UNITED STATES
NUCLEAR REGULATORY COMMISSION
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August 30, 2022

PEACH BOTTOM ATOMIC POWER STATION, UNIT 2 - AUTHORIZATION AND SAFETY EVALUATION FOR ALTERNATIVE REQUEST I5R-14, REVISION 1, (EPID L-2022-LLR-0006)

LICENSEE INFORMATION

Recipient's Name and Address: Mr. David P. Rhoades
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Licensee: Constellation Energy Generation, LLC

Plant Name and Unit: Peach Bottom Atomic Power Station (Peach Bottom), Unit 2

Docket No.: 50-277

APPLICATION INFORMATION

Submittal Date: December 20, 2021

Submittal Agencywide Documents Access and Management System (ADAMS) Accession No.: ML22003A002

Supplement Date: May 25, 2022

Supplement ADAMS Accession No.: ML22145A085

Applicable Inservice Inspection (ISI) Program Interval and Interval Start/End Dates: The fifth 10-year ISI interval, January 1, 2019, to December 31, 2028.

Alternative Provision: The licensee requested an alternative under Title 10 of the *Code of Federal Regulations* (10 CFR), paragraph 50.55a(z)(2). However, the U.S. Nuclear Regulatory Commission (NRC) staff will evaluate it in accordance with 10 CFR 50.55a(z)(1).

ISI Requirement: The American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code) requirements applicable to this request originate in Section XI, IWA-3000, IWA-4000, IWA-5000, and IWB-3000 which include:

- Corrective action and defect removal requirements of IWA-5250(a)(3), IWA-4412, and IWA-4611.1(a).
- Flaw characterization requirements of IWB-3420, IWA-3300(a) and (b).

- Flaw evaluation requirements of IWB-3522.1, IWB-3142.1(b), IWB-3610(b), and IWB-3600.
- ASME Code Case N-749, "Alternative Acceptance Criteria for Flaws in Ferritic Steel Components Operating in the Upper Shelf Temperature Range Section XI, Division 1." ASME Code Case N-749 has been incorporated by reference into 10 CFR 50.55a via inclusion in Regulatory Guide (RG) 1.147, Revision 20, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1," with a condition. The condition states that in lieu of the code case defined upper shelf transition temperature T_c, the NRC-defined $T_c = 154.8^o F + 0.82\ RT_{NDT}$ shall be used. In addition, the NRC defines temperature $T_{c1} = 95.36^o F + 0.703\ RT_{NDT}$ which the linear elastic fracture mechanics (LEFM) must be applied. Between the NRC-defined T_{c1} and T_c, although the fracture mode is in transition from LEFM to elastic plastic fracture mechanics (EPFM), users should consider whether it is appropriate to apply the EPFM. Alternatively, a different T_c value may be used if it can be justified by the plant-specific Charpy curves.

Applicable Code Edition and Addenda: The code of record for the fifth 10-year ISI interval is the 2013 Edition with no addenda of the ASME Code, Section XI. The code of construction for the reactor vessel (RV) is the 1965 Edition through Winter 1965 Addenda of ASME Code, Section III.

Brief Description of the Proposed Alternative: The licensee proposed that the previously repaired RV nozzle N-16A continue to remain in service for the remainder of the fifth 10-year ISI interval which is scheduled to end on December 31, 2028, and the plant life which will end on August 8, 2053. For support of its proposed alternative, the licensee provided for the NRC review the following analyses to demonstrate that the structural integrity and leak tightness of the repaired RV nozzle N-16A will be maintained through the remainder of the plant life.

- An analysis of the worst-case flaws left in service in the original nozzle N-16A J-groove weld that could propagate into the RV shell during plant life.
- An analysis of general corrosion, crevice corrosion, and galvanic corrosion of the RV low-alloy steel (LAS) that could be exposed to the boiling water reactor (BWR) coolant during plant life because of the half-nozzle repair of nozzle N-16A.

As part of background information, the licensee stated that a leak was discovered at the 2-inch RV instrument penetration nozzle N-16A during routine pre-startup system leakage test in the refueling outage P2R23 on October 29, 2020. A visual examination of nozzle N-16A wetted surface from the inside of RV supplemented by an ultrasonic testing (UT) of nozzle N-16A from the outside surface of RV confirmed a surface connected planar radial-axial crack in the J-groove weld. Neither planar axial cracks in the adjacent RV LAS base material nor circumferential cracks in the J-groove weld and RV LAS were detected. Currently, the UT techniques are not qualified in accordance with the ASME Code, Section XI, Appendix VIII, and are not capable to accurately characterize the crack geometries in dissimilar metal J-groove weld. By letters dated November 4, 2020 (ML20309B020), and November 24, 2020 (ML20329A345), the licensee submitted alternative request I5R-14 in accordance with 10 CFR 50.55a(z)(2) in which it proposed to restore the reactor coolant pressure boundary (RCPB) of nozzle N-16A by an alternative half-nozzle repair, and it provided the basis that compliance with the ASME Code repair would result in hardship. This alternative repair method consisted of partially replacing the existing Alloy 600 nozzle with Alloy 690/52 nozzle and leaving the remnant of original Alloy 600 nozzle and its Alloy 182 partial penetration attachment weld that contained the crack in service. This repair method could expose the RV LAS base material to the BWR coolant environment. Operating experience has shown that Alloy 600/182 materials are susceptible to the intergranular stress corrosion cracking (IGSCC). Alloy 690/52

materials are known to be less susceptible to the IGSCC than Alloy 600/182. To support its alternative repair of nozzle N-16A, the license performed a flaw and corrosion analysis to justify one-cycle operation. By verbal authorization dated November 6, 2020 (ML20314A028), followed by safety evaluation dated April 23, 2021 (ML21110A680), the NRC authorized alternative request I5R-14, which included the licensee's design of the half-nozzle repair, analysis of the flaw left in service, and analysis of the RV LAS corrosion for the duration of one-cycle operation which is scheduled to end in the fall of 2022.

For additional details on alternative request I5R-14, Revision 1, please refer to the documents located at the ADAMS Accession Nos. identified above.

STAFF EVALUATION

The NRC staff evaluated alternative request I5R-14, Revision 1, pursuant to 10 CFR 50.55a(z)(1). The licensee provided technical bases to support the continued operation for the remainder of the fifth 10-year ISI interval which is scheduled to end on December 31, 2028, and additional technical bases for the remainder of plant life which will end on August 8, 2053. The NRC staff focused on whether the proposed alternative (i.e., the previously repaired RV nozzle N-16A with the technical bases to support the continued operation for the remainder of the fifth 10-year ISI interval) provides an acceptable level of quality and safety. The NRC staff's review of the licensee's additional technical basis are as follows:

Evaluation of Licensee's Plant-Specific Flaw Analysis

The licensee's flaw analysis consists of a flaw growth evaluation into RV LAS by fatigue and SCC, and a combination of LEFM and EPFM evaluations in accordance with the ASME Code, Section XI. The licensee considered a projected 80-year transient cycles in its flaw analysis. The licensee used the analysis to show that the existing flaw left in service in the original nozzle N-16A J-groove weld that could propagate into the RV LAS shell would not impact the structural integrity of the RV during the plant life. Detail of the flaw analysis is provided in non-proprietary Attachments 6 and 7 of I5R-14, Revision 1. In its review, the NRC staff verified that:

- The licensee assumed the entire as-left original N-16A J-groove weld is completely cracked, and the crack will potentially propagate into the RV LAS base material. The staff finds the licensee's assumption is conservative on the basis that (a) the currently available nondestructive examination (NDE) techniques have not been able to characterize any "as-left" flaws in the J-groove weld with reasonable confidence, (b) this postulated initial flaw is the worst-case flaw that bounds any actual cracks left in service that have existed in the attachment weld of nozzle N-16A, and (c) this characterization of a leaked flaw based on the worst-case assumption is consistent with industry practice.

- The licensee assumed the preferential direction for potential crack propagation into the LAS material is radial-axial relative to the nozzle and RV. The NRC staff finds the assumption of radial-axial crack is conservative because the hoop stress in the RV at the nozzle N-16A J-groove weld location is determined to be dominant.

- The licensee calculated fatigue crack growth for cyclic loading conditions using combined welding residual stress (WRS) and operational stresses from pressure and thermal loads in accordance with ASME Code, Section XI, Appendix A, A-4300. The licensee calculated the crack growth for 34 years of operation starting from the time of nozzle N-16A repair in 2020 through the remainder of 80-year operating license ending on August 8, 2053. The final flaw size includes fatigue crack growth from all applicable transients including the crack growth due to stress corrosion cracking (SCC). The NRC

staff finds the licensee's crack growth calculation is adequate and complies with the ASME Code, Section XI.

- The licensee used a bounding crack growth rate data in topical report, BWR Vessel and Internals Project (BWRVIP)-60-A, "BWR Vessel and Internals Project, Evaluation of Stress Corrosion Crack Growth in Low Alloy Steel Vessel Materials in the BWR Environment," to determine cracking into the RV LAS base material from the service--related degradation. The NRC staff finds that BWRVIP-60-A contains an NRC acceptable methodology for determination of crack growth due to SCC in RV LAS in the BWR environment, thus is adequate for this analysis.

- The licensee utilized a finite element model to obtain the applied stresses and WRS in the RV shell at the nozzle J-groove weld location in its flaw analysis. The crack driving force are the applied stresses (i.e., thermal and pressure) and WRS. The applied stresses were based on bounding design basis transients of normal/upset condition (heat-up/cool-down, loss-of-pump, and single relief) and emergency/faulted condition (overpressure). The licensee's modeling included the RV LAS base material, remnant of original Alloy 600/182 nozzle with its attachment J-groove weld, stainless steel cladding, Alloy 52M weld pad, Alloy 690/52M replacement nozzle with its attachment weld. The NRC staff finds that the licensee's finite element model is acceptable because appropriate materials, plant-specific configurations, and loading conditions were used.

- The NRC staff confirmed that the licensee's flaw analysis of as-left N-16A J-groove weld used the same projected bounding transient cycles to 80 years operation as the Peach Bottom subsequent license renewal application which the NRC has approved. Therefore, the NRC staff finds it acceptable.

- The NRC staff confirmed that the fracture material properties including adjusted reference nil-ductility temperature RT_{NDT} (ART) of N-16A nozzle location are calculated using the method from RG 1.99, Revision 2, "Radiation Embrittlement of Reactor Vessel Materials." Therefore, that NRC staff finds it acceptable.

- In its fracture mechanics analysis of the final flaw size, the licensee utilized the criteria in ASME Code Case N-749 with the condition in RG 1.147, Revision 20, to determine acceptability of flaw in the RV LAS when the metal temperature is in the upper shelf range. The NRC imposed condition for the N-749 criteria is: (a) use the EPFM method of analysis if the metal temperature exceeds the NRC-defined temperature T_c, (b) use the LEFM method of analysis if the metal temperature drops below the NRC-defined temperature T_{c1}, and (c) for metal temperature between T_c and T_{c1}, assess suitability of using EPFM since the fracture mode is in transition from LEFM to EPFM. To satisfy the above condition (b), the licensee performed LEFM evaluation for the final flaw size obtained from its crack growth calculation. The applied stress intensity factor, K, is evaluated accounting for the plastic zone correction, and its acceptability is evaluated based on the rules outlined in ASME Code, Section XI, IWB-3612. IWB-3612 requires that the applied stress intensity factor be less than the available fracture toughness at the crack tip temperature, with appropriate safety factor in accordance with ASME Code, Section XI. The licensee's LEFM results for the bounding crack tip position are shown in Table 6-15 of I5R-14, Revision 1, for the bounding transient conditions. To satisfy the above conditions (a) and (c), the licensee performed EPFM evaluation for the final flaw

size obtained from its crack growth calculation. EPFM is performed based on Section 3 criteria of N-749 to evaluate crack driving force and flaw stability when the flaw related failure mechanism is unstable ductile tearing. The licensee's EPFM results are shown in Table 6-16 of I5R-14, Revision 1. From review of licensee's LEFM and EPFM results, the NRC staff verified that the licensee's calculated margins exceed the ASME Code, Section XI required margins during each of the transients. Therefore, the ASME Code acceptance criteria are met for the remainder of the current fifth 10-year ISI interval.

Therefore, the NRC staff concludes that the licensee's flaw analysis is acceptable because a conservative initial flaw size is assumed, the projected bounding transient cycles to 80 years is used in the flaw growth calculation to obtain the final flaw size, conservative flaw growth rate due to SCC is assumed, and the flaw analysis has demonstrated that the bounding postulated worst-case flaw in nozzle N-16A left in service will not grow to an unacceptable depth into the RV LAS base material for the remainder of the current fifth 10-year ISI interval.

Evolution of Licensee's Plant-Specific Corrosion Analysis

The licensee performed a plant-specific corrosion analysis to show that the corrosion of RV LAS base material exposed to the BWR water conditions due to the half-nozzle repair of nozzle N-16A would not impact the structural integrity of RV during the plant life. The nozzle N-16A repair exposes the RV LAS reactor vessel in a small area to a water environment. The possible corrosion mechanisms for LAS in BWR environment are known to be general corrosion, galvanic corrosion, crevice corrosion, and SCC. The reactor water chemistry control program for Peach Bottom is based on BWRVIP-190, Revision 1, "BWR Vessel and Internals Project, Volume 2: BWR Water Chemistry Guidelines." Detail of the corrosion analysis is provided in non-proprietary Attachment 8 of I5R-14, Revision 1. In its review, the NRC staff verified that:

- The licensee calculated the general corrosion rate on a per year basis for LAS based on bounding laboratory testing data and showed that the total surface corrosion of RV LAS at the exposed location for remaining life of the plant following nozzle N-16A repair would be very low. From review of the licensee's general corrosion calculations, the NRC staff finds that the potential metal loss due to general corrosion of RV LAS is insignificant for the remainder of the current fifth 10-year ISI interval following nozzle N-16A repair.

- The licensee addressed the crevice corrosion and galvanic corrosion susceptibly of LAS based on laboratory simulation and operating experience (OE). The licensee cited the maximum amount of the crevice and galvanic corrosion rates of RV LAS at the exposed location for the remainder of the current fifth 10-year ISI interval is minimal and bounded by the general corrosion rate. The NRC staff finds the licensee's assertion is acceptable based on the laboratory findings, OE, and implementation of industry standard corrosion mitigate program at Peach Bottom (e.g., on-line noble metal chemical addition with hydrogen water chemistry).

- The licensee assessed the potential for SCC of the RV LAS at the exposed location for the remainder of the current fifth 10-year ISI interval and concluded that the potential for SCC is not a concern. The NRC staff finds that the licensee's assertion acceptable because the laboratory studies illustrated that crack initiation and growth is extremely difficult and no incidence of the SCC induced damage has been observed in LAS in the BWR environment.

In summary, the NRC staff finds the licensee's plant-specific analysis acceptable because a conservative initial flaw is assumed, and the flaw evaluation has demonstrated that the initial worst-case flaw will not grow to an unacceptable depth into the RV LAS base material over the current fifth 10-year ISI interval. Furthermore, the corrosion impact on RV LAS from exposure to the BWR coolant is determined to be low over the current fifth 10-year ISI interval. As a result, the NRC staff finds that the licensee's alternative repair of nozzle N-16A has restored the RCPB and provides reasonable assurance of the RV and nozzle N-16A structural integrity for the remainder of the current fifth 10-year ISI interval.

CONCLUSION

The NRC staff determined that the licensee's proposed alternative provides an acceptable level of quality and safety. The NRC staff concludes that the licensee has adequately addressed all of the regulatory requirements set forth in 10 CFR 50.55a(z)(1). The NRC staff authorizes the use of proposed alternative I5R-14, Revision 1, at Peach Bottom, Unit 2, for the remainder of the current fifth 10-year ISI interval ending December 31, 2028.

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

Principal Contributor: A. Rezai, NRR

Date: August 30, 2022

Hipolito J. Gonzalez

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PEACH BOTTOM ATOMIC POWER STATION, UNIT 2 – AUTHORIZATION AND SAFETY EVALUATION FOR ALTERNATIVE REQUEST I5R-14, REVISION 1, (EPID L-2022-LLR-0006) DATED AUGUST 30, 2022

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