transients used in those analyses are more conservative than those in the GE cycle loading diagram. The response also indicated that BWRVIP-55-A, "BWR Vessel and Internals Project Lower Plenum Repair Design Criteria," was used as guidance and that the final design transients used in the analyses presented in Reference 14 conservatively envelope the design transients presented in the GE cycle loading diagram, those used in previous stress analyses, and the BWRVIP-55-A recommended guidance.

The NRC staff found the response to RAI K acceptable because the licensee clarified that for conservatism, the highest pressure loading for any of the transients combined with the highest safety factor (that for Service Level A) was used for the end-of-life stability evaluation of the axial and circumferential flaws. Additionally the licensee's response clarified that all applicable service level loadings were considered for each flaw type. Additionally, for the cylindrical flaws, which are evaluated using linear elastic fracture mechanics (LEFM), the response clarified that the highest stress intensity and lowest fracture toughness of any of the service level loadings were combined to produce a conservative evaluation. Further, the licensee clarified the source of the transient information in the NMP1 design basis is the GE load cycle diagram for NMP1 as supplemented based on a review of previous NMP1 vessel, CRD penetration, and nozzle stress analyses to determine if the thermal transients used in those analyses were more conservative than those in the GE load cycle diagram.

<u>*Circumferential and Axial Weld Flaws*</u>

For the circumferential and axial flaws in the weld, for end-of-life stability, the procedures of the ASME Code, Section XI, Appendix C (Appendix C), Article C-6000, which is for elastic-plastic fracture mechanics (EPFM) analysis, were used. Reference 13 describes these evaluations as "limit load evaluations," which is the recommended technique from Appendix C, for a weld metal

flaw in a nonflux weld. In response to RAIs M and N (Ref. 7) the licensee clarified that for additional conservatism, the evaluation technique used was EPFM, which is appropriate for a flux weld even though a nonflux welding technique, GTAW, is used to make the repair weld. Since the change from the recommendation of Appendix C results is conservative, the NRC staff finds the change acceptable.

With respect to the acceptance criteria for the flaws at end-of-life, for the axial and circumferential flaws propagating horizontally through the repair weld, the licensee used the criteria of the ASME Code, Section XI, IWB-3642, which allows the use of the analytical procedures of Appendix C if the flaws exceed the acceptance criteria of the ASME Code, IWB-3514. The results of the analysis showed that for the circumferential flaw, both the circumferential and axial flaws met the Appendix C acceptance criteria with considerable margins.

Cylindrical Flaw

The licensee applied procedures of the ASME Code, Section XI, Appendix A (Appendix A) for evaluating the end-of-life stability of the cylindrical flaw in both the RV low-alloy steel and the austenitic stainless steel weld material. Both IWB-3610 and Appendix A Paragraph A-1100 allow the use of procedures as described in Appendix A for ferritic steel components 4 inches and greater in thickness. Use of these procedures based on LEFM is conservative for the stainless steel weld, because LEFM procedures are based on brittle behavior, whereas stainless steel weld materials are typically very ductile.

For the cylindrical flaws in both materials, the licensee used the acceptance criteria of IWB-3612. These criteria require the applied SIFs (K_I) to be:

$K_I < K_{Ia}/\sqrt{10}$ for normal and upset conditions (margin = $K_{Ia}/K_I > \sqrt{10}$)

$K_I < K_{Ic}/\sqrt{2}$ for emergency and faulted conditions (margin = $K_{Ic}/K_I > \sqrt{2}$)

Where K_I is the applied SIF, K_{Ia} is the crack arrest fracture toughness, and K_{Ic} is the static crack initiation fracture toughness

The results of the analysis of the cylindrical flaw in both the weld and the RV low alloy steel materials showed that the acceptance criteria above were met for Service Level A, B and C conditions.

<u>Summary – Triple Point Anomaly</u>

The NRC staff finds the licensee's evaluation of the triple point anomaly acceptable because:

- The evaluation was performed using methods and acceptance criteria that meet the requirements of an addition and addenda of the ASME Code, Section XI, which has been incorporated by reference in 10 CFR 50.55a(b);

- The NRC staff finds the inputs and assumptions of the evaluation to be appropriate and conservative;

- The assumed flaw depth of the triple point anomaly has been shown to be readily detectable by the NDE that will be performed;

- The results of the evaluation showed the acceptance criteria of the ASME Code, Section XI, are met with considerable margins at the end-of-life.

Based on the NRC staff's evaluation documented in this section, the NRC staff find's the licensees proposed alternative to the acceptance criteria of ASME Section III NB-5330 related to the triple point anomaly is acceptable pursuant to 10 CFR 50.55a (a)(3)(i).

3.5.5 Interpass Temperature Monitoring

ASME Code Section XI, IWA-4610(a), requires the use of thermocouples and recording instruments to monitor process temperatures, such as preheat and interpass temperature. The licensee requested relief from this requirement because the weld region is inaccessible during welding. In Revision 0 of the relief request, the licensee had proposed to use either heat transfer calculations or interpass temperature measurements on test coupons during a simulation of the welding process in lieu of direct interpass temperature measurement during welding. In RAI 1 the NRC staff requested, considering the importance of not exceeding the maximum interpass temperature, whether the licensee would modify the relief request to require both heat transfer calculations and coupon temperature measurement. In response to follow-up RAI 1 (Ref. 4), the licensee stated that [in lieu of measuring interpass temperatures with thermocouples] they would both perform heat transfer calculations and measure interpass temperatures on a test coupon. Further, the licensee revised its relief request related to interpass temperature measurement accordingly in Revision 1 of the relief request (Attachment 2 to Reference 4).

The NRC staff reviewed the licensee's criteria for performing the heat transfer calculations and coupon temperature measurements included in the basis for the alternative (Section 3.4.5). The NRC staff finds that these criteria are consistent with the criteria of Code Case N-638-4 for these activities. Code Case N-638-4 is conditionally approved in RG 1.147, Revision 16. A condition imposed in RG 1.147 allows either calculation of the interpass temperature or measurement of the interpass temperature on a coupon only when it is impractical to directly measure the interpass temperature, such as in situations where the weldment area is inaccessible (e.g., internal bore welding) or when there are extenuating radiological conditions. Both Code Case N-606-1 and Code Case N-638-4 address ambient temperature temper bead welds applied using machine GTAW. Based on the similarity of the two Code Cases, the NRC staff finds the substitution of calculations plus coupon measurements of interpass temperature for direct measurement to be reasonable under the same situation, specifically inaccessibility in the case of the current request. Further, Code Case N-638-4 would only require one of the methods of determining interpass temperature to be used. Therefore, use of both methods provides additional assurance that interpass temperatures would be maintained below the required value.

Based on the above, the NRC staff finds the licensee's proposed alternative to the interpass temperature measurement requirements of the ASME Code Section XI, IWA-4610(a), to be acceptable in accordance with 10 CFR 50.55a(a)(3)(i).

4.0 CONCLUSION

Based on the discussion above, the NRC staff concludes that the alternatives proposed in NMPNS Relief Request 1ISI-004, Revision 1 to perform a repair of CRD housing penetrations at NMPNS will provide an acceptable level of quality and safety. Therefore, pursuant to 10 CFR 50.55a (a)(3)(i), the NRC staff authorizes NMPNS Relief Request 1ISI-004, Revision 1 for the repair of CRD housing penetrations at NMPNS. This relief request is authorized for use during the remaining term of the NMP1 renewed operating license, which expires on August 22, 2029. It should be noted that (a) the licensee must perform inservice inspection (ISI) on the repair area within 12 years of implementing the repair, as detailed in Section 3.5.3 of this SE, (b) the relief request is authorized for use with all the applicable conditions and limitations of the Code Case N-606-1, and (c) The maximum allowable flaw size at the triple point is 0.1 inch long for the full circumference of the repair weld at the triple point.

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

5.0 REFERENCES

1. Nine Mile Point, Unit 1, Request to Utilize an Alternative to The Requirements of 10CFR50.55a(g) for Repair of Control Rod Drive Housing Penetrations for The Remainder of License Renewal Period of Extended Operation, March 4, 2011 (ADAMS Accession No. ML110680291)

2. Nine Mile Point, Unit 1 - Request to Utilize an Alternative to the Requirements of 10CFR 50.55a(g) for the Repair of Control Rod Drive Housing Penetrations for the Remainder of the License Renewal Period of Extended Operation, March 25, 2011 (ADAMS Accession No. ML110950307)

3. Nine Mile Point Nuclear Station Unit No. 1 - Request to Utilize an Alternative to the Requirements of 10 CFR 50.55a(g) for the Repair of Control Rod Drive Housing Penetrations - Response to NRC Request for Additional Information, September 29, 2011 (TAC No. ME5789). (ADAMS Accession No. ML11279A037)

4. Nine Mile Point, Unit 1 - Request to Utilize an Alternative to the Requirements of 10 CFR 50.55a(g) for the Repair of Control Rod Drive Housing Penetrations - Response to NRC Follow-up Request for Additional Information, April 9, 2012 (ADAMS Accession No. ML12102A112)

5. Nine Mile Point, Unit 1, Request to Utilize an Alternative to the Requirements of 10 CFR 50.55a(g) for the Repair of Control Rod Drive Housing Penetrations - Revised Affidavits Justifying Withholding Proprietary Information, May 22, 2012 (ADAMS Accession No. ML12152A173

6. Nine Mile Point, Unit 1, Request to Utilize an Alternative to the Requirements of 10 CFR 50.55a(g) for the Repair of Control Rod Drive Housing Penetrations - Withdrawal of the Portion of the Request Regarding Rotary Peening (TAC No. ME5789), June 7, 2012 (ADAMS Accession No. ML12160A349)

7. Nine Mile Point, Unit 1 - Request to Utilize an Alternative to the Requirements of 10 CFR 50.55a(g) for the Repair of Control Rod Drive Housing Penetrations - Response

to NRC Request for Additional Information, October 31, 2012 (ADAMS Accession No. ML12312A255)

8. Nine Mile Point Nuclear Station, Unit No. 1 - Request to Utilize Alternative of Applying ASME Code Case 730 for Repair and ISI of Control Rod Drive Bottom Head Penetrations for the License Renewal Period of Extended Operation (TAC No. MD9604), August 3, 2009 (ADAMS Accession No. ML091980454)

9. Nine Mile Point Nuclear Station, Unit No. 1, Request for Additional Information (RAI) Re: Request No. 1ISI-004, Request to Utilize an Alternative for the Repair of Control Rod Drive Housing Penetrations (TAC No. ME5789), September 13, 2012 (ADAMS Accession No. ML12250A806)

10. EPRI Report 1013558, "48-Hours Hold Requirement for Ambient Temperature Temperbead Welding Applications," December 2006 (ADAM Accession No. ML070670060)

11. PRA 05-08 Technical Basis Paper, "N-638-x, "Ambient Temperature Temperbead Welding: Begin 48 Hour Hold After 3rd Layer Completion" (ADAMS Accession No. ML070790679)

12. Calculation 32-9157438-000, "NMP-1 LAS SCC/SICC Evaluation, (Non –Proprietary) October 31, 2012 (ADAMS Accession No. ML12312A256)

13. Calculation 32-9138066-001, Revision 015, "NMP-1 CRD Housing IDTB Weld Anomaly Analysis," (Non-Proprietary Version) Attachment 3, March 17, 2011 (ADAMS Accession Number ML110950312)

14. Calculation 32-9138065-002, Revision 015, "NMP-1 CRD Housing IDTB Weld Anomaly Analysis," (Proprietary Version) Attachment 5, March 17, 2011 (ADAMS Accession Number ML110950319)

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Date: March 15, 2013

10 CFR 50.55a(a)(3)(i), and is in compliance with the ASME Code's requirements. Therefore, pursuant to 10 CFR 50.55a(a)(3)(i), the NRC staff authorizes NMPNS Relief Request 1ISI-004, Revision 1 for the repair of CRD housing penetrations at NMPNS. This relief request is authorized for use during the remaining term of the NMP1 renewed operating license, which expires on August 22, 2029. It should be noted that (a) the licensee must perform inservice inspection (ISI) on the repair area within 12 years of implementing the repair, as detailed in Section 3.5.3 of this SE, (b) the relief request is authorized for use with all the applicable conditions and limitations of the Code Case N-606-1, and (c) The maximum allowable flaw size at the triple point is 0.1 inch long for the full circumference of the repair weld at the triple point.

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

Please contact me at (301) 415-1711, or the Project Manager, Bhalchandra K. Vaidya at (301) 415-3308, if you have any questions.

Sincerely,

/ra/

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Docket Nos. 50-220

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