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

August 15, 2018

ANO Site Vice President
Arkansas Nuclear One
Entergy Operations, Inc.
N-TSB-58
1448 S.R. 333
Russellville, AR 72802

SUBJECT: ARKANSAS NUCLEAR ONE, UNIT 2 – ALTERNATIVE TO EXAMINATION OF REACTOR PRESSURE VESSEL FLANGE THREADS (EPID L-2018-LLR-0003)

Dear Sir or Madam:

By application dated February 5, 2018, Entergy Operations, Inc. (Entergy, the licensee) submitted a request for an alternative for Arkansas Nuclear One, Unit 2. The licensee proposed an alternative to performing the inservice inspection volumetric examinations that are required to be performed on the reactor pressure vessel (RPV) closure flange in accordance with American Society of Mechanical Engineers Boiler and Pressure Vessel Code ASME Code, Section XI, Division 1.

Specifically, the licensee submitted the proposed alternative in accordance with the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) paragraph 50.55a(z)(1) on the basis that the alternative provides an acceptable level of quality and safety.

The U.S. Nuclear Regulatory Commission (NRC) staff has reviewed the subject request, and concludes, as set forth in the enclosed safety evaluation, that Entergy has adequately addressed all of the regulatory requirements set forth in 10 CFR 50.55a(z)(1) for the proposed alternative. Therefore, the NRC staff authorizes the alternative ISI criteria for the RPV closure flange threads for the fourth 10-year interval at ANO-2 until March 25, 2020.

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 Inservice Inspector.

If you have any questions, please contact the Project Manager, Thomas Wengert at (301) 415-4037 or by e-mail at Thomas.Wengert@nrc.gov.

Sincerely,

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

Docket No. 50-368

Enclosure:
Safety Evaluation

cc: Listserv

UNITED STATES
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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELIEF REQUEST FOR ALTERNATIVE INSERVICE INSPECTION REQUIREMENTS

FOR CLOSURE FLANGE THREADS IN THE REACTOR PRESSURE VESSEL

ENTERGY OPERATIONS, INC.

ARKANSAS NUCLEAR ONE, UNIT 2

DOCKET NO. 50-368

1.0 INTRODUCTION

By letter dated February 5, 2018 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML18038A876), Entergy Operations, Inc. (Entergy, the licensee) submitted inservice inspection (ISI) Relief Request No. ANO2-ISI-020 for Arkansas Nuclear One, Unit 2 (ANO-2). The licensee proposed to use a linear elastic fracture mechanics (LEFM) evaluation as an alternative to performing the ISI volumetric examinations that are required to be performed on the reactor pressure vessel (RPV) closure flange in accordance with American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME Code), Section XI, Division 1.

Specifically, pursuant to Title 10 of the *Code of Federal Regulations* (10 CFR) paragraph 50.55a(z)(1), the licensee requested to use the proposed alternative on the basis that the alternative provides an acceptable level of quality and safety.

2.0 REGULATORY EVALUATION

The regulations in 10 CFR 50.55a establish the U.S. Nuclear Regulatory Commission's (NRC or the Commission) regulatory requirements for applying and using industry codes and standards in the licensing bases of U.S. light water reactor (LWR) facilities. The rule requires licensees to perform ISI of their LWR facilities using the requirements in ASME Code, Section XI.

The regulations in 10 CFR 50.55a(g)(4), "Inservice inspection standards requirements for operating plants," require components defined as ASME Code Class 1, 2, or 3 components (including ASME code class component supports) to meet the requirements set forth in ASME Code, Section XI, except the design and access provisions and the preservice examination requirements. Furthermore, for these types of components, the regulation in 10 CFR 50.55a(g)(4)(ii), "Applicable ISI Code: Successive 120-month intervals," requires licensees to apply and comply with the requirements of the latest edition and addenda of the ASME Code incorporated by reference in 10 CFR 50.55a(g), 12 months prior to the start of the 120 month (i.e., 10-year) ISI interval, or use the optional ASME Code Cases listed in NRC

Regulatory Guide (RG) 1.147, Revision 17, "Inservice Inspection Code Case Acceptability, ASME Section XI, Division 1," dated August 2014 (ADAMS Accession No. ML13339A689), as subject to the conditions listed in 10 CFR 50.55a(b), "Use and conditions on the use of standards."

The regulations in 10 CFR 50.55a(z), "Alternatives to codes and standards requirements," permit alternatives to the requirements 10 CFR 50.55a when authorized by the Director of the NRC's Office of Nuclear Reactor Regulation. A proposed alternative must be submitted and authorized prior to implementation, and the licensee must demonstrate either: (1) the proposed alternative 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 staff approval of an ISI alternative and for the NRC to review the proposed alternative for acceptability and approval.

3.0 TECHNICAL EVALUATION

3.1 The Licensee's Alternative

3.1.1 ASME Components Affected

The proposed alternative applies to the threads located in the RPV closure flange, which constitutes part of the reactor coolant pressure boundary for the LWR at ANO-2.

3.1.2 Applicable Code Edition and Addenda

The applicable ASME Code section requirements are those provided in the 2001 Edition of ASME Code Section XI, inclusive of the 2003 Addenda, which was the most current edition and addenda of ASME Code Section XI referenced in 10 CFR 50.55a, 12 months prior to entry into the fourth 10-year ISI interval for ANO-2. ANO-2's fourth 10-year ISI interval commenced on March 26, 2010, and is currently scheduled to end on March 25, 2020.

3.1.3 Applicable Code Requirements

The ISI requirements set forth in ASME Code Section XI for performing ISI of RPV closure flange threads are given in ASME Code Section XI, Table IWB-2500-1, Examination Category B-G-1, "Pressure Retaining Bolting, Greater Than 2 in. (50.8 mm) In Diameter," Inspection Item B6.40, "Reactor Vessel - Threads in Flange." This ASME inspection item requires the licensee to perform volumetric inspections of 100 percent of the threaded regions in the RPV closure flange holes during each 10-year ISI interval.

3.1.4 Reason for the Request

The licensee stated that it has coordinated with the Electric Power Research Institute (EPRI) and other licensed members of the U.S. LWR industry to formulate a generic technical basis for eliminating the ISI volumetric inspections that are required to be performed on RPV closure flange threads during a scheduled 10-year ISI interval. The licensee stated that imposition of the current ISI requirements for the threads are not commensurate with additional burden

placed on the licensee if the ISI inspections were performed in accordance with the ASME Section XI requirements.[1]

3.1.5 Proposed Alternative

The licensee's proposed alternative uses the generic methodology in EPRI Technical Report (TR) No. 3002007626, "Nondestructive Evaluation: Reactor Pressure Vessel Threads in Flange Examination Requirements," dated March 2016 (ADAMS Accession No. ML16221A068) and a plant-specific LEFM analysis to serve as an alternative ISI basis in lieu of implementing the volumetric inspections that are required to be performed on the RPV closure flange threads during the fourth 10-year ISI interval. The generic methodology uses finite element modeling to establish the applied stress intensity factors (i.e., applied K_I values) for postulated flaw sizes evaluated in the report and LEFM methods to establish the upper bound limit (i.e., maximum allowable K_I value) on the applied stress intensity factors for postulated flaw sizes in the stress analysis. The licensee's request also includes a plant-specific LEFM analysis of the RPV closure flange to demonstrate that any postulated flaws in the threaded regions of the flange would be stable through 80 years of licensed power operations of the facility, even if additional licensee-imposed conservatisms are accounted for in the plant-specific analysis basis. The licensee also provided plant-specific design data to demonstrate that the RPV closure flange design at ANO-2 is within scope of the generic RPV closure flange design analyzed in the EPRI report.

3.2 NRC Staff Evaluation

3.2.1 Basis for Accepting Use of the Generic Methodology in EPRI TR No. 3002007626

The generic methodology in EPRI TR No. 3002007626 has not yet been endorsed for use in any ASME Code Case approved for use in RG 1.147 or in an NRC staff-issued safety evaluation for the methodology. Therefore, the NRC staff finds it appropriate that any basis for using the methodology to eliminate the ISI volumetric examinations of RPV closure flange threads during a scheduled 10-year ISI interval would need to be included as part of a Code relief submitted in accordance with 10 CFR 50.55a(z) requirements. The alternative ISI requirement proposal submitted by the licensee's letter dated February 5, 2018, fulfills this regulatory necessity.

The licensee relied on the EPRI report for the technical basis for the proposed alternative to eliminate examination of threads in RPV flanges. The NRC staff focused its evaluation of the proposed alternative on the deterministic stress analyses and flaw tolerance evaluation in the EPRI report, but also considered operating experience and potential degradation mechanisms. Each of these topics were discussed in the EPRI report and in the licensee's submittal.

By letter dated January 26, 2017 (ADAMS Accession No. ML17006A109), the NRC staff authorized Southern Nuclear Operating Company, Inc. (SNC) to use a similar alternative at Vogtle Electric Generating Plant, Units 1 and 2, and Joseph M. Farley Nuclear Plant, Unit 1, which was also based on the generic stress analysis and flaw tolerance evaluation in the EPRI

[1] The licensee identified plant worker exposure, personnel safety, radwaste generation, critical path time, and additional time at reduced reactor coolant inventory as examples of the types of burdens that implementation of the volumetric examinations would impose on Entergy if performed in accordance with the applicable ISI requirements.

report. Section 3.2.1 of the safety evaluation for the SNC authorization documents the staff's evaluation of the EPRI report, and concludes that EPRI's generic stress analysis and flaw tolerance evaluation are acceptable and the results can be used to support eliminating the examination of threads in the RPV flange. For Entergy's proposed alternative, the staff relied on this previous evaluation and focused on the plant-specific RPV flange thread information to determine if EPRI's generic stress analysis and flaw tolerance evaluation is applicable to ANO-2. The following paragraphs briefly summarize key aspects of the generic methodology used in EPRI TR No. 3002007626.

For the generic pressurized-water reactor (PWR) flange design (which was based on an evaluation of the RPV closure flanges in 10 PWRs), EPRI calculated that preloads up to a maximum value of 42,338 pounds per square inch (psi) would be needed to ensure the integrity of RPV closure flanges used in the U.S. LWR industry. EPRI also used finite element modeling (FEM) to establish the applied K_I values for the following range of flaw sizes evaluated in the EPRI report: (a) a flaw with a flaw depth-to-thickness (a/t) ratio of 0.02, (b) a flaw with an a/t ratio of 0.29, (c) a flaw with an a/t ratio of 0.55, and (d) a flaw with an a/t ratio of 0.77, which represents the limiting flaw size in an RPV closure flange allowed by the ASME Code Section XI. The K_I values for these a/t ratios are identified in Table 1 below:

Table 1 – EPRI Applied K_I Values at Crack Tip vs "a/t" Flaw Depth-to-Thickness Ratios				
Loading Combination	Applied K_I Values (ksi$\sqrt{}$inch) at Crack Tips for Assumed Flaw Depth Ratios			
	a/t of 0.02	a/t of 0.29	a/t of 0.55	a/t of 0.77
Stud Preload Only[1]	11.2	17.4	15.5	13.9
Preload + Heatup + Pressure[2]	13.0	19.8[3]	16.1	16.3

1. Based on minimum temperature for the closure flange under preloaded stud conditions prior to pressurization and heat-up of the reactor.
2. Based on an EPRI limiting assessed reactor coolant system temperature of 600 degrees Fahrenheit (°F) under preloaded conditions after pressurizing and heating up the reactor. The EPRI basis assumes that the preloads in the studs will remain intact as additional pressure and thermal loads are imparted to the studs during the heat-up process of the reactor. EPRI also bases its Kic of 220 ksi$\sqrt{}$inch for the generic analysis on this temperature value, as EPRI assumes that the plant will be at an elevated temperature associated with critical, full power operations for the majority of the 10-year ISI interval.
3. In contrast, the licensee's plant-specific basis added a 1.7 percent safety margin to this value, based on the licensee's own assumption that the RPV closure flange is designed with 60 studs, with one of the studs being inoperable during plant service. Thus, the licensee's value for this flaw depth and loading condition is 20.14 ksi$\sqrt{}$inch.

The EPRI methodology uses ASME Code Section XI, paragraph IWB-3612 (See Equation 1 below) as the basis for establishing the maximum allowable K_I value for the stress analysis:

$$K_I < K_{Ic} \div \sqrt{10} \quad \text{(Equation 1)}$$

In this equation, K_I is the maximum allowable stress intensity factor for the LEFM analysis, and K_{Ic} is the lower bound fracture toughness value derived from ASME Code Section XI, Figure A-4200-1.

3.2.2 Licensee's Plant-Specific Analysis

Demonstration that the Design of the RPV Closure Flange at ANO-2 is Bounded by the RPV Closure Flange Design Evaluated in EPRI TR No. 3002007626

In its letter dated February 5, 2018, Entergy provided a table (i.e., Table 1 in the Attachment to the letter) to demonstrate that the parameters and design of the RPV closure flange at ANO-2 are within the generic design assumptions for PWR closure flanges evaluated in EPRI TR No. 3002007626. The NRC staff noted that this provides sufficient evidence that the amount of RPV stud preload stress needed to secure the RPV closure flange assembly at ANO-2 (i.e., 36,210 psi) is sufficiently bounded by the maximum preload (i.e., 42,338 psi) that EPRI has identified is needed to secure RPV closure flange designs in the EPRI report. Thus, the staff finds that the design of the RPV closure flange assembly at ANO-2 is sufficiently bounded by the generic RPV closure flange design evaluated in EPRI TR No. 3002007626.

Evaluation of ANO-2's Plant-Specific LEFM Evaluation

The NRC staff verified that this is the first time that the licensee has submitted a relief request for eliminating the ASME Code Section XI, Examination Category B-G-1, Inspection Item B6.40 requirements for the RPV closure flange threads during a scheduled 10-year ISI interval. The staff assessed the validity of licensee's plant-specific LEFM analysis basis to determine whether the analysis provides a sufficiently conservative flaw tolerance basis for eliminating the ISI volumetric examinations of the RPV closure flange threads that are required for the fourth 10-year ISI interval. The staff noted that the licensee's plant-specific LEFM basis is based on stresses for preloading the RPV studs at room temperature, before the plant is heated up or taken critical during power operations. The licensee calculated a K_{Ic} value of 102.0 ksi$\sqrt{in}$ for these loading conditions based on a 70 degree Fahrenheit (°F) minimum permissible temperature for preloading the closure studs and a 10 °F material nil ductility transition reference temperature (RT_{NDT}) value for the alloy steel material used in the design of the closure flange, as obtained from plant records. This is in contrast to EPRI's use of a K_{Ic} value of 220.0 ksi$\sqrt{in}$ for the generic analysis, which is based on an assumed operating temperature of 600 °F during full power operations.

The NRC staff noted that the licensee's basis results in a reduced and more conservative maximum allowable K_I value of 32.3 ksi$\sqrt{in}$ for the licensee's limiting loading case when compared to that used in the generic analysis (i.e., EPRI's maximum allowable K_I value of 69.6 ksi$\sqrt{in}$). The staff also noted that the licensee's basis demonstrates that the stress intensities for postulated flaws in the EPRI report will remain acceptable even when evaluated against the licensee's maximum allowable K_I value of 32.3 ksi$\sqrt{in}$ (i.e., 20.14 ksi$\sqrt{inch}$ < 32.3 ksi$\sqrt{inch}$) in the plant-specific analysis. Therefore, the staff finds the licensee plant-specific LEFM basis to be acceptable because: (a) the licensee's LEFM analysis uses more limiting K_{Ic} and maximum allowable K_I values from those assumed and used by EPRI in its generic LEFM analysis, (b) the maximum allowable K_I value calculated by the licensee still bounds all applied K_I values calculated by EPRI for postulated flaw sizes and loading conditions in Table 6-1 of the EPRI report, and (c) the licensee's plant-specific analysis provides sufficient demonstration and reasonable assurance that any postulated flaws in the RPV closure flange threads will be stable for the duration of the fourth 10-year ISI interval for the unit, which is scheduled to expire on March 25, 2020.

The NRC staff also finds that the licensee's plant-specific analysis provides an adequate deterministic basis for authorizing the licensee's proposal to eliminate the ISI volumetric

examinations of the closure flange threads during the fourth 10-year ISI interval. As a result, the staff has determined that authorization of the licensee's ISI proposal may be granted without any need for considering core damage frequency risk arguments in the analytical basis for the request.

Operating Experience Review

In its letter of February 5, 2018, the licensee provided an operating experience summary of the number of PWR RPV flange inspections that had been performed on PWR RPV flange threads. The licensee stated that the threads in the RPV flanges of 61 PWRs (including those designed by Westinghouse, Combustion Engineering, and Babcock and Wilcox) have been inspected to date and that, of the 6869 inspections performed, no service-induced degradation has been identified.

The NRC staff confirmed that Appendix A of EPRI TR No. 3002007626 provides an operating summary of all ASME Code Section XI required inspections performed on RPV closure flange threads in commercial LWRs and that the appendix supports a conclusion that, to date, there is no evidence of cracking in PWR RPV closure flange assemblies. The staff finds that the licensee's operating experience review supports use of the deterministic LEFM methodology to eliminate the ISI volumetric examinations that are required for the RPV closure flange threads during the fourth 10-year ISI interval at ANO-2.

4.0 CONCLUSION

As set forth above, the NRC staff determines that the proposed alternative in the licensee's letter of February 5, 2018, provides an acceptable level of quality and safety in lieu of performing the required ASME Section XI inspections of the RPV closure flange threads during the fourth 10-year ISI interval for ANO-2. 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 alternative ISI criteria for the RPV closure flange threads at ANO-2 until March 25, 2020.

All other ASME Code, Section XI requirements for which relief was not specifically requested and approved remain applicable, including inspections of RPV closure studs, nuts, washers, and bushings required by ASME Section XI, Examination Category B-G-1, Inspection Items B6.10, B6.20, B6.30, and B6.50, and a third-party review by the Authorized Nuclear Inservice Inspector.

Principal Contributor: J. Medoff, NRR/DMLR/MVIB

Date: August 15, 2018

SUBJECT: ARKANSAS NUCLEAR ONE, UNIT 2 – ALTERNATIVE TO EXAMINATION OF REACTOR PRESSURE VESSEL FLANGE THREADS (EPID L-2018-LLR-0003) DATED AUGUST 15, 2018

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