



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

February 2, 2021

Mr. John A. Krakuszeski  
Site Vice President  
Brunswick Steam Electric Plant  
Duke Energy Progress, LLC  
8470 River Rd., SE (M/C BNP001)  
Southport, NC 28461

SUBJECT: BRUNSWICK STEAM ELECTRIC PLANT, UNITS 1 AND 2 – REQUEST FOR  
ALTERNATIVE TO INSERVICE INSPECTION OF REACTOR PRESSURE  
VESSEL WELDS AND NOZZLE INNER RADIUS SECTIONS  
(EPID L-2020-LLR-0091)

Dear Mr. Krakuszeski:

By letter dated June 23, 2020, as supplemented by letters dated July 30, 2020, and October 27, 2020, Duke Energy (the licensee) submitted request RA-19-0047 to the U.S. Nuclear Regulatory Commission (NRC) for the use of an alternative to certain American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI requirements at the Brunswick Steam Electric Plant (BSEP), Units 1 and 2.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(z)(1), the licensee proposed an alternative on the basis that the alternative provides an acceptable level of quality and safety. The alternative to the inservice inspection (ISI) requirements in 10 CFR 50.55a, "Codes and standards," and Division 1 of the ASME Code applies to inspections of reactor pressure vessel (RPV) nozzle-to-vessel shell welds and RPV nozzle inner radius sections. This alternative is based on ASME Code Case N-702, "Alternative Requirements for Boiling Water Reactor (BWR) Nozzle Inner Radius and Nozzle-to-Shell Welds."

The NRC staff determined that the licensee's proposed alternative provides an acceptable level of quality and safety in lieu of complying with the requirements in ASME Code, Section XI, Table IWB-2500-1, Examination Category B-D, Inspection Items B3.90 and B3.100. 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 authorizes the licensee's proposed alternative for inspection of nozzle-to-vessel shell welds and nozzle inner radius sections for the requested RPV nozzles at BSEP, Units 1 and 2, for the Fifth 10-Year ISI Interval and the remainder of the period of extended operation.

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

J. Krakuszeski

- 2 -

If you have any questions, please contact the Project Manager, Andrew Hon, at 301-415-8480 or [Andrew.Hon@nrc.gov](mailto:Andrew.Hon@nrc.gov).

Sincerely,

Undine S. Shoop, Chief  
Plant Licensing Branch II-2  
Division of Operating Reactor Licensing  
Office of Nuclear Reactor Regulation

Docket No. 50-324 and 50-325

Enclosure:  
Safety Evaluation

cc: Listserv

SUBJECT: BRUNSWICK STEAM ELECTRIC PLANT, UNITS 1 AND 2 – REQUEST FOR ALTERNATIVE TO INSERVICE INSPECTION OF REACTOR PRESSURE VESSEL WELDS AND NOZZLE INNER RADIUS SECTIONS (EPID L-2020-LLR-0091) DATED FEBRUARY 2, 2021

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**ADAMS Accession No. ML21005A010**

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NAME	AHon	BAbeywickrama	HGonzalez
DATE	01/04/2021	01/05/2021	12/22/2020
OFFICE	NRR/DSS/SNSB/BC	NRR/DORL/LPL2-2/BC	NRR/DORL/LPL2-2/PM
NAME	SKrepel	UShoop	AHon
DATE	12/23/2020	02/02/2021	02/02/2021

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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

PROPOSED ALTERNATIVE TO

FIFTH 10-YEAR INSERVICE INSPECTION INTERVAL

DUKE ENERGY PROGRESS, LLC

BRUNSWICK STEAM ELECTRIC PLANT, UNITS 1 AND 2

DOCKET NOS. 50-325 AND 50-324

1.0 INTRODUCTION

By letter dated June 23, 2020 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML20181A004), as supplemented by letters dated July 30, 2020 (ADAMS Accession No. ML20212L731) and October 27, 2020 (ADAMS Accession No. ML20301A475), Duke Energy (the licensee) submitted request RA-19-0047 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, Division 1 for inservice inspections at the Brunswick Steam Electric Plant (BSEP), Units 1 and 2.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(z)(1), the licensee proposed an alternative on the basis that the alternative provides an acceptable level of quality and safety. The alternative to the inservice inspection (ISI) requirements in 10 CFR 50.55a, "Codes and standards," and Division 1 of the ASME Code applies to inspections of reactor pressure vessel (RPV) nozzle-to-vessel shell welds and RPV nozzle inner radius sections. This alternative is based on ASME Code Case N-702, "Alternative Requirements for Boiling Water Reactor (BWR) Nozzle Inner Radius and Nozzle-to-Shell Welds."

2.0 REGULATORY EVALUATION

The ISI of ASME Code Class 1, 2, and 3 components is performed in accordance with Section XI of the ASME Code and applicable addenda to detect anomalies and degradation indications so that structural integrity of these components is maintained during the licensed service term. 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(z). The exception states 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. The rule states that the proposed alternative must be submitted and authorized prior to implementation and that the licensee must demonstrate that either: (1) the proposed alternative will provide an acceptable level of quality and safety, or (2) compliance with the specified requirement(s) in 10 CFR 50.55a

Enclosure

would result in hardship or unusual difficulty without a compensating increase in the level of quality and safety.

The ASME Code, Section XI, requires 100 percent of the RPV nozzles of each type to be inspected during each 10-year ISI interval. The ASME Code, Section XI also requires that 100 percent of the nozzle-to-vessel shell weld volumes and 100 percent of the nozzle inner radius section volumes be inspected in accordance with the stated volumes defined in ASME Code, Figures IWB-2500-7(a) through (d) "Nozzle in Shell or Head," of ASME Code, Section XI for the applicable nozzle type. However, for boiling water reactor (BWR) facilities, ASME Code Case N-702 provides an alternative that would allow only 25% of the nozzle inner radii and nozzle-to-shell weld locations to be inspected during each 10-year ISI interval, so long as at least one nozzle from each system and nominal pipe size is performed in accordance with the applicable ASME Table IWB-2500-1, Examination Category B-D requirements. The volumes required to be inspected in each nozzle remains 100 percent of the applicable nozzle-to-vessel shell weld volume and nozzle inner radius section volume, as specified in the applicable ASME Section XI IWB-2500-7 figure for specified nozzle location. ASME Code Case N-702 is conditionally approved in Regulatory Guide (RG) 1.147, Revision 19, "Inservice Inspection Code Case Acceptability," Section XI, Division 1, dated October 2019 (ADAMS Accession No. ML19128A244).

For application of Code Case N-702, the licensee is required to address the following conditions specified in RG 1.147, Revision 19:

The applicability of Code Case N-702 for the first 40 years of operation must be demonstrated by satisfying the criteria in Section 5.0 of NRC Safety Evaluation regarding BWRVIP-108, dated December 19, 2007 (ADAMS Accession No. ML073600374) or Section 5.0 of NRC Safety Evaluation regarding BWRVIP-241, dated April 19, 2013 (ADAMS Accession No. ML13071A240).

The use of Code Case N-702 in the period of extended operation is not approved.

If VT-1 is used, it shall utilize Code Case N-648-2, "Alternative Requirements for Inner Radius Examination of Class 1 Reactor Vessel Nozzles, Section XI Division I," with associated required conditions specified in RG 1.147.

The topical reports, BWRVIP-108, "Technical Basis for the Reduction of Inspection Requirements for the Boiling Water Reactor Nozzle-to-Vessel Shell Welds and Nozzle Inner Radii" (ADAMS Accession Nos. ML023360232 and ML023360234; non-publicly available) and BWRVIP-241, "Probabilistic Fracture Mechanics (PFM) Evaluation for the Boiling Water Reactor Nozzle-to-Vessel Shell Welds and Nozzle Blend Radii" (ADAMS Accession Nos. ML11119A042, non-publicly available; ML11119A043, publicly available) contain PFM analysis results supporting Code Case N-702. Both topical reports are for 40 years of operation. The staff issued safety evaluations (SEs) on both reports (ADAMS Accession Nos. ML073600374 and ML13071A240). BWRVIP-241 contains additional PFM results supporting revision of the evaluation criteria under "Conditions and Limitations" in the U.S. Nuclear Regulatory Commission (NRC) SE for BWRVIP-108. The NRC staff has accepted the BWRVIP's revised evaluation criteria in its SE for BWRVIP-241.

To address the extended period of operation, the NRC issued an SE dated April 26, 2017 (ADAMS Accession No. ML17114A096) on a supplemental BWRVIP document for license renewal, BWRVIP-241, Appendix A, "BWR Nozzle Radii and Nozzle-to-Vessel Welds Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10 CFR 54.21)" (ADAMS Accession No. ML12290A017). This license renewal Appendix A provides the basis and framework for licensees in the period of extended operation to consider the effects of aging and time limited aging analysis evaluations when applying Code Case N-702.

10 CFR Part 50, "Domestic Licensing Of Production And Utilization Facilities," Appendix H, Paragraph III.A, states that "no material surveillance program is required for reactor vessels for which it can be conservatively demonstrated by analytical methods applied to experimental data and tests performed on comparable vessels, making appropriate allowances for all uncertainties in the measurements, that the peak neutron fluence at the end of the design life of the vessel will not exceed  $10^{17}$  n/cm<sup>2</sup> (E > 1 MeV)." NRC Regulatory Guide (RG) 1.190, dated March 2001 (ADAMS Accession No. ML010890301), "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence," describes the NRC approved methodology to calculate the neutron fluence.

The ASME Code of record for BSEP, Units 1 and 2, for the Fifth 10-Year ISI Interval is the 2007 Edition of the ASME Code, Section XI, through the 2008 Addenda.

### 3.0 TECHNICAL EVALUATION

#### 3.1 Licensee Evaluation

##### Component(s) for which Alternative is Requested (ASME Code Class 1)

The licensee is seeking relief from examining 100 percent of the RPV nozzle-to-vessel shell welds and RPV nozzle inside radius sections of RPV nozzles N1, N2, N3, N5, N6, N8, N11, and N12, as specified in Enclosure 1, "Relief Request Serial No. RA-19-0447," of the submittal.

##### Examination Category

The ASME Code, Section XI, Table IWB-2500-1, Examination Category B-D, "Full Penetration Welded Nozzles in Vessels"

##### Examination Item Number(s)

ASME Code Inspection Items B3.90, "Nozzle-to-Vessel Welds" and B3.100, "Nozzle Inside Radius Section," as defined in the ASME Code, Section XI, Table IWB-2500-1, Examination Category B-D

##### ASME Code Requirement for which Alternative is Requested

The ASME Code Inspection Item No. B3.90 requires a volumetric examination of all RPV nozzles with full penetration welds to the vessel shell (or head) and integrally cast nozzles during each 10-year ISI interval, with the 100 percent volume requirement defined in the applicable figure for the specific nozzle weld configuration in the ASME Code, Section XI,

Figures IWB-2500-7(a) – (d). the ASME Code Inspection Item No. B3.100 includes analogous requirements for volumetric examinations of RPV nozzle inside radius sections.

#### Licensee's Proposed Alternative to the ASME Code

Pursuant to 10 CFR 50.55a(z)(1), the licensee proposed an alternative to performing the required examinations on 100 percent of the RPV nozzles identified as Item Nos. B3.90 (welds) and B3.100 (inner radius sections) for the remainder of the fifth ISI interval and the period of extended operation. The licensee's alternative is submitted in accordance with ASME Code Case N-702. The licensee proposed that a minimum of 25 percent of the RPV nozzles (i.e., the nozzle-to-vessel welds and nozzle inner radius sections of these nozzles), including at least one nozzle from each system and nominal pipe size, be volumetrically examined. The specific nozzles to be examined for each RPV nozzle group are listed in Enclosures 2 and 3 of the submittals. The licensee will perform either volumetric examination or VT-1 visual examination for the nozzle inner radii examination, as specified in Code Case N-702. In the licensee's supplement dated October 27, 2020, the licensee stated that implementation of ASME Code Case N-648-2 is required in case that VT-1 is used in lieu of volumetric examination for the RPV inner radius section inspections.

#### Licensee's Bases for Alternative

The licensee's alternative is based on the PFM results documented in the BWRVIP-108 and BWRVIP-241 reports. Because the duration of this relief request includes the fifth ISI interval and the remaining period of extended operation, the licensee invoked BWRVIP-241, Appendix A, as part of the basis for the proposed alternative. The licensee selected the evaluation criteria in BWRVIP-241 to satisfy the NRC conditions on the use of Code Case N-702 that were defined in the NRC's SE for BWRVIP-108. The licensee's assessment results for the conditions are summarized in the following subsections:

##### (1) Max RPV Heatup/Cooldown Rate

First criterion: the maximum RPV heatup/cooldown rate is limited to  $< 115^{\circ}\text{F/hr}$ .

The licensee stated that BSEP Units 1 and 2 meet the first criterion on maximum RPV heatup and cooldown rate, as stated in Enclosure 1 of the submittal:

"BSEP Unit 1 and Unit 2, Reactor Coolant System heatup and cooldown rates provided in the respective units' Technical Specifications 3.4.9, 'RCS Pressure and Temperature (P/T) Limits,' are limited to a maximum of  $100^{\circ}\text{F}$  in any 1-hour period."

##### (2) Recirculation Inlet Nozzles (N2)

Second criterion:  $(pr/t) / C_{\text{RPV}} < 1.15$ , where

p = RPV normal operating pressure (psi),  
r = RPV inner radius (inch),  
t = RPV wall thickness (inch), and  
 $C_{\text{RPV}} = 19332$

The licensee stated that BSEP Units 1 and 2 meet the second criterion for assessment of N2 RPV inlet nozzles based on the input parameters for this nozzle in Enclosure 1 of the submittal, as summarized in the calculation below:

$$[(1035 \times 110.2)/5.68]/19332 = 1.039 < 1.15$$

Third criterion:  $[p(r_o^2+r_i^2)/(r_o^2-r_i^2)] / C_{NOZZLE} < 1.47$ , where

p = RPV normal operating pressure (psi),  
r<sub>o</sub> = nozzle outer radius (inch),  
r<sub>i</sub> = nozzle inner radius (inch),  
t = RPV wall thickness (inch), and  
C<sub>NOZZLE</sub> = 1637

The licensee stated that BSEP Units 1 and 2 meet the third criterion for assessment of N2 RPV inlet nozzles based on the input parameters for this nozzle in Enclosure 1 of the submittal, as summarized in the calculation below:

$$[(1035 \times (14.125^2 + 7.0625^2)) / (14.125^2 - 7.0625^2)] / 1637 = 1.054 < 1.47$$

### (3) Recirculation Outlet Nozzles (N1)

Fourth criterion:  $(pr/t) / C_{RPV} < 1.15$ , where

p = RPV normal operating pressure (psi),  
r = RPV inner radius (inch),  
t = RPV wall thickness (inch), and  
C<sub>RPV</sub> = 16171

The licensee stated that BSEP Units 1 and 2 do not meet the fourth criterion for the assessment of the N1 RPV outlet nozzles based on the input parameters for this nozzle in Enclosure 1 of the submittal, as summarized in the calculation below:

$$[(1035 \times 110.2)/5.68]/16171 = 1.242 > 1.15$$

Therefore, to address this discrepancy, the licensee performed a PFM analysis for the N1 Recirculation Outlet Nozzles. The staff assesses this PFM later in this SE.

Fifth criterion:  $[p(r_o^2+r_i^2)/(r_o^2-r_i^2)] / C_{NOZZLE} < 1.59$ , where

p = RPV normal operating pressure (psi),  
r<sub>o</sub> = nozzle outer radius (inch),  
r<sub>i</sub> = nozzle inner radius (inch),  
t = RPV wall thickness (inch), and  
C<sub>NOZZLE</sub> = 1977

The licensee stated that BSEP, Units 1 and 2 meet the fifth criterion for assessment of the N1 RPV outlet nozzles based on the input parameters for this nozzle in Enclosure 1 of the submittal, as summarized in the calculation below:

$$[(1035 \times (24.375^2 + 13.0625^2)) / (24.375^2 - 13.0625^2)] / 1977 = 0.945 < 1.59$$

As discussed above, the N1 RPV outlet nozzles at BSEP did not satisfy the fourth criterion in the NRC's SE for BWRVIP-241. To address this issue, the licensee performed a component-specific PFM analysis for the N1 RPV outlet nozzles as documented in the licensee's supplement dated July 30, 2020. As part of the PFM analysis, the licensee performed a finite element stress analysis. The modeled nozzle geometry was based upon licensee design drawings, as illustrated in Section 3.2.1 and Figure 1 of the licensee's July 30, 2020 supplement. Material properties for the model are documented in Tables 1 - 4 of the licensee's supplement. Thermal transient and internal pressure loads were modeled in separate finite element models. The licensee stated that the "Improper Start of the Cold Recirculation Loop" transient was the bounding transient for the analyses. The licensee also stated that the total number of fatigue cycles from all transients for 40 years of operation was 491. To account for extended operation, the licensee scaled this value to 737 cycles for the 60-year PFM assessment of the N1 RPV outlet nozzles. The licensee assumed all 737 cycles to be due to the bounding improper start transient. The licensee also accounted for extended power uprate conditions in the stress analysis.

The licensee performed the PFM analysis using the VIPERNOZ software with  $1 \times 10^6$  Monte Carlo realizations. The deterministic and random variables in the analysis are respectively listed in Tables 9 and 11 of the licensee's supplement. The licensee performed the analysis assuming that 25 percent of the nozzle-to-shell welds and nozzle inner radii are inspected each ISI interval. The model included stress corrosion cracking and fatigue crack growth as degradation mechanisms. The licensee stated that, in Section 5.0 of the supplement, no failures were observed in  $1 \times 10^6$  realizations, leading to estimated probabilities of failure of  $1.67 \times 10^{-8}$  for normal operations and  $1.67 \times 10^{-11}$  for the limiting low temperature overpressure protection event (i.e., inadvertent start of the recirculation pump while under cold conditions) assessed in the PFM analysis.

### Management of Aging Effects

For management of aging effects, the licensee adopted the BWRVIP-05 position that there was no material degradation mechanism impacting the subject nozzles. Further, the licensee stated that neutron fluence should be monitored at the nozzle locations for potential impact on material toughness. The licensee described the Pressure Temperature Limits Report (PTLR) and concluded that the peak fluence for the subject nozzles over the period of extended operation was less than the fluence criterion of  $1 \times 10^{17}$  n/cm<sup>2</sup> (E > 1.0 MeV). The licensee indicates that Chapter 18 of the Updated Final Safety Analysis Report (UFSAR) addresses the licensee's bases for implementing aging management programs and time-limited aging analyses (TLAAs) during the period of extended operation, as required by 10 CFR 54.21. For aging management programs and TLAAs that relate to the assessment in RR No. RA-19-0047, the licensee cited UFSAR Section 18.1.14 for the licensee's neutron irradiation monitoring activities, UFSAR Section 18.1.1 for the licensee's ASME Section XI, aging management program, UFSAR Section 18.1.30 for the licensee's reactor vessel and internals structural integrity program, and UFSAR Section 18.2.2 for the licensee's metal fatigue TLAA.

The licensee stated that neutron fluence requires monitoring in order to evaluate irradiation effects on material fracture toughness. The licensee further stated that the nozzles in this request for alternative lie outside of the beltline region and are thus not exposed to fluence exposures in excess of  $1 \times 10^{17}$  n/cm<sup>2</sup> (E > 1.0 MeV) at the end of the period of extended operation. The licensee also stated that existing programs implement various inspection or

performance monitoring requirements, such as implementation of the licensee's fatigue management program and the ASME Code Section XI ISI program.

#### Period of Application

The licensee requests the proposed alternative for the duration of the Fifth 10-Year ISI interval (ending May 10, 2028) and the remainder of the period of extended operation, which ends on September 8, 2036 for BSEP Unit 1 and December 27, 2034 for BSEP Unit 2.

### 3.2 NRC Staff Evaluation

The NRC staff evaluated the licensee's PFM analysis of subject RPV nozzles, management of aging effects on the subject RPV nozzles, including the neutron fluence calculations.

#### 3.2.1 Recirculation Outlet Nozzle Probabilistic Fracture Mechanics Evaluation

The conditions for Code Case N-702 specified in RG 1.147, Revision 19 require that the applicability of Code Case N-702 be shown by demonstrating that the acceptance criteria in the SE for BWRVIP-108 or the SE for BWRVIP-241 are met. These acceptance criteria were developed to ensure that the probabilities of failure (PoFs) from the supporting PFM results for RPV nozzles are below the NRC safety goal of  $5 \times 10^{-6}$  per year. The acceptance criteria in the SE for BWRVIP-241 are more relaxed than the acceptance criteria in the SE for BWRVIP-108. This relaxation is supported by additional PFM results documented in BWRVIP-241 for limiting RPV nozzles. The licensee selected the acceptance criteria in the NRC's SE for BWRVIP-241 as the basis for addressing the conditions on Code Case N-702 that were defined in the NRC's SE for BWRVIP-108, and demonstrated that all RPV nozzles except the N1 recirculation outlet nozzles met the NRC's acceptance criteria, as shown in Section 3.1 of this SE.

The licensee, therefore, performed a component-specific PFM for the N1 recirculation outlet nozzles in order to demonstrate the impact of adopting Code Case N-702 for that nozzle type. The licensee performed the N1 nozzle PFM analysis using the VIPERNOZ software. The staff reviewed the methods applied in VIPERNOZ as part of the topical report review for BWRVIP-108 and documented the staff's review in the associated safety evaluation. The staff concluded that VIPERNOZ was an appropriate analytical tool for the purpose of demonstrating the acceptability of Code Case N-702 at U.S. BWRs. Therefore, the staff finds the analytical PFM methods applied by the licensee in RA-19-0447 are acceptable for the objectives of the proposed alternative.

The staff reviewed the N1 nozzle PFM analysis documented in the licensee's supplement dated July 30, 2020. The staff noted that the licensee appropriately accounted for plant-specific parameters, such as nozzle geometry, in the stress analysis, and that the licensee included an inherent conservatism in the PFM by assuming all fatigue cycles were due to the most limiting cold overpressure transient.

In the licensee's supplement dated October 27, 2020, the licensee provided additional information about the N1 nozzle plant-specific PFM, including a correction of the number of PFM calculational realizations performed in the analysis from a value of  $2 \times 10^6$  realizations to  $1 \times 10^6$  realizations. The staff noted that, using the approved VIPERNOZ methods, the licensee calculated PoF values of  $1.67 \times 10^{-8}$  per reactor year for normal operations of the BSEP units and  $1.67 \times 10^{-11}$  per reactor year for the assessed limiting cold overpressure event. The staff determined that this provides sufficient demonstration that the N1 RPV outlet nozzles will meet the NRC's acceptance criteria and safety goal of  $5 \times 10^{-6}$  per year, as defined in RG 1.174.

“An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis” dated January 2018 (ADAMS Accession No. ML17317A256).

Based on the licensee’s evaluation discussed in Section 3.1 of this SE, the staff confirmed that all other BSEP RPV nozzle-to-shell welds and nozzle inner radii sections have met the conditions and criteria for applying Code Case N-702 that were defined in the staff’s SE for BWRVIP-108. Therefore, the NRC staff finds the licensee’s calculations acceptable for all other RPV nozzles.

The NRC staff finds that the licensee has demonstrated by either a plant-specific PFM analysis or generic PFM analysis that all subject RPV nozzles and associated attachment welds have PoFs that are within the NRC’s safety goal and acceptance criterion of  $5 \times 10^{-6}$  per year.

### 3.2.2 Management of Aging Effects

The staff noted that, since the licensee is requesting relief in the period of extended operation, the licensee has appropriately addressed aging management and TLAA evaluation considerations. Specifically, the staff noted that the procedure described in BWRVIP-241 Appendix A provides a framework for licensees to reference BWRVIP-108 and BWRVIP-241 in an integrated plant assessment or TLAA evaluation. The staff noted that the evaluation in BWRVIP-241 Appendix A appropriately addresses management or evaluation of stress corrosion cracking (SCC), fatigue and neutron embrittlement aging mechanisms in RPV nozzle locations.

The staff further noted that the licensee appropriately addressed both SCC-induced flaw growth and fatigue or cycle-dependent flaw growth for the N1 RPV outlet nozzles in its PFM analysis that was included in the licensee’s July 30, 2020 letter. The staff also confirmed that, in the licensee’s past license renewal application for BSEP, Units 1 and 2, the licensee assessed the environmental impacts of fatigue on the cumulative usage factor analyses ( $CUF_{en}$  analyses) for the Unit 1 and 2 RPV components, as verified in NUREG-1856, “Safety Evaluation Report Related to the License Renewal of Brunswick Steam Electric Plant, Units 1 and 2” (ADAMS Accession Nos. ML061730123 and ML061730129). The staff verified that this included the licensee’s 60-year  $CUF_{en}$  assessments for the RPV inlet and outlet nozzles and that the licensee demonstrated the  $CUF_{en}$  values of the RPV nozzles will remain below an acceptance criterion of 1.0 through the end of the 60-year service term for the BSEP units.

From an aging management and a deterministic condition-monitoring inspection basis, the staff noted that the license proposes to use ultrasonic testing (UT) as the basis for inspecting the 25 percent population of nozzles during the expanded 20-year plant life, with one potential exception on the inspection method selected for the examinations of the nozzle inner radius sections. Specifically, the licensee stated that ASME Code Case N-702 permits use of VT-1 visual examination methods in lieu of the volumetric UT examinations of the nozzle inner radius sections. However, the licensee stated that, since the NRC staff has not endorsed the use of Code Case N-702 for VT-1 examinations, Code Case N-648-2 will be used according to the conditions specified in RG 1.147, Revision 19, if a VT-1 visual examination is performed in lieu of UT for a given nozzle inner radius section. In the licensee’s supplement dated October 27, 2020, the licensee acknowledged and confirmed that Code Case N-648-2 is required and will be used if VT-1 is used in lieu of UT for a given RPV nozzle inner radius section.

The staff finds performing a VT-1 visual examination in lieu of UT inspection for a designated RPV nozzle inside radius section in the referenced 25 percent nozzle population acceptable because: (a) the criteria in 10 CFR 50.55a(b)(5) permit industry licensees to use alternative ASME ISI requirements in ASME Section XI, Code Cases if the Code Cases are endorsed for use in the latest version of RG 1.147 issued by the staff, as subject to any NRC-issued limitations or conditions on use of the Code Case cited in the specified version of RG 1.147, and (b) ASME Code Case N-648-2 has been endorsed for use in RG 1.147, Revision 19, with one condition that does not impact the licensee's application of the code case during the period of extended operation.<sup>1</sup>

Based on 10 CFR Part 50, Appendix H, Paragraph III.A, the staff reviewed the projected neutron fluence at the end of the period of extended operation (54 effective full power years) for the referenced reactor pressure vessel nozzle-to-vessel weld and inner radii section locations and verified that the fluence exposures will not exceed the neutron fluence criterion of  $1.0 \times 10^{17}$  n/cm<sup>2</sup> (E>1 MeV) at the end of the period of extended operation.

Specifically, the licensee indicates that the calculations for neutron fluence projections for pressure-temperature limit report (PTLR) were performed based on the NRC-approved methodology as described in WCAP-17660, "Neutron Exposure Evaluations for Core Shroud and Pressure Vessel Brunswick Units 1 and 2" dated May 29, 2018 (ADAMS Accession No. ML18149A487). The licensee also stated that the neutron fluence projections or evaluation for the BSEP reactor pressure vessel nozzle-to-vessel welds and inner radii over the period of extended operation (54 effective full power years) can be found from the relief request, WCAP-17660 and PTLR-related documents.

In the supplement dated October 27, 2020, the licensee provided the additional information related to the fluence analysis for the BSEP RPVs and RPV nozzles that were assessed in Westinghouse Letter No. LTR-REA-13-19 (Attachment 1 of the supplement), "Additional Request for RPV Fast Neutron Fluence at Brunswick Unit 1 and 2, February 27, 2013." The staff observed that this Westinghouse letter provides the life-time fluence for 54 Effective-Full-Power-Years (EFPY) of operation at the recirculation outlet nozzles (N1) at 0° and 180° azimuths and vessel heights for the nozzles, with the top elevations of these nozzles being 192.9" above vessel zero height. Since the reactor exhibits quadrant symmetry (i.e., only a 0° to 90° sector is depicted), the azimuthal profiles clearly indicate that the life-time fluences of the N1 RPV outlet nozzle locations are below the extended beltline fluence threshold of  $1.0 \times 10^{17}$  n/cm<sup>2</sup> (E > 1MeV) for BSEP Unit 1 and Unit 2. In addition, the licensee confirmed in a November 17, 2020, supplement that the neutron fluence results as provided in the October 27, 2020, supplement are based on the same model, computer code, and methodology used in WCAP-17660, Revision 0 without any changes.

Based on the above, the staff finds that the projection for the neutron fluence at the end of the period of extended operation for the RPV nozzle-to-vessel welds and inner radii sections will not exceed the neutron fluence criterion of  $1.0 \times 10^{17}$  n/cm<sup>2</sup> (E>1 MeV) at the end of the period of extended operation. The staff finds that the projection meets the acceptance criteria specified in 10 CFR Part 50, Appendix H, Paragraph III.A, because: (1) the licensee is applying the same fluence methodology in WCAP-17660-NP as the basis for calculating the neutron fluence values

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<sup>1</sup> The condition states Code Case N-648-2 shall not be used to eliminate the preservice or inservice volumetric examination of plants with a combined license under 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," or a plant that receives its operating license after October 22, 2015. This condition does not apply to BSEP for the evaluated relief request and the period that applies to the relief request.

of the RPV nozzles assessed in RR No. RA-19-0447 through the end of the period of extended operation, and (2) the staff has verified and accepted that this fluence methodology has been applied to the neutron fluence analysis in extended beltline region since the same neutron fluence analysis model and methodology has been applied to the neutron fluence analysis in extended beltline region in the past and accepted by the staff as the current licensing basis for the BSEP (US NRC Letter to Carolina Power & Light Company "Brunswick Steam Electric Plant Units 1 and 2 – Issuance of Amendment Re: Pressure Temperature Limit Curves," June 18, 2003, (ADAMS Accession No. ML031690683)).

Based on these evaluations, the staff finds that the licensee has appropriately considered aging management considerations and both deterministic and probabilistic time limited aging analysis implications in the subject PFM assessments for the RPV nozzles, including the plant-specific PFM performed for the N1 RPV outlet nozzles and the generic PFM assessment for the N2 RPV inlet nozzles.

### 3.2.4 Technical Evaluation Summary

The NRC staff determined that the licensee has addressed the conditions for using ASME Code Case N-702 specified in RG 1.147, Revision 19. The conditions require evaluation of the plant-specific RPV nozzle information against the five evaluation criteria specified in the NRC's SE for BWRVIP-108 dated December 19, 2007, or the NRC's SE for BWRVIP-241 dated April 19, 2013. The NRC staff further determined that:

- (1) the subject RPV nozzles, including the N1 RPV outlet nozzles, satisfy the NRC acceptance criteria of  $5 \times 10^{-6}$  per year;
- (2) the licensee has adequately addressed aging management and TLAA evaluation considerations of the RPV nozzles during the period of extended operation; and
- (3) the licensee's neutron fluence projections for the RPV nozzles at the end of the period of extended operation have been considered and accounted for in the applicable RPV nozzle PFM assessments.

Therefore, the NRC staff determined that with the exception of the assessment for the N1 RPV outlet nozzles, the licensee has adequately addressed the conditions in RG 1.147, Revision 19, for the use of ASME Code Case N-702 for the subject RPV nozzles of BSEP, Units 1 and 2 for the Fifth 10-Year ISI Interval and the remainder of the period of extended operation.

For the N1 RPV outlet nozzles, the staff has determined that the licensee's supplemental and component-specific PFM analysis of the nozzles has been performed in accordance with the staff-accepted PFM methodology in BWRVIP-241-A and that the licensee has sufficiently demonstrated that the PoF of the RPV nozzles will be no greater than  $5 \times 10^{-6}$  per reactor year, even if the postulated failure location is predicated on a failure of the N1 RPV outlet nozzle in the RPV design. Thus, for the N1 RPV outlet nozzles, the staff has determined that the licensee has demonstrated that the PFM for the N1 RPV nozzles meets the acceptance criteria set in RG 1.174 and that the licensee has justified inclusion of N1 RPV outlet nozzles in the scope of the RPV nozzle population proposed and assessed in this request for alternative.

#### 4.0 CONCLUSION

Based on the above evaluation, the NRC staff determined that the licensee's proposed alternative provides an acceptable level of quality and safety in lieu of complying with the requirements in ASME Code, Section XI, Table IWB-2500-1, Examination Category B-D, Inspection Items B3.90 and B3.100. 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). Therefore, the NRC staff authorizes the use of proposed alternative RA-19-0047 for inspection of nozzle-to-vessel shell welds and nozzle inner radius sections for the requested RPV nozzles at BSEP, Units 1 and 2, for the Fifth 10-Year ISI Interval and the remainder of the period of extended operation.

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.

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Date: February 2, 2021