REQUEST FOR ADDITIONAL INFORMATION

PROPOSED ALTERNATIVE TO ASME SECTION XI REQUIREMENTS FOR

REPAIR/REPLACEMENT OF EMERGENCY COOLING POND SUPPLY PIPING

ARKANSAS NUCLEAR ONE, UNITS 1 AND 2

ENTERGY OPERATIONS, INC.

DOCKET NOS. 50-313 AND 50-368

This document contains proprietary information pursuant to
Section 2.390 of Title 10 of the *Code of Federal Regulations.*

Proprietary information is identified by text enclosed within double brackets [[Example]].

By letter dated November July 15, 2020 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML20218A672), Entergy Operations, Inc. (the licensee) submitted a request, pursuant to Section 50.55a(a)(z)(1) of Title 10 of the *Code of Federal Regulations* (10 CFR), to use an alternative to certain requirements of the American Society for Mechanical Engineers (ASME) Boiler & Pressure Vessel Code, Section XI, "Rules for In-Service Inspection of Nuclear Power Plant Components." Specifically, the licensee requested approval to allow the use of a carbon fiber reinforced polymer (CFRP) composite system for the internal repair of the emergency cooling pond (ECP) supply piping to the service water system at Arkansas Nuclear One, Units 1 and 2 (ANO-1 and ANO-2). To complete its review, the Nuclear Regulatory Commission staff requests the following additional information.

Regulatory Basis

Pursuant to 10 CFR 50.55a(a)(z)(1), the applicant shall demonstrate that proposed alternatives to Code requirements would provide an acceptable level of quality and safety.

Request for Additional Information (RAI)

Mechanical Engineering and Inservice Testing Branch (EMIB) RAI-1

On page 2 of 16 of Enclosure 1 of the submittal the licensee states that that there are currently no small branch connections to other systems or vents/drains on the ECP supply piping. However, Figure 8 of Attachment D to Enclosure 5 (proprietary, non-public) of the submittal provides **[[ ]]** using CFRP. Clarify if there are any larger diameter outlets within the scope of the repair using CFRP. If they do exist, provide the outlet diameter sizes and the accessible length that can be repaired using CFRP and inspected satisfactorily to maintain adequate structural integrity.

EMIB RAI-2

The evaluations performed in Section 8.2 of Attachment C to Enclosure 5 of the submittal are based on the **[[ ]]** method. Figure 8 of Attachment

D to Enclosure 5 of the submittal provides **[[ ]].** Curved segments and intersections are stress concentration locations compared to straight segments, and ASME Code Section III Subsection ND, as well as B31.1, utilize stress intensification factors for such locations in the allowable stress design methodology. Attachment E to Enclosure 5 of the submittal discusses the comparison of certain aspects with the original design standards ASME Section III (1971) and USAS B31.1.0 (1967). The NRC staff has only accepted Allowable Stress Methodology for safety related piping analysis and has not yet generically approved the **[[ ]]** methodology for piping analysis. Provide values for the computed stress intensification factors for elbows, bends and outlets for ANO-1 and ANO-2 applicable pipe sizes so that the NRC staff can assess whether additional CFRP layer provided in these locations provides adequate structural and pressure boundary integrity from stress intensification considerations.

EMIB RAI-3

According to Enclosure 5, Attachment A, page 2 of 253 of the licensee's submittal, the characteristic value of CFRP composite tensile strength (obtained from tests per ASTM D3039) is based on the **[[ ]** (calculated in accordance with ASTM D7290, as specified in American Water Works Association (AWWA) C305). Enclosure 5, Attachment C describes a proposed alternative to use the **[[ ]]** for repair of buried 36-inch diameter and 42-inch diameter carbon steel ECP piping using CFRP. The NRC staff notes that ASTM D7290 was specifically developed for civil engineering structural applications. AWWA C-305 is for non-safety related non-nuclear CFRP renewal and strengthening of Prestressed Concrete Cylinder Pipe (PCCP). However, in the aerospace composite design, A-basis and B-basis values of composite strength are often used. An A-basis value is the 1st-percentile with 95 percent confidence and a B-basis value is the 10th-percentile with 95 percent confidence. A-basis strength is applied to the single components whose failure would cause loss of structural integrity whereas B-basis strength is applied to the components where the load would be safely redistributed after the specific component's failure. The NRC staff notes that the characteristic value equation for the tensile strength reduction of multilayer CFRP laminate compared to single ply laminate as shown on page 10 of 42 of Enclosure 5 Attachment C of the request is based on very limited test data. Further, there are many uncertainties associated with non-isotropic CFRP material properties and analytical methods. The computed effective factors of safety listed in the Table of Summary of Results for All Indices on page 128 of 253 in Enclosure 5 of the licensee's submittal are based on **[[ ]]** for ASME and B31.1 safety related Class 3 piping repair.

The NRC staff requires additional information to understand the methodology for ensuring structural integrity of the ECP repair due to many unknown uncertainties, as a means of determining the sensitivity, and to assess the margin difference for the acceptance criteria of the CFRP system used in ECP piping repair. Provide a summary of calculation results using **[[ ]]** for the repair of 36-inch diameter safety related B31.1 and ASME Class 3 safety related 42-inch diameter carbon steel ECP piping for **[[ ]]** similar to the Summary of Results for All Indices table shown on page 128 of 253 of Enclosure 5.

EMIB RAI-4

Attachment D to Enclosure 5 of the licensee's submittal discusses CFRP composite system termination detail at straight ends and repair terminations, where a certain length of host pipe is required to act compositely with the CFRP system. At the ends of the repair, a good bond with host pipe substrate is critical to maintain structural integrity, so that the CFRP composite system can transfer loads to the host pipe. Provide additional discussion to address the following related to the intact or non-repaired side of the terminations.

(a) Whether the intact piping on the non-repaired side of terminations is buried, or whether all non-repaired side is exposed. If buried, discuss whether credit is taken for attenuation along the buried length.

(b) The distance from the termination end to the end of the buried portion of pipe or to the beginning of aboveground piping in the building penetrations or valve pits.

(c) The distance from the termination end to the piping supports or anchors in the vicinity for the aboveground piping.

(d) Repair terminations interface with the repaired and the non-repaired sides of the piping. It appears that the loads from the repaired side are considered. Provide a discussion on the structural integrity of the repair terminations from consideration of any dead weight, thermal, seismic, and any other applicable loadings from the non-repaired side.

(e) Figure 7 of Enclosure 5 shows the termination detail at the concrete wall. Clarify whether all the CFRP repair terminations with the host pipe are of this type only.

EMIB RAI-5

According to Attachment F to Enclosure 5, the seismic analysis of the piping is performed using the analytical software **[[ ]]**.

(a) Discuss if the work performed in accordance with the Simpson Gumpertz & Heger (SGH) Quality Assurance for Nuclear Facilities Program includes analysis of standard benchmark problems.

(b) Attachment F to Enclosure 5 states that seismic ground strain analysis is based on the 100-40-40 combination rule described in ASCE 4-16. Discuss how this seismic analysis compares with the original design criteria. The 100-40-40 combination refers to three orthogonal directions. Eight load cases were considered but included only the two horizontal directions. The third orthogonal direction (vertical) appears to be not considered. Please provide a rationale to justify the approach used.

EMIB RAI-6

The submittal mentions sample calculations, sample seismic analysis, sample installation, and sample quality plan in attachments A and B to Enclosure 6 (proprietary, non-public), and in attachments C, and F to Enclosure 5 of the licensee's submittal.

Please clarify what is meant by “sample calculations,” and whether the design calculations are applicable to specific ANO-1 and ANO-2 ECW piping that is proposed for repair using CFRP. The NRC staff requires ANO-specific evaluations and not sample calculations in order to reach a safety conclusion.

EMIB RAI-7

Tables 3, 4, and 5 in Enclosure 5 of the submittal provide Resistance Factors, Material Adjustment Factors, and Time Effect Factors, respectively, for the CFRP system. Provide additional information regarding the material properties used in the evaluations in the following respects:

(a) [[

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(b) Table 4 shows CFRP material adjustment factors for strength in tension, flexure, and shear, while for modulus it was provided for tension only. Explain how the material adjustment factors for modulus values in flexure and shear that are not listed in the table, but needed in the evaluations, are obtained.

(c) Table 4 shows material adjustment factors for three different exposure conditions: water, salt solution, and alkali solution. Clarify which exposure condition is applicable to ANO.

(d) Discuss the dependence of values listed in Table 3 (Resistance Factors) and Table 5 (Time Effect Factors) on temperature, as the values in the tables do not show the variation of these with temperature.

EMIB RAI-8

Page 72 of 253 of Enclosure 5 notes that the characteristic value of modulus for multilayer CFRP laminate is estimated as **[[** **]].** But the equation uses **[[**
]]. The NRC staff cannot determine where the positive and negative signs were used.

(a) Explain the basis for this equation, and its source.

(b) Explain which evaluations use a plus sign, and which evaluations use a minus sign.

(c) Clarify if a minus sign is used in buckling-related limit states to calculate the allowable buckling pressure, and whether a plus sign is used in rupture-related limit states to calculate the allowable strain.

EMIB RAI-9

Minimum Required Values of Shear Bond Strength & Tensile Strength and Strain:

(a) Page 62 of 253 and several other pages of Enclosure 5 list the design value for the single layer of the CFRP laminate **[[**

] listed in Table 1 on page 9 of 22 of Attachment B to Enclosure 4. Discuss the significance of not meeting the minimum required value.

(b) Page 116 of 253 of Enclosure 5 lists characteristic value of the tensile strength in [[

] listed in Table 1 on page 9 of 22 of Attachment B to Enclosure 4 (proprietary, non-public). Discuss the significance of not meeting the minimum required value.

(c) Page 116 of 253 of Enclosure 5 lists the ultimate tensile strain in **[**

] listed in Table 1 on page 9 of 22 of Attachment B to Enclosure 4. Discuss the significance of not meeting the minimum required value.

EMIB RAI-10

At a May 11, 2020, public skype meeting at the ASME Boiler and Pressure Vessel Code meeting on the development of an ASME Code Case concerning the carbon fiber repair process, new data was presented showing the effect of curing temperature and test temperature on the tensile strength of CFRP. The data preliminarily identifies an issue with a potential reduction in strength to be considered in the final application design strength for the life of the repair (e.g., approximately a 50 percent reduction in strength at design or maximum operating temperatures versus strength at room temperature when the polymer is cured at room temperature). The preliminary data suggested that the strength of the CFRP depends on the curing temperature and will have an impact on the CFRP strength used in the design evaluations.

The NRC staff requires additional information to ensure that the final installed material strength is comparable to the design strength. Therefore, the NRC staff requests a description of the processes planned for implementation of the CFRP. This description should include the following:

(a) details to address the application of in-field curing of each layer, including temperature, duration of curing and a description of how each layer is cured through the installation process.

(b) recomputed factors of safety for the 9 limit states accounting for the strength reduction as affected by cure temperature. This should also be based on A-basis characteristic values.

(c) details to address verification testing of the final field sample strength, including location of test samples to be evaluated, number of tests, testing temperature, curing temperature, and a description of the testing process. In addition, clarify whether the test specimens use the thickening agent consistent with the CFRP composite and are tested at the maximum achievable water temperature of the ECP piping. If not, provide justification for why the test specimens can represent the CFRP composite and its operating conditions.

(d) an assessment of how the licensee will validate the design strength used to develop the CFRP and used in the design evaluations with the field sample strength tests. It appears that the effective factors of safety do not account for the CFRP strength reduction for the field cure temperature effect. Provide the effective factors of safety for the 9 limit states accounting for the cure temperature effect on strength, and also based on A-Basis characteristic strength and modulus values similar to the Summary of Results for All Indices table shown on page 128 of 253 of Enclosure 5.

EMIB RAI-11

Some recent limited testing data indicates that the glass transition temperature (Tg) is also dependent on the cure temperature. If the actual cure temperature in the field is not high enough, the glass transition temperature, as listed in Enclosure 4 of the licensee's submittal Attachment B Table 3, of Tg greater than or equal to (≥) max **[[ ]]** may not be achieved. When Tg is very close to Tmax with no **[[ ]]**, the epoxy may become rubbery and the CFRP system may lose its structural integrity and therefore capability to support the applied loads.

(a) Provide discussion and any test data on field cure temperature effect, and the realistic glass transition temperature achievable with curing temperatures attainable during actual CFRP repair field installation conditions at ANO.

(b) Include a detailed discussion to provide assurance that the epoxy will not become rubbery, and the CFRP system will be capable of supporting the applied loading at the maximum operating temperature of 121 ^{o}F.

(c) It appears that Enclosure 7 (proprietary, non-public) and Enclosure 6 (proprietary, non-pubic) Attachment C address tension testing and degree of cure testing of witness panels. However, the submittal does not discuss testing for glass transition temperature of the as-installed field cured CFRP repair. Please address the testing of witness panels representing the as-installed field cured conditions to demonstrate that Tg ≥ max **[[ ]]** is achieved.

EMIB RAI-12

Page 12 of 28 of Enclosure 8 of the licensee's submittal states that post-cure at elevated temperatures is planned for this project.

(a) Provide additional details on post-cure temperatures that will be used, and their effect on CFRP strength and glass transition temperature. Provide any specific test data or literature regarding the post-cure for the specific epoxy used in the ANO repair.

(b) Polymer crosslinking is achieved during initial curing and subsequent post-curing may not provide any benefit to improve the strength of the CFRP or the glass transition temperature. Provide a discussion of whether the CFRP strength used in the ANO design evaluations considered any benefit from post-curing. Provide a discussion on how saturated the crosslinking of the polymer is during initial curing

(c) The following cautionary note is provided in in section 401-VIII-4 CURE of the ASME PCC-2-2018 standard:

> Caution: Each polymer in the repair system can be cured to a range of glass transition temperatures. Repair systems will not achieve the ultimate glass transition temperature determined by the qualification testing specified in this Standard unless they experience the same temperature for the same period of time as the sample tested. Repairs designed for elevated temperature service will not meet the requirements of this Article unless they are subject to a post-cure (heating) cycle that matches the thermal history of the sample tested during qualification.

Please provide a discussion on whether the ANO CFRP piping repair installation will satisfy the preceding cautionary note.

(d) Attachment A to Enclosure 9 (proprietary, non-public) discusses operating experience and provides a list of successful applications of CFRP composite piping systems. Clarify if any of these included post-cure at elevated temperatures, and whether the epoxy used is the same as that planned for use at ANO.

Piping and Head Penetration Branch (NPHP) RAI-1

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NPHP RAI-2

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NPHP RAI-3

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NPHP RAI-4

Section III, "Basis for Relief" of the alternative request states that the licensee will continue the performance of service water flow testing each refueling outage in accordance with station procedures, including test configurations that require the service water pump suction to be aligned from the ECP.

a. Clarify whether the service water flow testing and related activities meet the pressure test provisions in ASME Boiler and Pressure Vessel Code, Section XI, IWA- 5000 and IWD-5000, including IWA-5244 for buried components.

b. Clarify whether a system pressure test will be performed prior to returning the repaired piping to service.

c. Discuss inspection activities that will be performed on the repaired pipe after the CFRP system installation, as part of the ANO aging management programs (e.g., Buried Pipe Inspection Program).

NPHP RAI-5

Enclosure 5, Attachment D, Figure 9a of the request addresses typical patch details for defective areas of the CFRP system. Describe the lengths of the patch that extend beyond the defective area. In addition, discuss the basis for the extended lengths, including why those lengths are sufficient to maintain the structural integrity.

NPHP RAI-6

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NPHP RAI-7

In Enclosure 13 of the licensee's request dated July 15, 2020, the licensee makes a regulatory commitment to perform a baseline visual examination of 100 percent of the accessible area of the composite system prior to placing the ECP supply piping back into service and again within the first five years post-installation. Further, the licensee makes a regulatory commitment to conduct visual inspections of the accessible areas and volumetric examinations (acoustic testing) at selected termination ends prior to startup. Enclosure 6, Attachment B, Section 6 identifies inspections of the field installation; however, detailed descriptions of the inspections to be conducted or acceptance criteria are not provided there or elsewhere in the submittal. ASME Code Case N-871, "Repair of Class 2 and 3 Piping Using Carbon Fiber-Reinforced Polymer Composite," specifies nondestructive examinations to be conducted prior to installation, during installation, and as preservice and inservice examinations. In addition to requirements for examination of the entirety of the installed composite system, the Code Case further specifies examinations of the terminal end. Considering this framework provided by ASME Code Case N-871, please address the following:

a. Examination of the entire system: Describe the examinations that will be conducted on the entire installed composite system during installation, and for preservice and inservice inspections. Describe the inspection methods that will be used, including the applicable ASME Code requirements (e.g. ASME Code, Section XI, IWA-2210) as appropriate. How will the inspection methods and personnel implementing them be qualified to perform the examinations? What acceptance criteria will be applied to the inspection results?

b. Examination of the terminal ends prior to and during fabrication: Describe the examinations, including the applicable ASME Code requirements (e.g., Section V, Article 5), that will be conducted of the terminal end base material prior to installation of the composite repair. How will the inspection methods and personnel implementing them be qualified, if necessary, to perform the examinations? What acceptance criteria will be applied to the inspection results?

   In addition, describe the examinations that will be conducted on the composite repair system at the terminal end during the installation of the composite system. Describe the inspection methods that will be used, including the applicable ASME Code requirements. How will the inspection methods and personnel implementing them be qualified to perform the examinations? What acceptance criteria will be applied to inspection results?

c. Preservice and inservice examination of the terminal ends: Examination of the terminal ends base materials for inservice inspection is essential to ensure the integrity of the host substrate (e.g., no loss of metal pipe thickness under the terminal end of the composite repair due to corrosion). As such, describe the preservice and inservice examinations of the terminal ends. Specifically address how the underlying base material will be examined for inservice inspections, as well as how the base material to composite interface will be examined. What inspection methods will be used? How will the inspection methods and personnel implementing them be qualified to perform the examinations? Will representative mockups be used for qualification? What acceptance criteria will be applied to inspection results?

d. There is extensive use of thickened epoxy throughout the repair process. Please describe how the presence of several layers of thickened epoxy will impact inspections. As part of the response, address whether the thickened epoxy will impact the ability to examine the terminal ends base material for inservice inspection.

e. Paragraph V-2100(a) of ASME Code Case N-871 specifies visual examinations of a CFRP system between 4 and 6 years following return of the repaired area to service and a minimum frequency of once per 10-year interval thereafter in the same inspection period of each succeeding inspection interval. Clarify the inservice inspection frequency specified for the CFRP system. Provide justification for any differences between the planned inservice inspection and that specified by Code Case N-871.