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

March 30, 2015

Mr. Randall K. Edington
Executive Vice President Nuclear/
Chief Nuclear Officer
Mail Station 7602
Arizona Public Service Company
P.O. Box 52034
Phoenix, AZ 85072-2034

SUBJECT: PALO VERDE NUCLEAR GENERATING STATION, UNIT 3 – REQUEST FOR APPROVAL OF AN ALTERNATIVE TO ASME CODE, SECTION XI REQUIREMENTS FOR FLAW REMOVAL, FLAW CHARACTERIZATION, AND SUCCESSIVE EXAMINATIONS (TAC NO. MF4169)

Dear Mr. Edington:

By letter dated May 16, 2014, as supplemented by letters dated May 16, 2014, and January 16, 20, and 29, 2015, Arizona Public Service Company (APS, the licensee) submitted a request to the U.S. Nuclear Regulatory Commission (NRC) for the use of an alternative to certain requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI requirements related to axial flaw indications identified in a reactor pressure vessel bottom-mounted instrument nozzle for Palo Verde Nuclear Generating Station (PVNGS), Unit 3.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, paragraph 50.55a(a)(3)(i), the licensee submitted Relief Request 52 to implement an alternative to the ASME Code, Section XI requirements of IWA-4421 for flaw removal, IWA-3300 for flaw characterization, and IWB-2420 for successive examinations on the basis that the alternative provides an acceptable level of quality and safety. As an alternative, the licensee proposed a half-nozzle repair and a flaw evaluation. By letter dated April 10, 2014, NRC staff approved Relief Request 51 for a similar alternative to the ASME Code, Section XI requirements for flaw removal and flaw characterization and its duration was through operating cycle 18. The duration of Relief Request 52 is for the remainder of the third 10-year inservice inspection (ISI) interval, which expires on January 10, 2018.

The paragraph headings in 10 CFR 50.55a were changed by *Federal Register* notice dated November 5, 2014 (79 FR 65776), which became effective on December 5, 2014 (e.g., 10 CFR 50.55a(a)(3)(i) is now 50.55a(z)(1), and 50.55a(a)(3)(ii) is now 50.55a(z)(2)) and have been adjusted accordingly.

The NRC staff has reviewed the subject request for PVNGS, Unit 3 and determined, as set forth in the enclosed safety evaluation, that the proposed alternative 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(z)(1), and is in compliance with the ASME Code requirements. Therefore, the NRC staff authorizes the use of the half-nozzle repair and the use of the flaw evaluation as an alternative for the remainder of the third 10-year ISI interval for PVNGS, Unit 3, which expires on January 10, 2018.

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

If you have any questions, please contact Balwant Singal at (301) 415-3016 or via e-mail at Balwant.Singal@nrc.gov.

Sincerely,

E. R. Oesterle for M. Markley

Michael T. Markley, Chief
Plant Licensing Branch IV-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. STN 50-530

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 52 REGARDING ALTERNATIVE TO FLAW REMOVAL,

FLAW CHARACTERIZATION AND SUCCESSIVE EXAMINATIONS OF THE FLAW IN

BOTTOM-MOUNTED INSTRUMENT NOZZLE J-GROOVE WELD

ARIZONA PUBLIC SERVICE COMPANY

PALO VERDE NUCLEAR GENERATING STATION, UNIT 3

DOCKET NO. STN 50-530

1.0 INTRODUCTION

By letter dated May 16, 2014[1] (Agencywide Documents Access and Management System (ADAMS) Package Accession No. ML14149A349), as supplemented by letters dated May 16, 2014, and January 16, 20, and 29, 2015 (ADAMS Accession Nos. ML14141A545, ML15023A047, ML15023A039, and ML15037A048, respectively), Arizona Public Service Company (APS, the licensee) submitted a request to the U.S. Nuclear Regulatory Commission (NRC) for the use of an alternative to certain requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI requirements related to axial flaw indications identified in a reactor pressure vessel (RPV) bottom-mounted instrument (BMI) nozzle for Palo Verde Nuclear Generating Station (PVNGS), Unit 3. Portions of the supplemental letters dated May 16, 2014, and January 16, 2015, contain sensitive unclassified non-safeguards information and accordingly, have been withheld from public disclosure.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, paragraph 50.55a(a)(3)(i), the licensee submitted Relief Request 52 to implement an alternative to the ASME Code, Section XI requirements of IWA-4421 for flaw removal, IWA-3300 for flaw characterization, and IWB-2420 for successive examinations on the basis that the alternative provides an acceptable level of quality and safety. As an alternative, the licensee proposed a half-nozzle repair and a flaw evaluation to support continued operation of the unit until the end of the third 10-year inservice inspection (ISI) interval. By letter dated April 10, 2014, NRC staff approved Relief Request 51 for a similar alternative to the ASME Code, Section XI requirements for flaw removal and flaw characterization (ADAMS Accession No. ML14093A407), and its duration was through operating cycle 18. In addition, Relief Request 51 did not address the successive examination requirements of IWB-2420. The duration of Relief Request 52 is for the remainder of the third 10-year ISI interval, which expires on January 10, 2018.

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[1] Designated as letter dated May 16, 2014 (A).

Enclosure

The paragraph headings in 10 CFR 50.55a were changed by *Federal Register* notice dated November 5, 2014 (79 FR 65776), which became effective on December 5, 2014 (e.g., 10 CFR 50.55a(a)(3)(i) is now 50.55a(z)(1), and 50.55a(a)(3)(ii) is now 50.55a(z)(2)) and have been adjusted accordingly.

2.0 REGULATORY EVALUATION

Inservice inspection of the ASME Code Class 1, 2, and 3 components is performed in accordance with Section XI of the ASME Code and applicable addenda as a way to detect anomaly and degradation indications so that structural integrity of these components can be maintained. This is required by 10 CFR 50.55a(g), except where specific relief has been granted by the Commission pursuant to 10 CFR 50.55a(g)(6)(i). The regulations at 10 CFR 50.55a(z) state that alternatives to the requirements of paragraphs (b) through (h) of 10 CFR 50.55a or portions thereof may be used, when authorized by the Director, Office of Nuclear Reactor Regulation. A proposed alternative must be submitted and authorized prior to implementation. The applicant or licensee must demonstrate that: (1) the proposed alternative would provide an acceptable level of quality and safety; or (2) compliance with the specified requirements of this section would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

The regulations at 10 CFR 50.55a(g)(4) state, in part, that the "components (including supports) that are classified as ASME Code Class 1, Class 2, and Class 3 must meet the requirements, except design and access provisions and preservice examination requirements, set forth in Section XI of editions and addenda of the ASME BPV Code [ASME Code]..., that become effective subsequent to editions specified in paragraphs (g)(2) and (3) of this section... 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 successive 120-month inspection interval (following the initial 120-month inspection interval) must comply with the requirements in the latest edition and addenda of the ASME Code, which was incorporated by reference in 10 CFR 50.55a(a), 12 months before the start of the 120-month interval (or the optional ASME Code Cases listed in NRC Regulatory Guide (RG) 1.147, Revision 17," Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1," October 2014 (ADAMS Accession No. ML13339A689), subject to the conditions listed in 50.55a(b).

The ASME Code of record for PVNGS, Unit 3 for the third 10-year interval ISI program is the 2001 Edition of the ASME Code, Section XI, with 2003 Addenda.

3.0 TECHNICAL EVALUATION

The information including the technical bases provided by APS in support of the request for relief from ASME Code, Section XI requirements is documented below. This relief request is pursuant to "acceptable level of quality and safety" as permitted by 10 CFR 50.55a(z)(1).

3.1 ASME Code Component Affected

The affected component is RPV BMI Nozzle Penetration Number 3 (BMI nozzle 3), which is an ASME Code Class 1, Examination Category B-P, Item B15.80 component.

3.2 ASME Code Requirements (as stated by the licensee)

By letter dated May 16, 2014 (A), the licensee identified the following ASME Code requirements:

> Section XI, Article IWA-4000 provides requirements for repair/replacement activities.
>
> > IWA-4421 states, in part:
> >
> > > Defects shall be removed or mitigated in accordance with the following requirements...
> >
> > IWA-4422.1(a) states, in part:
> >
> > > A defect is considered removed when it has been reduced to an acceptable size...
> >
> > IWA-4422.1(b) states, in part:
> >
> > > Alternatively, the defect removal area and any remaining portion of the defect may be evaluated and the component accepted in accordance with the appropriate flaw evaluation provisions of Section XI...
>
> Section XI, Article IWA-3000 provides standards for examination evaluation.
>
> > IWA-3100(a) states, in part:
> >
> > > Evaluation shall be made of flaws detected during an inservice examination as required by IWB-3000 for Class 1 pressure retaining components...
> >
> > IWA-3300(b) states, in part:
> >
> > > Flaws shall be characterized in accordance with IWA-3310 through IWA-3390, as applicable.

Section XI, Article IWB-3000 provides acceptance standards for Class 1 components.

IWB-3420 states:

> Each detected flaw or group of flaws shall be characterized by the rules of IWA-3300 to establish the dimensions of the flaws. These dimensions shall be used in conjunction with the acceptance standards of IWB-3500.

Section XI, Article IWB-2000 provides examination and inspection requirements for Class 1 components.

IWB-2420(b) states, in part:

> If a component is accepted for continued service in accordance with IWB-3132.3 or IWB-3142.4, the areas containing flaws or relevant conditions shall be reexamined during the next three inspection periods listed in the schedule of the inspection program of IWB-2400...

3.3 Licensee's Proposed Alternative and Bases (as stated by the licensee):

By letter dated May 16, 2014 (A), APS proposed the following alternative for BMI Nozzle Penetration No. 3 and provided a basis for its request:

1. A completed half nozzle repair at BMI nozzle 3 using PWSCC [primary water stress-corrosion cracking] resistant material relocated the pressure boundary weld from inside to outside the reactor vessel. The half-nozzle repair of BMI nozzle 3 will not remove the flaws in the original J-groove weld or Alloy 600 nozzle material near this weld. Crack propagation into the vessel wall can be addressed by analysis since low alloy base material is not susceptible to PWSCC, and effectively arrests as a propagation mechanism at the interface of the low alloy base material and the J-groove weld. The repair is described in Relief Request 51. (Reference 3 [of the letter dated May 16, 2014 (A)]). [Related to IWA-4421 regarding flaw removal.]

2. Since current NDE [non-destructive examination] procedures are not capable of sizing the extent of crack growth into the PWSCC susceptible weld material, the flaw evaluation postulated a maximum bounding flaw that extends through the J-groove weld and buttering. The analysis calculated further propagation of the flaw into the [RPV] low alloy base material to a depth conservative with respect to the remaining [PVNGS,] Unit 3 licensed operating life. [Related to IWA-3300 regarding flaw characterization.]

> ASME Code Section XI flaw evaluations (Attachment 1 [of the Enclosure to the letter dated May 16, 2014 (A)]) were performed to qualify the reactor vessel bottom head for the effects of the remnant J-groove weld flaw for the remaining life of the plant (until the expiration of the current operating license in 2047). Due to the unique profile of the J-groove partial penetration weld, explicit three-dimensional finite element crack models were developed to accurately characterize crack tip stress intensity factors for evaluating postulated flaws at the uphill and downhill sides of the weld. Flaw growth analysis, linear elastic, and elastic plastic fracture mechanics evaluations were performed to demonstrate that there is sufficient fracture toughness or ductile tearing resistance available for the [RPV] to qualify the final flaw sizes for the remaining life of the plant. [Related to IWB-2420 regarding successive examinations.]

3.4 Duration of the Proposed Alternative

As stated by letter dated January 20, 2015, in the licensee's response to Request for Additional Information (RAI) Question 1 (RAI-1), the duration of the request is to the end of the PVNGS, Unit 3 third inservice interval, which ends on January 10, 2018.

3.5 NRC Staff Evaluation

3.5.1 Evaluation of the Remnant Flaw in the BMI J-groove Weld

In Attachment 1 to the Enclosure of the letter dated May 16, 2014 (A), "ASME Section XI End of Life Analysis of PVNGS[,] Unit 3 [RPV] BMI Nozzle Repair" (ADAMS Accession No. ML14149A333), the licensee documented a flaw evaluation considering fatigue crack growth to the end of the PVNGS, Unit 3 operating license. Similarly to the approved Relief Request 51 for one operating cycle, the licensee used a fracture mechanics analysis to demonstrate the structural integrity of the RPV with the repaired BMI nozzle to the end of the license. The general approach of the fracture mechanics analysis in Attachment 1 is the same as that in the approved Relief Request 51. For instance, the assumed initial flaw size, the material properties, and the evaluation criteria remain unchanged. However, certain elements of the analysis are modified using more detailed 3-dimensional, nozzle-specific finite element (FE) methodology solutions for the stress intensity factors (K) (applied K_1 in the crack growth and the linear elastic fracture mechanics (LEFM) mode of the fracture mechanics analysis). The fatigue crack growth analysis has also been improved using plant-specific design transients and cycles. Hence, the NRC staff's review of Attachment 1 focused on these areas that had not been reviewed in the effort related to Relief Request 51.

Attachment 1, Section 2.1, "Stress Intensity Factor Solution," proposed an extrapolation rule for estimation of the K_1 associated with a flaw size larger than the largest flaw in the FE model of the PVNGS, Unit 3 bottom head and BMI nozzle. Since extrapolation could be a source of potential error in applied K_1 calculations, the licensee was requested to discuss the extent of using this extrapolation rule to demonstrate that the calculated crack growth, based on the ΔK_1 values, are still valid in RAI-3 issued by NRC letter dated December 4, 2014 (ADAMS Accession No. ML14330A510). By letter dated January 20, 2015, the licensee's response to

RAI-3 indicated that for this application, the extrapolation procedure was not needed and therefore not utilized to obtain the K_1 values.

Attachment 1, Section 2.4.1, "Screening Criteria," mentioned use of the failure mode criteria for LEFM, elastic plastic fracture mechanics (EPFM), and limit load analysis in the ASME Code, Section XI, Appendix C, "Evaluation of Flaws in Piping," in the current RPV application. Since applying the failure mode criteria for piping to RPV does not appear to be justified, in RAI-4 issued by letter dated December 4, 2014, the NRC staff requested that the licensee revise the fracture mechanics analysis using the criteria in ASME Code Case N-749, "Alternative Acceptance Criteria for Flaws in Ferritic Steel Components Operating in Upper Shelf Temperature Range," with the NRC staff's modification. The licensee performed additional analyses using ASME Code Case N-749 with the NRC staff's modification. The licensee's response indicated that reexamination of all loading cases confirmed that the EPFM analyses performed are still valid except for the case of heatup and cooldown transients where LEFM should be used in accordance with ASME Code Case N-749 with the NRC staff's modification. As a result, the licensee performed additional LEFM analyses for heatup and cooldown, and the results show that the ASME Code acceptance criterion (margins) for LEFM is satisfied.

Attachment 1, Section 4.4.2, "Applied Stresses," discusses residual stresses. By letter dated December 4, 2014, RAI-5 requested the licensee to discuss the difference in the residual stresses of Relief Requests 51 and 52 and explain the significant change of residual stress patterns along the path away from the J-groove weld. The licensee's response in its letter dated January 20, 2015, indicated that the new FE model in Relief Request 52 reflects (1) the specific geometry of BMI nozzle 3, (2) separation of residual stresses from operating stresses to maximize the flexibility of the new model, and (3) a detailed 3-dimensional FE model which would results in stress distribution over the entire crack face for subsequent applied K_1 calculations. The NRC staff determined that all these three areas would contribute to a better simulation of the real nozzle assembly. For the significant change of residual stress patterns along the path away from the J-groove weld, the licensee provided additional FE plots, showing that the "unique" stress patterns at some distance from the J-groove weld are caused by compressive stresses. This addressed the NRC staff's concern of possible modeling error, causing unexpected stress distribution in the bottom head.

On the material side, the licensee continued to use the lower bound J integral-resistance (J-R) curve from RG 1.161, "Evaluation of Reactor Pressure Vessels with Charpy Upper-Shelf Energy Less Than 50 Ft-Lb [Foot-Pound]," dated June 1995 (ADAMS Accession No. ML003740038), that was used in Relief Request 51 and is, therefore, acceptable.

Based on the above, the NRC staff determined that the licensee has demonstrated that the PVNGS, Unit 3 BMI nozzle 3 repair with an assumed through-weld crack in the J-groove weld will meet the ASME Code, Section XI acceptance criterion regarding LEFM and the NRC established acceptance criterion for EPFM for the remaining life of the nozzle. Consequently, the NRC staff concludes that Attachment 1 results provide adequate basis supporting relief from IWA-4421, IWA-3300, and IWB-2420.

3.5.2 Evaluation of the BMI Nozzle Repair Corrosion Analysis

In Attachment 2 of the Enclosure to the letter dated May 16, 2014 (A), "Corrosion Evaluation for [PVNGS,] Unit 3 Reactor Vessel BMI Nozzle Modification" (ADAMS Accession No. ML14149A342), the licensee documented the corrosion analysis for the repair configuration. As stated in the licensee's response to RAI-2 in letter dated January 20, 2015, the corrosion evaluation for Relief Request 51 was performed for the remainder of PVNGS, Unit 3 licensed operating life and is the same document provided as Attachment 2 in Relief Request 52. However, since the corrosion analysis is based on four assumptions which require plant-specific verification, RAI-6 issued by letter dated December 4, 2014 requested the licensee to describe how it would verify that these assumptions would continue to be valid for the remainder of plant life. The first two assumptions are related to plant operating conditions in terms of percentage of time at shutdown and start-up conditions; and the third and fourth assumptions are related to plant chemistry controls. The licensee's response by letter dated January 20, 2015, indicated that the percentage of time at both shutdown and start-up conditions is tracked by Engineering Study 13-MS-B041, "Alloy Steel Corrosion Analysis Supporting Alloy 600/690 Nozzle Repair/Replacement," which is already in place for half-nozzle repairs to other primary system components. The PVNGS Chemistry Program maintains the reactor coolant chemistry per the Electric Power Research Institute Pressurized Water Chemistry Guidelines and PVNGS Technical Requirements Manual to ensure that third and fourth assumptions of the corrosion evaluation for PVNGS, Unit 3 are satisfied. Since the licensee has programs to track and verify the assumptions used in the corrosion analysis, the NRC staff's concerns have been addressed. As stated earlier, the current corrosion analysis is identical to the one approved in Relief Request 51. Therefore, after plant-specific verification of the assumptions has been confirmed for the licensed operating life, the NRC staff determined that Attachment 2 continues to be acceptable for this relief request, and the identified corrosion and its rate can be used in the ASME Code, Section III stress analysis discussed in Section 3.5.4.

3.5.3 Evaluation of the BMI Nozzle Repair Weld Residual Stress Analysis

In Attachment 3 of the Enclosure to the letter dated May 16, 2014 (A), "Weld Residual Stress Analysis for PVNGS[,] Unit 3 [RPV] BMI Nozzle Repair" (ADAMS Accession No. ML14149A402), the licensee documented the weld residual stress (WRS) analysis to determine the stress fields due to the J-groove welding process of the original BMI nozzle to the inside surface of the RPV bottom head, and due to the removal of the boat sample in the J-groove weld. In the WRS analysis, the licensee has utilized an acceptable WRS methodology based on 3-dimensional FE methodology and has made FE modeling simplifications that are acceptable for the analysis. For instance, an important simplification is that the 3-dimensional FE model includes a half-symmetric model of the repaired PVNGS, Unit 3 BMI nozzle and a "pie-slice" portion of the RPV bottom head, with properly applied symmetry boundary conditions. This FE modeling technique is consistent with accepted FE modeling practice. Another important simplification is that actual weld beads are simulated in the 3-dimensional FE model by combining several beads together, which is consistent with acceptable practice in FE simulation of welding passes.

The licensee utilized temperature-dependent mechanical properties and stress-strain curves to properly simulate the heating and cooling of deposited weld passes and to simulate the elastic-plastic stress reversals during the welding process. The licensee utilized welding parameters applicable to the PVNGS, Unit 3 BMI nozzle to simulate the weld heat generation that was applied to the 3-dimensional FE model. The welding sequence includes the deposition of the weld buttering on the RPV bottom head, post-weld heat treatment, deposition of the J-groove weld passes, and hypothetical J-groove weld repair passes. This sequence is followed by hydrostatic and normal operating cycles consistent with recommended practice. Finally, the removal of the boat sample in the J-groove weld is simulated.

The NRC staff reviewed the resulting stresses in Figure 6-1, "Residual Hoop Stress (psi) at Cold Shutdown," and Figure 6-2, "Residual Axial Stress (psi) at Cold Shutdown," and has determined that the stresses are reasonable considering the stress distribution from similar FE modeling of the welding passes in MRP-216, Revision 1, "Advanced FEA Evaluation of Growth of Postulated Circumferential PWSCC Flaws in Pressurizer Nozzle Dissimilar Metal Welds," (ADAMS Accession No. ML072410240).

By letter dated December 4, 2014, the NRC staff issued RAI-7, RAI-8, and RAI-9 related to the effects from nearby BMI nozzles, clarification of material properties, and simulation of post-weld heat treatment conditions. By letter dated January 20, 2015, the licensee provided adequate information to address the NRC staff's concerns.

Since the licensee has utilized a WRS analytical methodology consistent with accepted practice, modeling assumptions and simplifications are reasonable and justified, and the licensee has addressed the NRC staff concerns in response to RAI-7, RAI-8, and RAI-9, the NRC staff has determined that, consistent with the stated purpose of the WRS analysis in Attachment 3, the resulting stress fields in Attachment 3 are acceptable for use in the fracture mechanics analysis of the bottom head discussed in Section 3.5.1 of this safety evaluation.

3.5.4 Evaluation of the BMI Nozzle Repair ASME Code, Section III Analysis

In Attachment 4 of the Enclosure to the letter dated May 16, 2014 (A), "ASME Section III End of Life Analysis of PVNGS[, Unit 3 RPV] BMI Nozzle Repair" (ADAMS Accession No. ML14149A403), the licensee documented the qualification of the PVNGS, Unit 3 BMI nozzle repair to the requirements of the ASME Code, Section III, Subsection NB, Class 1 components. The Edition of the ASME Code used is the 1998 Edition, through 2000 Addenda, which is different than the ASME Code of record for PVNGS, Unit 3. The licensee has performed a Code Reconciliation and has met the Code applicability and reconciliation requirements of ASME Code, Section XI, IWA-4220.

The ASME Code, Section III analysis is focused on the weld repair of the PVNGS, Unit 3 BMI nozzle on the outside diameter (OD) surface of the RPV bottom head because the OD surface weld repair is now the new pressure boundary. As such, stresses for ASME Code, Section III analysis were extracted from the region of the OD surface weld repair and not from the region of the original BMI nozzle J-groove weld. The NRC staff agrees with this approach because only the ASME Code, Section XI analysis is required for region of the original BMI nozzle J-groove weld,

The licensee has determined stresses for the ASME Code, Section III analysis utilizing a 3-dimensional FE linear-elastic model and has made FE modeling simplifications that are acceptable for the analysis. These simplifications were discussed and accepted in Section

3.5.3 related to WRS and are acceptable for the ASME Code, Section III Analysis. The licensee considered the effects of corrosion in the RPV bottom head bore that is exposed to the reactor coolant and the NRC staff agrees that the potential impact on the ASME Code, Section III analysis would be negligible. Further, temperature-dependent mechanical properties were utilized to properly simulate the temperature gradients during operational transients.

For one of the loading conditions, the licensee has applied the operational transients applicable to the PVNGS, Unit 3 BMI nozzle, which include temperature and pressure time histories. The licensee has applied the temperature conditions at the reactor coolant inlet nozzle as input to the thermal analysis of the PVNGS, Unit 3 BMI nozzle. In the NRC staff's letter dated December 4, 2014, RAI-13 requested the licensee to explain why the temperature conditions at the reactor coolant inlet nozzle are applicable to the location of the PVNGS, Unit 3 BMI nozzle. In its response dated January 20, 2015, the licensee stated that since the fluid flows down the core support barrel annulus at a rapid rate, there is limited heat transfer from the core to the bulk fluid. The NRC staff determined the response to be acceptable.

For external loading conditions, the licensee considered the external loads on the repair nozzle and remnant nozzle. The results from the repair nozzle were included in the ASME Code, Section III analysis of the PVNGS, Unit 3 BMI nozzle, and the results from the remnant nozzle were used in an ASME Code, Section XI flaw evaluation of the original J-groove weld, which is evaluated in Section 3.5.1 of this safety evaluation. The licensee used bounding values for the repair nozzle external loads. Since these external loads are defined at the juncture of the repair nozzle and the outside surface of the RPV bottom head, in RAI-11 from letter dated December 4, 2014, the NRC staff requested that the licensee address whether the appropriate moment arm has been applied to modify the external loads due to bending moment. The licensee responded that the external loads decrease as one travels farther down the repair nozzle. Therefore, the external loads defined at the juncture of the repair nozzle and the outside surface of the RPV bottom head were determined to be conservative.

The 3-dimensional FE analysis consists of a thermal analysis followed by the structural (stress) analysis. For thermal analysis, the licensee has applied the appropriate thermal boundary conditions on the appropriate surfaces of the 3-dimensional FE model. The licensee-selected time points in the thermal analysis based on maximum/minimum thermal gradients that are expected to produce the maximum range of thermal stresses. To examine this selection basis, RAI-14 issued by letter dated December 4, 2014, requested the licensee to explain how the methodology used in selecting time points from the thermal analysis (explained in Attachment 4, Section 6.2, "Thermal Analysis") captures the maximum thermal stress range. The licensee explained that critical locations, where maximum and minimum thermal gradients would be expected, were selected, and that refined time increments were applied near peaks and valleys in the temperature time history of each transient. The NRC staff determined this approach to be reasonable in capturing maximum and minimum thermal stress states.

For the subsequent structural (stress) analysis, the licensee used the time points from thermal analysis to determine stresses due to the thermal gradients imposed on the 3-dimensional FE model during the thermal transients. These stresses are used in the primary plus secondary stress intensity range limit checks and in the fatigue usage calculations defined in ASME Code, Section III, NB-3220.

The licensee considered the loading due to internal pressure and external loads for the primary stress intensity limit checks of the ASME Code, Section III, NB-3220. In response to RAI-10 dated December 4, 2014, the licensee confirmed that only primary stresses were included in the Design Condition stress limits. The NRC staff determined the response to be acceptable.

The licensee computed the cumulative fatigue usage factor (CFUF) consistent with the procedures in ASME Code, Section III, NB-3222.4, considering the 60-year design cycles for each transient. The licensee utilized the appropriate fatigue curves of Appendix I, "Design Fatigue Curves," of ASME Code, Section III. The NRC staff noted that one path in the RPV bottom head did not have the highest primary plus secondary stress intensity range, but had the highest CFUF. In RAI-16 issued by letter dated December 4, 2014, the NRC staff requested clarification and in its response dated January 20, 2015, the licensee stated that because of the conservative methodology of applying a fatigue strength reduction factor to compute CFUF, the CFUF in one or both of the nodes that comprises the path could be highest even though the primary plus secondary stress intensity range is not highest for that same node. The NRC staff determined the response to be acceptable.

By letter dated December 4, 2014, RAI-17 requested the licensee to confirm whether the PVNGS, Unit 3 BMI nozzle repair met the "Thermal Stress Ratchet" limit requirements of ASME Code, Section III, NB-3222.5. In its response, the licensee stated that in general, since the primary plus secondary stress intensity ranges are less than twice the yield stress, the thermal stress ratchet check of ASME Code, Section III, NB-3222.5 is not needed. The NRC staff determined the response to be acceptable.

Since the applicable stress range criteria and fatigue usage criteria of ASME Code, Section III have been met, and since all the NRC staff concerns regarding the ASME Code, Section III analysis in Attachment 4 have been resolved, the NRC staff has determined that the operating stresses generated in the ASME Code, Section III analysis of Attachment 4 can be used in the fracture mechanics analyses discussed in Section 3.5.1 of this safety evaluation.

3.5.5 Evaluation of the BMI Nozzle Repair Crack Growth Analysis

In Attachment 5 of the Enclosure to letter dated May 16, 2014 (A), "[PVNGS,] Unit 3 – BMI Nozzle Crack Growth Analysis," (ADAMS Accession No. ML14149A404), the licensee documented a crack growth analysis, due to PWSCC and fatigue, to demonstrate that radial axial flaws in the BMI nozzle will not grow to both ends of the nozzle at the end of the licensed operating life. For the crack growth rates due to both mechanisms, the licensee used the crack growth rates due to both mechanisms in ASME Code Case N-694-1, "Evaluation of Flaws in PWR Reactor Vessel Head Penetration Nozzles," which are identical to ASME Code, Section XI, Appendix O, "Evaluation of Flaws in PWR Reactor Vessel Head Penetration Nozzles." For the K_1 value in the crack growth rate equation, the licensee used the K solutions in API 579-1/ASME FFS-1 2007, "Fitness-For Service." Both approaches follow standard industry practice accepted by the NRC. Further, in the response to RAI-18 by letter dated December 4, 2014, the licensee attributed the apparent inconsistency between local stresses along the nozzle and the stresses in Table 5-3, "Crack Growth Calculation for Single Edge Notched Plate," of Attachment 5 to stress averaging permitted in the K_1 calculation, and thus resolved NRC staff concern. In summary, since crack growth calculations using plant-specific geometric, operating, and material information indicated that at the end of the PVNGS, Unit 3 licensed operating life the existing crack in the BMI nozzle will not grow to the top of the remnant nozzle and generate loose parts, the NRC staff determined the results of analysis in Attachment 5 to be acceptable. Although Attachment 5 is not required to support Relief Request 52, the licensee is prudent to demonstrate that loose part generation is not likely to occur for this repaired nozzle before the end of the licensed operating life of PVNGS, Unit 3.

3.5.6 Evaluation of the BMI Nozzle Repair Dynamic Analysis

In Attachment 6 of the Enclosure to the letter dated May 16, 2014 (A), "Natural Frequency and Structural Integrity Analysis for PVNGS[,] Unit 3 [RPV] BMI Nozzle Repair" (ADAMS Accession No. ML14149A407), the licensee documented the dynamic analysis for the repair configuration to demonstrate that there is no potential excitation of the nozzle due to the vortex shedding. By letter dated December 4, 2014, in RAI-19 the NRC requested the licensee to provide justification for simulating the crack in the dynamic model by removing certain FE elements. The NRC staff was concerned that this could bring the fundamental frequency of the remnant nozzle closer to the exciting frequencies. In its response by letter dated January 20, 2015, the licensee indicated that even if the natural frequency does approach the pump blade frequency, the cracked configuration is acceptable based on the highly conservative analysis, which considered load at resonance with minimum cross-section. The staff determined the response to be acceptable because loads at resonance were already used in the existing analysis. Since the NRC staff's concerns have been addressed and the structural integrity analysis results considering pump and white noise excitations show acceptable margin, the NRC staff determined the results of the analysis in Attachment 6 to be acceptable. Similar to Attachment 5, Attachment 6 is not required to support Relief Request 52. The licensee is prudent to demonstrate that the repaired nozzle is not likely to have dynamic failure before the end of the licensed operating life of PVNGS, Unit 3.

4.0 CONCLUSION

The NRC staff concludes that the half-nozzle repair and the use of the flaw evaluation as an alternative to the ASME Code, Section XI requirement for flaw removal, flaw characterization, and successive examinations is acceptable for the remaining third 10-year ISI interval. This conclusion is based on (1) the flaw evaluation is consistent with the approved methodology for RPV penetrations, and (2) the LEFM and EPFM results support operation to the end of the licensed operating life with the flaw in the J-groove weld of the subject BMI penetration. Therefore, the proposed alternative provides an acceptable level of quality and safety, and the alternative is authorized pursuant to 10 CFR 50.55a(z)(1) for the remainder of the third 10-year ISI interval for PVNGS, Unit 3, which expires on January 10, 2018.

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

Principal Contributors: Simon Sheng, NRR/DE/EVIB
David Dijamco, NRR/DE/EVIB

Date: March 30, 2015

the half-nozzle repair and the use of the flaw evaluation as an alternative for the remainder of the third 10-year ISI interval for PVNGS, Unit 3, which expires on January 10, 2018.

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

If you have any questions, please contact Balwant Singal at (301) 415-3016 or via e-mail at Balwant.Singal@nrc.gov.

Sincerely,

/RA Eric R Oesterle for/

Michael T. Markley, Chief
Plant Licensing Branch IV-1
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. STN 50-530

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Safety Evaluation

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