



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

March 11, 2021

Mr. Thomas Saporito
Executive Director
Nuclear Energy Oversight Project
9995 SE Federal Hwy. Unit 1763
Hobe Sound, Florida 33475

SUBJECT: 2.206 PETITIONS FOR PRESSURIZED-WATER REACTOR NEUTRON
EMBRITTELEMENT

Dear Mr. Saporito:

The petitions you submitted on behalf of Nuclear Energy Oversight Project, dated October 31, 2020, and November 8, 2020 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML20307A664 and ML20324A227, respectively), addressed to the U.S. Nuclear Regulatory Commission (NRC) Executive Director for Operations, were referred to the Office of Nuclear Reactor Regulation pursuant to Section 2.206 of Title 10 of the *Code of Federal Regulations* (10 CFR). In the petition dated October 31, 2020, you requested that the NRC take enforcement action against licensees of all pressurized-water reactors (PWRs) in the form of an immediate shut-down order until such time that each licensee provides an updated safety analysis of the degree of reactor pressure vessel (RPV) embrittlement, a detailed description of the methodology to provide the updated safety analysis, and a statement of full compliance with NRC regulations. The bases stated in the petition to support the requested actions are that:

- (1) the current methodology used by licensees to determine the degree of RPV embrittlement is not sufficient,
- (2) the use of shared data does not provide sufficient and reliable data,
- (3) licensees that participate in a surveillance program fail to consider modifications to the original licenses, and
- (4) direct fracture toughness data evaluation methodology is a more accurate methodology to determine the degradation and degree of embrittlement of an RPV.

Your November 8, 2020, petition requested that the NRC take the following enforcement action against Energy Harbor Nuclear Corporation (Energy Harbor) for Beaver Valley Power Station, Unit No. 2:

- “denial and refusal” of the assertions made by Energy Harbor in their letter dated October 28, 2020 (ADAMS Package Accession No. ML20302A376),
- issue a confirmatory order requiring the use of the Tinius-Olsen Model IT406 or Model IT542 pendulum impact test machine,
- issue an order to require the identification of the Instron Impulse system (striker) used by Energy Harbor to test Capsule Y, and

- issue an order requiring Energy Harbor to identify any outside contractor used to perform Charpy testing on Capsule Y.

The basis stated in the petition to support the requested actions is:

- (1) the model number of the striker used in the testing referenced in the October 28, 2020, letter was not provided and the testing used an outdated Charpy test machine.

Consistent with NRC Management Directive (MD) 8.11, "Review Process for 10 CFR 2.206 Petitions" (ADAMS Accession No. ML18296A043), a petition review board (PRB) was established to evaluate your petitions. The PRB consists of staff from NRC headquarters who are knowledgeable of the requirements related to PWR RPV embrittlement. In evaluating your petitions, the PRB reviewed and analyzed the NRC's records regarding the concerns you raised in your petitions.

The PRB's initial assessment was that your petitions do not meet the criteria in Sections III.C.1(a) and III.C.1(b)(ii) of MD 8.11 for acceptance because either the petitions do not specify sufficient facts that constitute the basis for taking the requested action or the technical issues raised in your petitions have already been the subject of NRC staff review and evaluation, and none of the additional Section III.C.1(b)(ii) circumstances apply.

On December 21, 2020, you were informed by e-mail of the PRB's initial assessment. On January 22, 2021, you provided supplemental information by e-mail (ADAMS Accession No. ML20307A662) to the petition manager. Your petitions, the PRB's initial assessment, and the supplemental information was discussed at a public teleconference between you and the PRB, also held on January 22, 2021 (transcript found at ADAMS Accession No. ML21033B008).

In your January 22, 2021, supplement, you requested that the NRC issue confirmatory orders to all PWR licensees requiring the licensees to:

- state and affirm under oath how the general public could realistically evacuate during a loss-of-coolant accident (LOCA),
- perform a one-time inspection of the continuous circumferential transition cone closure weld on each steam generator,
- perform a one-time inspection of the reactor vessel extended beltline region,
- reduce full-power operations to no more than 80 percent due to neutron fluence during the period of extended operations, and
- affirm under oath that the capsule data that was used from another nuclear reactor vessel surveillance capsule fully complies with the Regulatory Guide (RG) 1.99, "Radiation Embrittlement of Reactor Vessel Materials," Revision 2, dated May 1988 (ADAMS Accession No. ML031430205).

The bases stated in the supplement to support the requested actions are:

- (1) approval of power uprate amendments only considered the existing operating period and not subsequent renewal periods,
- (2) licensee emergency plans are not sufficient to protect the health and safety of the public from a LOCA,

- (3) one-time inspections of the continuous circumferential transition cone closure weld on each steam generator should be required because failure of this weld would result in a LOCA,
- (4) one-time inspection of the RPV extended beltline region should be required because failure of the RPV would result in a LOCA,
- (5) Charpy testing is not sufficient to ascertain the amount of embrittlement sustained by an RPV from neutron fluence for renewal periods at extended power operations,
- (6) Charpy testing cannot directly predict the reaction of material to real life loading,
- (7) the use of test capsule data as part of the reactor vessel surveillance program from one nuclear reactor vessel is not sufficient to accurately determine the amount of neutron embrittlement of another nuclear reactor vessel,
- (8) uprated reactor vessels operating after their initial 40-year licensing period and that referenced in RG 1.99, do not adequately consider pressurized thermal shock as required by 10 CFR 50 and 10 CFR 50.61, and
- (9) the use of attenuation based on displacement per atom (dpa) calculation specific to the reactor vessel provides a more accurate representation of fluence attenuation through the RPV and should be required.

The results of the evaluation of the supplemental information you provided have been considered in the PRB's final determination. The PRB has determined that your requests for immediate action are not warranted.

In addition, MD 8.11, Section I.B.3 states that "The Office of the Inspector General (OIG) addresses suspected wrongdoing by NRC employees and contractors such as mismanagement of agency programs that could adversely impact matters related to public health and safety." Consistent with these provisions, the PRB has forwarded the January 22, 2021, supplement to the NRC OIG for consideration.

October 31, 2020, Petition Item (1) and Supplement Items (5) and (6)

Your October 31, 2020, petition provided the following basis to support the requested enforcement actions:

- (1) the current methodology used by licensees to determine the degree of embrittlement is not sufficient.

Your January 22, 2021, supplement provided the following bases to support the original petitions:

- (5) Charpy testing is not sufficient to ascertain the amount of embrittlement sustained by an RPV from neutron fluence for renewal periods at extended power operations, and
- (6) Charpy testing cannot directly predict the reaction of material to real life loading.

The NRC staff is aware of the limitations associated with the use of Charpy impact testing to correlate to the actual fracture toughness of an RPV material. These limitations are neither mitigated nor improved by the use of instrumented Charpy testing. The NRC's regulatory framework for RPV embrittlement estimates relies on consensus codes and standards (such as ASTM International (formerly American Society for Testing and Materials Standards)) and includes conservatism and safety factors (as defined in the American Society of Mechanical Engineers (ASME) Code) that exceed the limited differences that would be found in data from standard (i.e., non-instrumented) and instrumented Charpy testing. ASTM Standards are

available for instrumented Charpy testing; however, the ASTM has not prohibited the use of standard Charpy testing. Instrumented Charpy testing is not necessary to demonstrate compliance with the regulations or to assess embrittlement of the RPV consistent with guidance in RG 1.99, "Radiation Embrittlement of Reactor Vessel Materials," Revision 2 (ADAMS Accession No. ML031430205).

October 31, 2020, Petition Item (2) and Supplement Item (7)

Your October 31, 2020, petition provided the following basis to support the requested enforcement actions:

- (2) the use of shared data does not provide sufficient and reliable data.

Your January 22, 2021, supplement provided the following basis to support the original petitions:

- (7) the use of test capsule data as part of the reactor vessel surveillance program from one nuclear reactor vessel is not sufficient to accurately determine the amount of neutron embrittlement of another nuclear reactor vessel.

Regulations in 10 CFR Part 50, Appendix H, Section III.C, outline the requirements for an "integrated surveillance program," and describe the criteria for approval of such a program. The NRC staff reviews and approves the use of integrated surveillance programs in lieu of a plant-specific surveillance program, and as part of its review, ensures that the representative materials chosen for surveillance of an RPV are irradiated in one or more other reactors that have similar design and operating features to permit accurate comparisons of the predicted amount of radiation damage.

The use of surveillance data from a different plant to supplement a plant-specific surveillance program is required for PWR plants by the pressurized thermal shock (PTS) rule (10 CFR 50.61), to ensure the most accurate estimates of RPV embrittlement.

The parameters that influence embrittlement (i.e., neutron fluence, neutron spectrum, irradiation temperature, and material chemistry) are well understood and are part of the NRC staff's review of plant-specific RPV embrittlement estimates. Other factors raised in the petition, such as transient behavior during reactor trips, have no discernable impact on the ability of surveillance specimens from one plant to provide relevant data to assess radiation embrittlement of another plant, since the elastic deformation of the RPV steel due to such evolutions does not affect the degree of embrittlement.

October 31, 2020, Petition item (3) and Supplement Items (1) and (8)

Your October 31, 2020, petition provided the following basis to support the requested enforcement actions:

- (3) Licensees that participate in a surveillance program fail to consider modifications to original licenses.

Your January 22, 2021, supplement provided the following bases to support the original petitions:

- (1) approval of power uprate amendments only considered the existing operating period and not subsequent renewal periods, and
- (8) uprated reactor vessels operating after their initial 40-year licensing period and that reference RG 1.99, "Radiation Embrittlement of Reactor Vessel Materials," Revision 2 (ADAMS Accession No. ML031430205), do not adequately consider PTS as required by 10 CFR 50 and 10 CFR 50.61.

Consistent with NRC staff guidance described on the NRC's public website (<https://www.nrc.gov/reactors/operating/licensing/power-uprates/related-reg-guides/guides-pu.html>), the review of license amendment requests for power uprates ensures continued compliance with 10 CFR 50.60, 10 CFR 50.61, and Appendices G and H to 10 CFR Part 50 under the proposed uprated conditions.

In addition, 10 CFR Part 54 provides the requirements for the renewal of operating licenses for nuclear power plants. NRC staff guidance described on the NRC's public website (<https://www.nrc.gov/reactors/operating/licensing/renewal/guidance.html>) for the review of license renewal applications specifically addresses methods to adequately manage embrittlement of the RPV during the period of extended operation and ensure accurate RPV embrittlement estimates.

As stated previously, the parameters that influence embrittlement (i.e., neutron fluence, neutron spectrum, irradiation temperature, and material chemistry) are well understood and are incorporated into the NRC staff's guidance and reviews of power uprate license amendments and license renewal applications, to ensure accurate estimates of RPV embrittlement. Since RPV fluence calculations explicitly consider the actual plant operating history, the additional neutron fluence from a power uprate or license renewal is incorporated in the plant-specific calculations.

October 31, 2020, Petition Item (4)

Your October 31, 2020, petition provided the following basis to support the requested enforcement actions:

- (4) direct fracture toughness is a more accurate methodology for determining degree of RPV embrittlement.

The petition suggests that direct fracture toughness measurements, as referenced in Pressurized Water Reactor Owners Group (PWROG)-18068, "Use of Direct Fracture Toughness for Evaluation of RPV Integrity," provide additional insight into the material toughness of RPV materials and is a more accurate measure of material toughness compared to data from Charpy testing.

The use of direct fracture toughness measurements is not prohibited by the NRC and would allow licensees to potentially reduce or remove the conservatism and safety factors that are incorporated when using data obtained from traditional Charpy testing. However, requiring inclusion and testing of fracture toughness specimens from RPV materials to monitor the change in material properties is not necessary to provide reasonable assurance of adequate

protection. The addition of these requirements would not have a corresponding benefit to public health and safety (see ADAMS Accession No. ML19038A477).

November 8, 2020, Petition

Your November 8, 2020, petition provided the following basis to support the requested enforcement actions:

- (1) The testing used an outdated Charpy test machine and the model number of the Instron Impulse system instrumented to the Charpy machine striker used was not provided in the licensee's October 28, 2020, letter to the NRC.

The test equipment identification information provided by the licensee meets Section 11.4.2.1 in ASTM E185-82, which is required by Appendix H to 10 CFR Part 50.

Test equipment used for Charpy testing is required per ASTM E185-82 to be calibrated and properly adjusted periodically to maintain accuracy and that calibration be conducted with standards traceable to the National Bureau of Standards, which is now the National Institute of Standards and Technology (NIST). The use of manual reading of data provides sufficiently accurate readings of the absorbed energy to fracture the surveillance specimens, consistent with the pertinent consensus codes and standards, to adequately assess the condition of the RPV.

The NRC's regulatory framework relies on the use of consensus codes and standards. As stated previously, ASTM standards are available for instrumented Charpy testing; however, the ASTM has not determined that it is necessary to prohibit the use of standard Charpy testing and to require only the use of the most modern apparatus to perform instrumented Charpy testing. The use of instrumented Charpy testing apparatuses would be capable of providing the data necessary to adequately assess RPV embrittlement; however, the mandatory use of these apparatuses is beyond the current regulations.

Given that the NRC's regulatory framework relies on consensus codes and standards (such as ASTM Standards) and includes conservatism and safety factors (as defined in the ASME Code) that accommodate the use of data from a calibrated standard Charpy impact testing apparatus, it is not necessary for the NRC to require the use of the most modern apparatus to perform instrumented Charpy testing.

Supplement Item (1)

Your January 22, 2021, supplement provided the following basis to support the original petitions:

- (1) licensee emergency plans are not sufficient to protect the health and safety of the public from a LOCA.

Under NRC regulations, each nuclear power plant (NPP) licensee is required to notify State and local government authorities within the site's 10-mile Emergency Planning Zone (EPZ) upon the declaration of an emergency classification and, if applicable, recommend protective actions for the public. The decision on the implementation of a specific protective action/measure resides with the respective government authorities. If ordered, an evacuation of the general public

would be conducted using the State and local radiological emergency response plans, which are submitted to, and reviewed by, the Federal Emergency Management Agency (FEMA).

Paragraph (a)(1)(i) to 10 CFR 50.47 states, in part, that "...no initial operating license for a nuclear power reactor will be issued unless a finding is made by the NRC that there is reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency. No finding under this section is necessary for issuance of a renewed nuclear power reactor operating license." In addition, Paragraph (a)(2) to 10 CFR 50.47 states, in part, that "The NRC will base its finding on a review of the Federal Emergency Management Agency (FEMA) findings and determinations as to whether State and local emergency plans are adequate and whether there is reasonable assurance that they can be implemented, and on the NRC assessment as to whether the applicant's onsite emergency plans are adequate and whether there is reasonable assurance that they can be implemented." Per paragraph (s)(3) to 10 CFR 50.54, "The NRC will base its finding of continued reasonable assurance on FEMA's continuous review of the adequacy of offsite plans and preparedness and FEMA findings and determinations as to whether State and local emergency plans are adequate and capable of being implemented." The processes and methods for FEMA's evaluation of offsite emergency response plans is outlined in FEMA's Radiological Emergency Preparedness (REP) Program Manual (FEMA P-1028 / December 2019): <https://www.fema.gov/about/reports-and-data/guidance>. The respective NRC and FEMA roles and responsibilities in making this determination is discussed in the "Memorandum of Understanding Between the Department of Homeland Security/Federal Emergency Management Agency and Nuclear Regulatory Commission Regarding Radiological Emergency Response, Planning, and Preparedness" (ADAMS Accession No. ML15344A371).

NRC regulations require the establishment of a 10-mile "Plume Exposure Pathway" EPZ in which pre-planned protective actions/measures are developed to protect the health and safety of the general public that could be adversely affected from a passing radioactive plume in the unlikely event of a severe radiological incident. Generally, for an existing large light water reactor, the 10-mile EPZ shall be determined in relation to local emergency response needs and capabilities as they are affected by such conditions as demography, topography, land characteristics, access routes, and jurisdictional boundaries. As such, the EPZ boundary does not simply constitute a 10-mile circle around the NPP site, but would reflect site-specific characteristics. The actual EPZ boundaries are reviewed as part of initial NPP licensing and any potential impediments to evacuation are considered. While pre-planned protective actions/measure for the general public are not required beyond the 10-mile EPZ, existing State and local radiological emergency plans do provide the basis for expanding protective actions/measures beyond the 10-mile EPZ if warranted in the judgement of offsite government officials. Following the Fukushima Dai-ichi accident, the Commission reviewed the existing emergency preparedness framework and regulations and concluded that they provide reasonable assurance of adequate protection of public health and safety in the event of a radiological emergency at a U.S. NPP.

Supplement Items (3) and (4)

Your January 22, 2021, supplement provided the following bases to support the original petitions:

- (3) one-time inspections of the continuous circumferential transition cone closure weld on each steam generator should be required because failure of this weld would result in a LOCA, and

- (4) one-time inspection of the RPV extended beltline region should be required because failure of the RPV would result in a LOCA.

Radiographic testing is primarily employed for examination of welds for a fabrication baseline to reveal flaws in the new weld, such as cracks, voids, lack of fusion, and other anomalies. The radiographic image is the permanent evidence of the condition of the weld pre-service. The preservice examination requirements for boiling and pressurized water reactors are governed by 10 CFR 50.55a. Once a weld is considered acceptable in accordance with criteria established by the regulations and consensus codes and standard (i.e., ASME Code) following examination, the weld is suitable for in-service operation. In regard to the steam generator, including the transition cone closure weld, once the component has been placed into service the inspection requirements to ensure its integrity are governed by Section XI of the ASME Code for the entire service time of the component. Additionally, guidance for aging management of the steam generators is available if a plant decides to pursue license renewal. In regard to the RPV, radiographic testing will not reveal changes in fracture toughness due to neutron embrittlement because the consequential loss in toughness is not detectable by radiographic inspection. Embrittlement of the RPV is assessed by the implementation of material surveillance programs required by Appendix H to 10 CFR Part 50. These programs include the periodic withdrawal and testing of materials specimens located in the RPV that have been exposed to neutron irradiation to monitor changes in fracture toughness of the RPV.

Supplement Item (9)

Your January 22, 2021, supplement provided the following basis to support the original petitions:

- (9) the use of attenuation based on dpa calculation specific to the reactor vessel provides a more accurate representation of fluence attenuation through the RPV and should be required.

The January 21, 2021, supplement states that the dpa method provides a more accurate representation of fluence attenuation through the RPV wall at all elevations of the pressure vessel because it accounts for neutron streaming in the cavity region and therefore should be required.

As stated in RG 1.99, the neutron energy spectrum changes significantly with location in the vessel wall and therefore calculating attenuation is necessary. RG 1.99 provides a formula for calculating the attenuation of radiation embrittlement through the vessel wall that is based on the attenuation of dpa through the RPV wall. Additionally, RG 1.99 also permits the ratio of dpa at the depth through the RPV wall to dpa at the inner surface to be used as a substitute for the exponential attenuation factor in this formula. The guidance in RG 1.99, including the attenuation formula, continues to be sufficient in determining the effects of neutron radiation embrittlement of the RPV for the current operating fleet.

Summary

In summary, the PRB's final determination is that your petition will not be accepted for further review on the following basis:

- The bases for item (1) from the October 31, 2020, petition; the item from the November 8, 2020, petition; and items (4), (5) and (6) from the January 22, 2021,

supplement, do not meet the following acceptance criteria in MD 8.11, Section III.C.1(a), “The petition specifies facts that constitute the basis for taking the requested action, and those facts are sufficient to provide support for the requested action...” The bases provided do not provide new information outside of the existing NRC depth of knowledge sufficient to warrant further inquiry.

- The bases for items (2), (3), (4) from the October 31, 2020, petition; and items (1), (2), (3), (7), (8), and (9) from the January 22, 2021, supplement do not meet the MD 8.11 acceptance criteria in Section III.C.1(b)(ii) because “The issues raised have previously been the subject of a facility-specific or generic NRC staff review...” as provided above for each of your bases, but none of the additional Section III.C.1(b)(ii) circumstances apply.

The regulations in 10 CFR 2.206 provide an opportunity for safety issues to be raised by interested persons. While the PRB determined that the issues raised do not require further review, the NRC understands that this process takes time, resources, and energy by petitioners. Accordingly, I thank you for taking the time to raise your concerns to the attention of the NRC and participating in this process.

Sincerely,

Gregory Bowman, Deputy Director
Division of Risk Assessment
Office of Nuclear Reactor Regulation

cc: Listserv

SUBJECT: 2.206 PETITIONS FOR PRESSURIZED WATER REACTOR NEUTRON EMBRITTLEMENT DATED MARCH 11, 2021

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OYee, NRR

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ADAMS Accession Nos.:

ML2020307A662 (Package);

ML21040A376 (Letter)

NRR-106

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