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

May 1, 2017

Mr. Adam C. Heflin
President, Chief Executive Officer,
and Chief Nuclear Officer
Wolf Creek Nuclear Operating Corporation
P.O. Box 411
Burlington, KS 66839

SUBJECT: WOLF CREEK GENERATING STATION – RELIEF FROM CERTAIN AMERICAN SOCIETY OF MECHANICAL ENGINEERS BOILER AND PRESSURE VESSEL CODE INSERVICE INSPECTION REQUIREMENTS FOR REACTOR VESSEL CLOSURE HEAD PENETRATION NOZZLES DURING REFUELING OUTAGE 21 AND THE FOURTH 10-YEAR INSERVICE INSPECTION INTERVAL (CAC NO. MF8456)

Dear Mr. Heflin:

By application dated October 11, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16293A582), as supplemented by letters dated October 14, October 20, November 1, and November 4, 2016 (ADAMS Accession No. ML16293A581, ML16300A214, 16313A081, and ML16319A371, respectively), the Wolf Creek Nuclear Operating Corporation (the licensee) requested relief from the requirements of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, Code Case N-729-1, "Alternative Examination Requirements for PWR [Pressurized-Water Reactor] Reactor Vessel Upper Heads with Nozzles Having Pressure-Retaining Partial-Penetration Welds Section XI, Division 1." Relief Request (RR) I4R-03 is for the alternative examination of all 78 penetration nozzles due to boric acid accumulation from the canopy seal weld leak on penetration 77 covering a portion of the reactor vessel closure head (RVCH). RR I4R-04 is for the alternative examination of penetration nozzles 77 and 78 since full examination volume required by ASME Code Case N-729-1 cannot be achieved due to physical configuration of the nozzles at the Wolf Creek Generating Station (WCGS).

Pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) paragraph 50.55a(z)(2), the licensee requested relief from the required examination coverage and to use alternative requirements for inservice inspection (ISI) of the penetration welds on the basis that compliance with the ASME Code, Section XI, requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the subject requests and concludes, as set forth in the enclosed safety evaluation, that the proposed alternatives in RRs I4R-03 and I4R-04 provide reasonable assurance of structural integrity of the RVCH and control rod drive mechanism penetration nozzles such that complying with the ASME Code, Section XI requirements would result in hardship or unusual difficulty without a compensating increase in the 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)(2) and 10 CFR 50.55a(g)(6)(ii)(D). Therefore, the NRC staff authorizes the use of RR I4R-03 during Refueling Outage 21 subject to the condition that if an unacceptable indication by the leak path assessment or volumetric examination is identified, the licensee will revert to the requirements of ASME Code Case N-729-1 and 10 CFR 50.55a(g)(6)(ii)(D). The NRC staff also authorizes the use of RR I4R-04 for the remainder of the fourth 10-year ISI interval, which began on September 3, 2015, and ends on September 2, 2025, at the WCGS.

The subject RRs were verbally approved by the NRC staff on November 7, 2016 (ADAMS Accession No. ML16313A483).

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

If you have any questions concerning this matter, please contact Mr. Balwant K. Singal of my staff at (301) 415-3016 or by e-mail at Balwant.Singal@nrc.gov.

Sincerely,

Robert J. Pascarelli, Chief
Plant Licensing Branch IV
Division of Operating Reactor Licensing
Office of Nuclear Reactor Regulation

Docket No. 50-482

Enclosure
Safety Evaluation

cc w/encl: Distribution via Listserv

SUBJECT: WOLF CREEK GENERATING STATION – RELIEF FROM CERTAIN AMERICAN SOCIETY OF MECHANICAL ENGINEERS BOILER AND PRESSURE VESSEL CODE INSERVICE INSPECTION REQUIREMENTS FOR REACTOR VESSEL CLOSURE HEAD PENETRATION NOZZLES DURING REFUELING OUTAGE 21 AND THE FOURTH 10-YEAR INSERVICE INSPECTION INTERVAL (CAC NO. MF8456) DATED MAY 1, 2017

DISTRIBUTION:
PUBLIC
LPL4 r/f
RidsACRS_MailCTR Resource
RidsNrrDeEpnb Resource
RidsNrrDorlLpl4 Resource
RidsNrrLAPBlechman Resource
RidsNrrPMWolfCreek Resource
RidsRgn4MailCenter Resource
JTsao, NRR/DE/EPNB
JCollins, NRR/DE/EPNB
JBowen, EDO RIV

ADAMS Accession No.: ML17110A302 ***Memo dated December 27, 2016 and April 3, 2017**

OFFICE	NRR/DORL/LPL4/PM	NRR/DORL/LPL4/LA	NRR/DRA/APLA/BC	NRR/DORL/LPL4/BC
NAME	BSingal	PBlechman	DAlley*	RPascarelli
DATE	04/27/17	04/27/17	04/03/17	05/01/17

OFFICIAL RECORD COPY

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

REACTOR VESSEL CLOSURE HEAD INSPECTIONS – REFUELING OUTAGE 21

AND FOURTH 10-YEAR INTERVAL INSERVICE INSPECTION

RELIEF REQUESTS I4R-03 AND I4R-04

WOLF CREEK NUCLEAR OPERATING CORPORATION

WOLF CREEK GENERATING STATION

DOCKET NO. 50-482

1.0 INTRODUCTION

By letter dated October 11, 2016 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML16293A582), as supplemented by letters dated October 14, October 20, November 1, 2016, and November 4, 2016 (ADAMS Accession Nos. ML16293A581, ML16300A214, ML16313A081 and ML16319A371, respectively), the Wolf Creek Nuclear Operating Corporation (the licensee) requested relief from surface examination requirements of paragraph -3200(b) of the American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, Code Case N-729-1, "Alternative Examination Requirements for PWR [Pressurized-Water Reactor] Reactor Vessel Upper Heads with Nozzles Having Pressure-Retaining Partial-Penetration Welds Section XI, Division 1," as conditioned in Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.55a, for the examination of control rod drive mechanism (CRDM) penetration nozzles on the reactor vessel closure head (RVCH) at the Wolf Creek Generating Station (WCGS).

Pursuant to 10 CFR 50.55a(z)(2), the licensee submitted Relief Requests (RRs) I4R-03 and I4R-04 on the bases that compliance with the specified ASME Code requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. RR I4R-03 is for the alternate examination of all 78 CRDM penetration nozzles and RR I4R-04 is for the alternate examination of CRDM penetration nozzle numbers 77 and 78 at the WCGS.

On November 7, 2016 (ADAMS Accession No. ML16313A483), the U.S. Nuclear Regulatory Commission (NRC) staff verbally authorized the use of RR I4R-03 for the fall 2016 Refueling Outage 21 (RF21) subject to the licensee's proposed alternative that if an unacceptable indication by the leak path assessment or volumetric examination is identified, the licensee will revert to the requirements of ASME Code Case N-729-1 and 10 CFR 50.55a(g)(6)(ii)(D). The NRC staff also verbally authorized the use of RRs I4R-04 for the remainder of the fourth 10-year inservice inspection (ISI) interval, which began on September 3, 2015, and ends on September 2, 2025.

2.0 REGULATORY EVALUATION

Pursuant to 10 CFR 50.55a(g)(6)(ii), "Augmented ISI program," the NRC may require the licensee to follow an augmented ISI program for systems and components for which the Commission deems that added assurance of structural reliability is necessary. The regulations in 10 CFR 50.55a(g)(6)(ii)(D), "Augmented ISI requirements," require augmented ISI of RVCH penetration nozzles of PWRs in accordance with ASME Code Case N-729-1, subject to the conditions specified in paragraphs (2) through (6) of 10 CFR 50.55a(g)(6)(ii)(D).

The regulations in 10 CFR 50.55a(z), "Alternatives to codes and standards requirements," state, in part, that alternatives to the requirements of 10 CFR 50.55a(g) may be used when authorized by the NRC if the licensee demonstrates: (1) the proposed alternatives would provide an acceptable level of quality and safety, or (2) compliance with the specified requirements would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

Based on the above, and subject to the following technical evaluation, the NRC staff finds that regulatory authority exists for the licensee to request and the NRC staff to grant the relief requested by the licensee

3.0 TECHNICAL EVALUATION

3.1 Relief Request I4R-03

3.1.1 ASME Code Components Affected

The affected components are all 78 ASME Code Class 1 RVCH penetration nozzles at the WCGS. The affected components include nozzle base material (UNS N06600) and J-groove partial penetration weld (UNS N06082 or UNS W86182) that attaches the nozzle base material to the underside of the RVCH.

3.1.2 Applicable Code Edition and Addenda

ASME Code Section XI, 2007 Edition through 2008 Addenda, as augmented by Code Case N-729-1 and as conditioned in 10 CFR 50.55a (10 CFR 50.55a(g)(6)(ii)(D)).

3.1.3 Applicable Code Requirement

Paragraph 10 CFR 50.55a(g)(6)(ii)(D)(1) requires that examinations of the RVCH penetration nozzles be performed in accordance with ASME Code Case N-729-1 subject to the conditions specified in paragraphs 10 CFR 50.55a(g)(6)(ii)(D)(2) through (6).

Paragraph -3200(b) of ASME Code Case N-729-1 states, in part,

> The supplemental examination performed to satisfy -3142.2 shall include volumetric examination of the nozzle tube and surface examination of the partial-penetration weld, or surface examination of the nozzle tube inside surface, the partial penetration weld, and nozzle tube outside surface below the weld, in accordance with Fig. 2 [of the Code Case]....

3.1.4 Reason for Request

The licensee stated that during RF21, the CRDM penetration nozzles were examined in accordance with both the WCGS inservice inspection and boric acid programs. A canopy seal weld leak led to the shutdown of the plant. The licensee determined it was necessary to perform the supplemental examinations in accordance with paragraph -3200(b) of ASME Code Case N-729-1, to resolve the relevant conditions indicative of possible nozzle leakage caused by the obscured penetrations before restarting from the refueling outage.

3.1.5 Proposed Alternative

As an alternative to the surface examination requirements of paragraph -3200(b) of ASME Code Case N-729-1, the licensee proposed to perform a demonstrated volumetric leak path assessment of each CRDM nozzle at WCGS (in addition to the volumetric examination). If an unacceptable indication by the leak path assessment or volumetric examination is identified, the licensee proposed to revert to the requirements of ASME Code Case N-729-1 and 10 CFR 50.55a(g)(6)(ii)(D).

3.1.6 Basis for Use

The licensee stated that the volumetric leak path assessment can be performed in tandem with the nozzle tube volumetric examinations and it will not add any additional radiological dose, and will not increase the length of the outage. The licensee stated that the combination of these inspection methods, the volumetric examination of the nozzle to verify no cracking in the nozzle, and the volumetric leak path assessment, to verify no through-weld leakage has occurred, will be able to confirm that any relevant condition of boric acid deposits on top of the RVCH were from other sources than RVCH nozzle penetration leakage. The licensee noted that the volumetric leak path assessment is effective at verifying no leakage is in the area for which any leakage must travel to come from a flaw in the J-groove weld.

The licensee documented that no previous indications of cracking in the nozzle or volumetric leak paths were identified in the previous examinations of the RVCH penetration nozzles at WCGS in 2006 and 2013. Also, the licensee stated that the results of the examinations performed during RF21 will be compared to the data from the previous two examinations for any changes in leak path data, thus, providing further assurance of no new leak path.

Hardship Justification

The licensee explained, that in order to meet the requirements of paragraph -3200(b) of ASME Code Case N-729-1, to perform surface examinations of each CRDM nozzle and associated partial penetration weld, significant radiological dose and outage time would be required. According to the licensee, the options for the surface examination of the partial penetration weld are 1) the liquid dye penetrant technique or 2) the eddy current technique. The use of liquid dye penetrant as the surface examination would require 117 roentgen equivalent man (rem) for all 78 nozzles (1.5 rem per nozzle). The use of eddy current examination technique could be performed remotely reducing the personnel exposure significantly. While the use of eddy current examination technique would reduce the radiological dose significantly as compared to the manual process, 500 millirem (mrem) would still be required. Further, the licensee stated that based on outage schedule projections, the space available, and qualified equipment and personnel requirements, the additional scope of eddy current testing of the partial penetration weld surfaces would extend the timeline of the refueling outage by at least 15 days, including the associated radiological dose of 2.25 rem during this time (150 mrem per day).

3.1.7 Duration of Proposed Alternative

The licensee proposed to use RR I4R-03 for RF21 subject to the condition that if an unacceptable indication by the leak path assessment or volumetric examination is identified, the licensee will revert to the requirements of ASME Code Case N-729-1 and 10 CFR 50.55a(g)(6)(ii)(D).

3.1.8 NRC Staff Evaluation

PWRs have experienced primary water stress-corrosion cracking in RVCH penetration nozzles as the result of the combination of susceptible material, such as nickel-based Alloy 600 or Alloy 82/182 weld metal, sufficient environment, and tensile stresses. The examination and analysis requirements of ASME Code Case N-729-1, as conditioned by 10 CFR 50.55a(g)(6)(ii)(D), are intended to monitor and ensure the leak tightness and structural integrity of CRDM penetration nozzles and associated J-groove welds.

The licensee stated that during RF21, the CRDM penetration nozzles were examined in accordance with both the WCGS inservice inspection and boric acid programs. A canopy seal weld leak led to the shutdown of the plant into RF21. The licensee stated that the canopy seal weld leak was from CRDM penetration nozzle 77, well above the RVCH surface. The leakage was uncharacteristically large (approximately 0.5 gallons per minute) compared to previous canopy seal weld leaks experienced at WCGS and within industry. This led to an undesirable buildup of boric acid residue on the RVCH surface. Due to ventilation in the area, deposits were distributed over the RVCH surface.

In its letter dated October 10, 2016, the licensee identified 12 CRDM nozzle penetrations with sufficient relevant conditions that supplemental examinations in accordance with paragraph -3200(b) would be required by ASME Code Case N-729-1. Therefore, the original scope of the proposed alternative was these initial 12 CRDM penetration nozzles. In its letter dated November 1, 2016, the licensee stated that the licensee failed to recognize the discovery of relevant conditions on the remaining annuluses between the CRDM penetration nozzles and RVCH surface. The licensee further noted that while these areas were not directly affected by the leak, the relevant conditions should have also resulted in a visual examinations with acceptance criteria of ASME Code Case N-729-1, paragraph -3142 being met.

The licensee indicated that a visual VT-2 examination was performed on the entire head. The licensee confirmed that there was no measureable wastage from the contour of the head. Further, the licensee stated, the surface rust, found during the examinations, in no way approached the amount of wastage required to encroach on the minimum wall thickness of the approximately 6-inch thick carbon steel structural portion of the RVCH. The licensee was not able to adequately confirm the condition of the remaining CRDM penetrations to the criteria of ASME Code Case N-729-1. At the time of this discovery, the licensee had already cleaned the head in such a way that it was no longer possible to perform an "as found" examination to meet the ASME Code requirements. Therefore, the licensee chose to perform a supplemental volumetric examination of all remaining CRDM penetration nozzles from the underside of the head in accordance with paragraph -3200(b) of ASME Code Case N-729-1 in lieu of the surface examination of the partial penetration welds associated with each nozzle.

The NRC staff finds that while the demonstrated volumetric leak path is not equivalent to a fully qualified surface leak path assessment, the licensee identified sufficient operational experience, technical basis, and radiological dose hardship to show that regulatory compliance would result in hardship without a compensating increase in the level of quality and safety.

For operating experience, the licensee described that there has been no previous identified cracking or leakage identified from the CRDM nozzle penetrations or welds of the upper head at WCGS. The NRC staff noted that while this fact does not preclude the possibility of cracking to be found as the plant continues to age, plants, which have previously identified cracking are more likely to see subsequent and more significant cracking in the future. Given the lack of the initial cracking being identified in the nozzle heats of material at the operating temperatures of WCGS, the NRC determined that the potential for significant cracking this outage was less likely.

For technical basis, the licensee identified that its inspection would be in compliance with the Wesdyne Technical Justification Document WDI-TJ-006-03-P, "Ultrasonic Testing of Interference Fit Samples for Leak Path Detection (PWROG PA-MSC-0532)" (not publicly available; proprietary information), showing an effective demonstration of the volumetric leak path technique. The NRC has accepted the use of a demonstrated volumetric leak path as part of the upper head inspection program under 10 CFR 50.55a(g)(6)(ii)(D). The licensee also referenced NUREG/CR-7142, "Ultrasonic Phased Array Assessment of the Interference Fit and Leak Path of the North Anna Unit 2 Control Rod Drive Mechanism Nozzle 63 with Destructive Validation" (ADAMS Accession No. ML12241A160), which found, in part, the use of a properly focused 0 degree probe could detect a leakage path under low leakage rates during operation that led to minimal wastage of the upper head low alloy steel. The licensee confirmed the minimum inspection coverage and probe details for each nozzle as part of its submittal. Therefore, the NRC staff determined that the information provided by the licensee does demonstrate the effectiveness of the volumetric leak path examination to detect low leakage rates, as performed in accordance with the licensee's proposed alternative.

For hardship, the licensee stated that alternate qualified surface leak path assessment methods would lead to a significant personnel dose and outage time versus the performance of a volumetric leak path assessment. The NRC staff determined both of these conditions to be of sufficient hardship given the operational experience and technical adequacy of the licensee's proposed alternative versus the regulatory requirement.

Therefore, the NRC staff concludes that the licensee's proposed alternative, to perform volumetric inspection of each RVCH penetration nozzle for cracking, and a demonstrated volumetric leak path examination to confirm no leakage rate of any significance through the weld, provides reasonable assurance of structural integrity of the RVCH until the next scheduled examination, and that compliance with the surface examination requirements of paragraph -3200(b) of ASME Code Case N-729-1, for the subject welds, would result in hardship without a compensating increase in the level of quality and safety.

3.2 Relief Request I4R-04

3.2.1 ASME Code Components Affected

The affected components are ASME Code Class 1 RVCH penetration nozzle numbers 77 and 78. The affected components include nozzle base material (UNS N06600) and J-groove partial penetration weld (UNS N06082 or UNS W86182) that attaches the nozzle base material to the underside of the RVCH.

3.2.2 Applicable Code Edition and Addenda

ASME Code Section XI, 2007 Edition through 2008 Addenda, as augmented by ASME Code Case N-729-1 and as conditioned by 10 CFR 50.55a(g)(6)(ii)(D).

3.2.3 Applicable Code Requirement

Paragraph 10 CFR 50.55a(g)(6)(ii)(D)(1) requires that examinations of the RVCH penetration nozzles be performed in accordance with ASME Code Case N-729-1 subject to the conditions specified in paragraphs 10 CFR 50.55a(g)(6)(ii)(D)(2) through (6).

Paragraph -2500 of ASME Code Case N-729-1 states, in part;

> If obstructions or limitations prevent examination of the volume or surface required by [Figure 2 of the Code Case] for one or more nozzles, the analysis procedure of Appendix I shall be used to demonstrate the adequacy of the examination volume or surface for each such nozzle. If Appendix I is used, the evaluation shall be submitted to the regulatory authority having jurisdiction at the plant site.

Figure 2 in ASME Code Case N-729-1, as referenced by paragraph -2500, requires that the volumetric or surface examination coverage distance below the toe of the J-groove weld (i.e., dimension "a") be 1.5 inches for nozzle tube incidence angle, Θ, less than or equal to 30 degrees; 1 inch for nozzle incidence angle, Θ, greater than 30 degrees; or to the end of the nozzle tube, whichever is less.

Nozzle penetration numbers 1 to 29 are required to inspect 1.5 inches below the toe of the J-groove weld because their incidence angles are less than or equal to 30 degrees. Nozzle penetration numbers 30 to 78 are required to inspect 1 inch below the toe of the J-groove weld because their incidence angles are greater than 30 degrees.

3.2.4 Reason for Request

The licensee stated that due to physical configuration of certain RVCH penetration nozzles, full examination volume required by ASME Code Case N-729-1 cannot be achieved for RVCH penetration nozzles 77 and 78; therefore, use of Mandatory Appendix I is requested in accordance with 10 CFR 50.55a(g)(6)(ii)(D)(6).

The licensee explained that RVCH penetration nozzles have two types of ends, referred to as Type "X" and Type "Y." Nozzles 1 through 73 are Type "Y" that are essentially a smooth wall cylinder with a radius at the outer diameter and inner diameter. Nozzles 74 through 78 have a threaded outside diameter and an internal taper. The design of RVCH penetration nozzles 74 through 78, referred to as Type “X”, includes a threaded section, approximately 1.19 inches in length at the bottom of the nozzles. These penetrations are located at the 48.7-degree location. The dimensional configuration at this location is such that the distance from the lowest point at the toe of the J-groove weld to the top of the threaded region could be less than the required coverage dimension "a" shown in Figure 2 of ASME Code Case N-729-1. Therefore, the licensee requested to deviate from the required inspection coverage (distance) for RVCH penetrations 77 and 78 because the licensee could not obtain the required coverage for these two penetrations.

The licensee stated that it achieved the required examination coverage for nozzles 74, 75, and 76 during the 2006 and 2013 inspections performed per NRC Order EA-03-009, “Issuance of First Revised NRC Order (EA-03-009) Establishing Interim Inspection Requirements for Reactor Pressure Vessel Heads At Pressurized Water Reactors,” February 20, 2004 (ADAMS Accession No. ML040220181) (performed in 2006) and ASME Code Case N-729-1 (performed in 2013).

The physical process of welding results in slightly different weld sizes/contours being applied to each nozzle. The licensee explained that this was a manual welding process, and it is not physically possible to manually apply the exact same amount of weld metal to each nozzle. This is acceptable as long as the minimum design weld size or contour is met. When access is limited, as the case on the downhill side of the peripheral penetrations, the condition of different weld size is magnified. This is the case in nozzles 77 and 78, as more weld metal was applied to the downhill portion of the weld, resulting in less of the nozzle (below the toe of the weld and above the threads) being available for examination.

By letters dated October 5, 2006, and November 1, 2006 (ADAMS Accession Nos. ML062890419 and ML063110631, respectively), the licensee submitted a similar RR to address inability to examine the required volume related to the initial examinations of RVCH penetration welds performed in accordance with NRC Order EA-03-009. By letter dated December 7, 2006 (ADAMS Accession No. ML063330294), the NRC approved this request.

By letter dated January 4, 2013 (ADAMS Accession No. ML12353A241), the NRC approved RR I3R-07 for the similar examinations of the RVCH nozzles at WCGS.

3.2.5 Proposed Alternative and Basis for Use

As an alternative to the volumetric and surface examination coverage requirements shown as dimension “a” in Figure 2 of ASME Code Case N-729-1, the licensee proposed to examine at least 0.5 inches (in lieu of 1.0 inch) below the toe of the lowest point of the J-groove weld for nozzle numbers 77 and 78. The use of 0.5 inches for nozzle numbers 77 and 78 will allow for improvements/changes in the vendor equipment that could lead to a more conservative measurement in the distance from the toe of the weld to the threaded area. The licensee noted that the required examination coverage dimension for all other penetration nozzles will be met or exceeded.

To support the alternative examination coverage for nozzle numbers 77 and 78, the licensee used the stress analysis and fracture mechanics analysis in WCAP-16589-NP, Revision 0, “Structural Integrity Evaluation of Reactor Vessel Upper Head Penetrations to Support Continued Operation: Wolf Creek,” August 2006 (ADAMS Accession No. ML062890420), to demonstrate that the proposed ultrasonic testing (UT) examination distance provides a reasonable assurance of structural integrity and leak tightness until the next scheduled examination.

The table below shows the examination coverage achieved in 2006 and in 2013 for nozzle numbers 77 and 78.

Penetration No.	Θ (degrees)	Code Case N-729-1 Required Examination Coverage(inches)	2006 Inspection Coverage Measurement Circumferential scan (inches)	2013 Inspection Coverage Measurement Axial scan (inches)
77	48.7	1.0	0.6	0.6
78	48.7	1.0	0.88	0.64

The licensee noted that the lower measurement in 2006 was performed using circumferential shooting time-of-flight diffraction (TOFD) transducers while the 2013 measurements were accomplished using axial shooting TOFD transducers. There is no change in coverage when comparing the Channel 2 data (which records the data from the circumferential shooting TOFD transducer) between the 2006 and 2013 examinations. The licensee stated that both circumferential and axial examination directions obtain coverage to the center of the thread relief area. For nozzle number 77, the data obtained from the axial shooting transducers shows the distance from the bottom of the J-groove weld to the center of the thread relief to be 0.6 inches, with the data from the circumferential shooting transducers indicating the same distance. For nozzle number 78, the data obtained from the circumferential shooting transducers shows the distance from the bottom of the J-groove weld to the center of the thread relief to be 0.88 inches, with the data from the axial shooting transducers indicating the distance to be 0.64 inches.

Stress Analysis

Appendix I of ASME Code Case N-729-1 provides the analysis procedure for evaluation of an alternative examination area or volume to that specified in Figure 2 of ASME Code Case N-729-1 if impediments prevent examination of the required zone. Section I-1000 of ASME Code Case N-729-1 requires, for alternative examination zones below the J-groove weld, that analyses shall be performed using either the stress analysis method of Section I-2000 or the deterministic fracture mechanics analysis method of Section I-3000 to demonstrate that the applicable examination coverage criteria are satisfied.

Section I-2000 of ASME Code Case N-729-1 requires that a plant-specific analysis demonstrates that the hoop and axial stresses remain below 20 kips per square inch (ksi) (tensile) over the entire region outside the alternative examination zone but [except] within the examination zone defined in Figure 2 of ASME Code Case N-729-1.

To satisfy Section I-2000, the licensee's stress analysis is based on WCAP-16589-P. The licensee performed the stress analysis using the plant-specific design weld dimensions.

The hoop stress distribution plots for nozzle numbers 77 and 78 as shown in RR I4R-04, indicate that the minimum achievable inspection coverage below the bottom of the J-groove weld demonstrated that stresses will remain below 20 ksi tensile over the entire region outside the alternative examination zone except within the examination zone as defined in Figure 2 of ASME Code Case N-729-1. The hoop stress distribution plots display the downhill side as this is more limiting. Also, stress distribution plots shown are for the inside and outside surface. The distance from below the toe of the downhill side J-groove weld to where both the inside and outside surface hoop stress drops below 20 ksi for nozzle numbers 77 and 78 is 0.3 inches.

Fracture Mechanics Analysis

The licensee also reviewed the fracture mechanics analysis in WCAP-16589-P and compared it to the requirements of I-3000. Because the alternative examination zone is below the J-groove weld, the applicable requirements are those of Section I-3200 of ASME Code Case N-729-1. The licensee stated that the operating temperature of the reactor vessel head has not changed since the analysis in WCAP-16589-P was performed.

The licensee determined that WCAP-16589-P has also satisfied the technique described in Method 1 of Section I-3200 of ASME Code Case N-729-1, except that WCAP-16589-P used the crack growth rate based on Electric Power Research Institute (EPRI) Report, "Materials Reliability Program (MRP) Crack Growth Rates for Evaluating Primary Water Stress Corrosion Cracking (PWSCC) of Thick-Wall Alloy 600 Material (MRP-55)," June 18, 2002 (ADAMS Accession No. ML023010510), not Appendix O of the 2004 Edition of the ASME Code, Section XI as required in ASME Code Case N-729-1. The licensee noted that WCAP-16589-P was prepared prior to NRC's approval to use ASME Code Case N-729-1. The licensee explained that because the same formula for crack growth rate is used in both EPRI MRP-55 and Appendix O, there is no technical difference, and WCAP-16589-P does meet the technical requirements for I-3200(a).

The licensee stated that the as-designed and as-built dimension of the J-groove weld at nozzle number 77 are 1.46 inches and 1.98 inches, respectively. The as-designed and as-built dimension of the J-groove weld at nozzle number 78 are 1.46 inches and 2.04 inches, respectively.

The licensee stated that the flaw evaluation in WCAP-16589-P is based on the as-designed J-groove weld dimensions, which assumed a smaller weld throat than the as-built condition. The as-built weld dimension on the downhill side of the RVCH nozzle is larger than the as-designed dimension because of access issues during fabrication. When the weld extends further down the outside surface of the RVCH nozzle due to a larger than as-designed fillet, it does not negatively affect the distance below the J-groove weld required for coverage. The licensee assessed similar RVCH design/configuration and showed that larger as-built J-groove welds have a reduced stress profile relative to smaller welds and also required lesser distance below the weld bottom for a transition to below 20 ksi. The cases considered were for weld heights of 1.46 inches, 2.35 inches and 2.97 inches, which were analyzed to determine their resulting stress profiles below the J-groove weld. The 20 ksi criterion is reached in shorter distance for the larger fillet welds. The licensee concluded that the 1.46-inch as-design dimension bounds the as-built dimensions of the RVCH nozzles for the current flaw evaluation.

The licensee stated that the results of the fracture mechanics analysis are shown as the flaw tolerance chart in Figure 3 of the RR submittal dated November 1, 2016, which can be used to determine the minimum required inspection coverage. The flaw tolerance chart demonstrates that a postulated through-wall flaw at the bottom edge of the proposed alternative examination zone, not being inspected, will not grow to the toe of the J-groove weld within an inspection interval of four refueling cycles. The crack growth prediction shows greater than six effective full power years of operation required to grow the postulated flaw to the toe of the J-groove weld. Additionally, the assumed initial upper extremity locations of axial through-wall flaws are conservative based on achievable inspection coverage, because the assumed upper crack extremities are located within the achievable inspection zone.

The licensee noted that examination of portions of the nozzle significantly below the J-groove weld is not pertinent to the phenomena of concern, which include leakage through the J-groove weld and circumferential cracking in the nozzle above the J-groove weld. In all cases, the proposed examination coverage is adequate to allow the licensee to continue to operate prior to the hypothetical flaws reaching the J-groove weld.

Hardship Justification

Paragraph 10 CFR 50.55a(g)(6)(ii)(D)(3) states in part;

> [I]f a surface examination is being substituted for a volumetric examination on a portion of a penetration nozzle that is below the toe of the J-groove weld..., the surface examination must be of the inside and outside wetted surface of the penetration nozzle not examined volumetrically.

To reduce personnel radiation exposure, the nozzles are typically inspected using remotely operated volumetric examination equipment. Although dye penetrant testing of threaded surfaces is possible, it is not practical. The threaded outside diameter makes a dye penetrant examination on the lower section of the nozzle impractical because of excessive bleed out from the threads. Eddy current examination would similarly not be effective due to the threaded configuration. Current known radiation levels under the RVCH are 4.5 rem/hr at the bottom of one nozzle. This could result in an exposure of approximately 1.5 rem per nozzle using 4500 mrem/hr and 20 minutes/nozzle. The licensee stated that based on its estimates of dose rates (based on recent measurements in the area) ranging from 4.5 rem/hr to 10 rem/hr at the bottom of the nozzles, the expected dose ranges from approximately 1.5 Rem to 3.3 rem per nozzle will result when performing a surface examination.

The licensee explained that shielding to some extent is possible but would do little to reduce the overall whole body submersion exposure of 2400 mrem/hr. The licensee concluded that it would be impractical to install shielding at this location, due to the additional dose consumed installing the shielding being greater than the resultant savings. Therefore, no alternative to the surface examination is proposed for nozzles numbers 77 and 78 with limited examination coverage below the J-groove weld.

3.2.6 Duration of Proposed Alternative

The licensee proposed to use RR I4R-04 for the remaining duration of the current fourth 10-year ISI interval, which ends on September 2, 2025.

3.2.7 NRC Staff Evaluation

PWRs have experienced primary water stress-corrosion cracking in RVCH penetration nozzles as the result of the combination of susceptible material, such as nickel-based Alloy 600 or Alloy 82/182 weld metal, corrosive environment, and tensile stresses. The examination and analysis requirements of ASME Code Case N-729-1, as conditioned by 10 CFR 50.55a(g)(6)(ii)(D), are intended to monitor and ensure the leak tightness and structural integrity of CRDM penetration nozzles and associated J-groove welds.

In lieu of required UT examination distance in ASME Code Case N-729-1, the licensee proposed to reduce the UT examination distance for nozzle numbers 77 and 78. Appendix I of ASME Code Case N-729-1 permits the use of either a stress analysis or a deterministic fracture mechanics analysis to support the reduced examination coverage. The licensee performed analyses as per WCAP-16589-P to demonstrate that the reduced examination distance is acceptable. The NRC staff evaluated the licensee's stress analysis and fracture mechanics analysis in accordance with ASME Code Case N-729-1 to ensure that the proposed UT examination distance provides a reasonable assurance of structural integrity and leak tightness for nozzles number 77 and 78 until the next scheduled examination.

Stress Analysis

Section I-2000 of ASME Code Case N-729-1 states, in part;

> The analysis shall be performed using either design or as-built weld dimensions for the specific nozzles for which a portion of [Figure 2 of ASME Code Case N-729-1] examination zone is being eliminated, or for nozzles shown to bound the stresses in those specific nozzles.

The NRC staff notes that the stress analysis in WCAP-16589-P used the plant-specific design weld dimensions. The NRC staff noted that the licensee performed three dimensional finite element stress calculations of the penetration nozzle. The analysis included operating stresses and the J-groove weld residual stresses. The operating temperature of the head has not changed since the analysis in WCAP-16589-P was performed.

The NRC staff notes that the flaw evaluation in WCAP-16589-P is based on the as-designed J-groove weld dimensions, which assumed a smaller weld throat than the as-built condition. The as-built J-groove weld dimension on the downhill side of the RVCH nozzle is larger than the as-designed dimension because of access issues during fabrication. When the J-groove weld extends further down the outside surface of the RVCH nozzle due to a larger than as designed fillet, it does not negatively affect the distance below the J-groove weld required for examination coverage. The NRC staff noted that similar RVCH nozzle configuration showed that larger as-built J-groove welds have a reduced stress profile relative to smaller as-designed welds and required lesser distance below the J-groove weld bottom for a transition to below 20 ksi. The 20 ksi criterion is reached in shorter distance for the larger J-groove welds. This means that the licensee proposed 0.5-inch inspection distance will cover the nozzle region that exceed the 20 ksi and a portion of the region that has stresses less than 20 ksi. This is desirable because the inspection will detect any potential flaw growth in both regions.

The NRC staff notes that the licensee used the as-designed weld height of 1.46 inches to generate stress distributions. The as-built dimensions of the RVCH nozzles are larger than the as-designed dimension of 1.46 inches. The stress distributions for the as-built configuration should be less than the as-designed configuration. The NRC staff determined that the stress distributions in the licensee's stress analysis in WCAP-16589-P bounds the as-built configuration and is acceptable.

The NRC staff noted that experimental tests have shown that primary water stress corrosion cracking would most likely initiate if the tensile stresses exceed 20 ksi. The result of the licensee's stress analysis, as shown in Figure 2 of the RR (Page 12, Attachment 2 to WCNOC letter dated November 1, 2016) demonstrated that the distance from below the toe of the downhill side J-groove weld to where both the inside and outside surface hoop stress drops below 20 ksi for nozzle numbers 77 and 78 is 0.3 inches. This means that the stresses will be greater than 20 ksi in the nozzle region from the toe of the J-groove weld measuring axially down to the 0.3-inch demarcation along the nozzle tube. The stresses will be less than 20 ksi in the nozzle region from the 0.3-inch demarcation to the end of the tube. The licensee proposed that it will inspect at least 0.5 inches from below the toe of the J-groove weld. The 0.5-inch examination distance covers 0.3 inches of the zone where stresses exceed 20 ksi. The structural integrity of the nozzle region that has stresses exceeding 20 ksi will be monitored by periodic examinations and, therefore, the integrity of that region is ensured.

The structural integrity of the nozzle region with less than 20 ksi stresses is ensured because a crack is not likely to initiate with stresses below 20 ksi. If a crack does initiate in the uninspected nozzle region and grow toward the J-groove weld, periodic examinations required by ASME Code Case N-729-1 will identify the flaw prior to its growing into the J-groove weld. If the crack is detected, the licensee is required to take corrective actions in accordance with NRC regulations and ASME Code Case N-729-1.

The NRC staff finds that the licensee's stress analysis has satisfied I-2000 of ASME Code Case N-729-1 because the hoop and axial stresses on the nozzle inside and outside surfaces remain below 20 ksi (tensile) over the entire region outside the alternative examination zone except the examination zone.

Fracture Mechanics Analysis

Because the alternative examination zone is below the J-groove weld, the applicable requirements for a fracture mechanics analysis are those of Section I-3200 of ASME Code Case N-729-1. The NRC staff notes that Section I-3200(a)(6) of requires the use of the crack growth rate in Appendix O of Section XI, in the 2004 Edition. However, WCAP-16589-P used the crack growth rate in EPRI MRP-55. The NRC staff notes that the same formula for the crack growth rate is used in both EPRI MRP-55 and Appendix O.

The NRC staff further determines that WCAP-16589-P does meet the requirements of Section I-3200(a) of ASME Code Case N-729-1 and uses appropriate J-groove weld dimension. The NRC staff determines that the licensee's fracture mechanics calculation demonstrates that a hypothetical crack in the uninspected region will not propagate to the toe of the J-groove weld before the next examination.

The NRC staff concludes that the proposed examination coverage of 0.5 inches below the toe of the lowest point of the J-groove weld for nozzle numbers 77 and 78 is acceptable based on the acceptability of the stress analysis and fracture mechanics analysis in WCAP-16589-P. The licensee's analyses demonstrated that within four refueling cycles, a potential flaw that initiates in the unexamined zone below the J-groove weld of the nozzle numbers 77 and 78 will not propagate into the J-groove weld. At the end of every fourth refueling cycle, the licensee will perform an examination to confirm the structural integrity of RVCH nozzle numbers 77 and 78. The structural integrity of nozzle numbers 77 and 78 and associated J-groove welds will be maintained as supported by the periodic examinations and flaw evaluation.

Hardship Justification

Paragraph 10 CFR 50.55a(g)(6)(ii)(D)(3) permits substitution of a surface examination of the nozzle inside and outside wetted surface for ultrasonic examination of the portion of a penetration nozzle that is below the toe of the J-groove weld (Point E on Figure 2 of ASME Code Case N-729-1). The NRC staff notes that the threaded portion on the outside diameter of the RVCH nozzle is not amenable to eddy current examination due to the presence of the threads. Although dye penetrant testing of threaded surfaces is possible, the NRC staff understands that the threaded outside diameter makes a dye penetrant examination on the lower section of the penetration impractical because of excessive bleed out from the threads.

In addition, the NRC staff notes that performance of a surface examination on the subject nozzles to obtain the required coverage below the lowest point in the J-groove weld toe would result in high-radiation dose. Also, it would be impractical to try to install shielding at this location to reduce the dose, as it would require more radiation dose to install the shielding than would be saved during the examinations. Based on the relatively high radiological dose, impracticality of the eddy current and dye penetrant testing, the NRC staff finds that performing the surface examination to attain the required coverage would present a hardship without a compensating increase in the level of quality and safety.

In summary, the NRC staff concludes that the licensee's proposed alternative UT inspection coverage for RVCH nozzle numbers 77 and 78 provides reasonable assurance of structural integrity and leak tightness until the next scheduled examination.

4.0 CONCLUSION

The NRC staff concludes that the proposed alternative provides reasonable assurance of structural integrity of the RVCH and all 78 CRDM penetration nozzles such that complying with the ASME Code requirement would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety. The NRC staff also concludes that the proposed alternative provides reasonable assurance of structural integrity of the RVCH nozzles numbers 77 and 78 and that complying with the ASME Code Case N-729-1 requirement would result in hardship or unusual difficulty without a compensating increase in the 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)(2) and 10 CFR 50.55a(g)(6)(ii)(D). Therefore, the NRC staff authorizes the use of RR I4R-03 at the WCGS during the RF21 subject to the licensee's proposed alternative that if an unacceptable indication by the leak path assessment or volumetric examination is identified, the licensee will revert to the requirements of ASME Code Case N-729-1 and 10 CFR 50.55a(g)(6)(ii)(D). The NRC staff also authorizes the use of RR I4R-04 at the WCGS for the remainder of the fourth 10-year ISI interval, which began on September 3, 2015, and ends on September 2, 2025.

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

Principal Contributors: Jay Collins, NRR/DE/EPNB
John Tsao, NRR/DE/EPNB

Date: May 1, 2017